Bachelor Thesis

Shockwarner for a Smartphone

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Abstract

The Smartphones today are provided with many sensors. The signals from these sensors can be used in different applications. In this project we used a signal from an accelerometer sensor to detect if the Smartphone is exposed to a hard or soft shock.

The Smartphone used in the experiments was a Sony Xperia Z3. The presented experiments are based on that we dropped the Smartphone 190 times, 50% of the experiments were on a hard floor, like a table, and the rest of the experiments were on a soft floor like a sofa.

In the project we developed a shock-warning algorithm in Matlab to detect a hard or a soft shock. The shock-Warner also counts the number of shocks the Smartphone has been exposed to.

The performance evaluation shows very good results, and combining several evaluation criteria a high performance shock-Warner is obtained.

Contents

1. Introduction

Nowadays we have a lot of applications in Smartphones, like camera, GSM and GPS. All of these applications use a lot of sensors to get information from the Smartphone.

One of the sensors which is used to measure the motion and the orientation of a Smartphone is the accelerometer sensor. The first time this sensor was used in a Smartphone was for guiding the Smartphone users for taking photos [1]. To explain how the accelerometer works we have to think about the main function of the accelerometer which is used to measure the acceleration over a period of time. The acceleration sensor can be used to detect if the camera is moving or not. The acceleration sensor can also be used in other applications, for example, detect earthquake, and be used in medical devices such as bionic limbs [2].

1.1 Context and Motivation

Smartphone users, all over the world, are continuously increasing year by year. As a result, Smartphone manufacturers are also increasing every day looking for new technologies to meet up with customers' needs. However, some users misuse this device. A research done by TechDigest shows that two of five Smartphone users walk around with a cracked smartphone [3] and the manufacturers are not responsible for fixing the broken smartphone because they cannot be sure whether the damage is from the careless user or a malfunction in the phone from the manufacturing process.

In order to solve this problem, manufacturers could easily find out the source of the damage by an application, proposed in our thesis, which is able to identify the number of shocks a phone has exposed to and the type of these shocks.

1.2 Aim of the project

This project aims to

1- Find a method to detect the shock from the acceleration signal by using accelerometer sensor data in a shock vibration app.
2- Determinate the type of shock (hard or soft) the smartphone has exposed to based on the information in the shock signal.

2. Method

2.1 Tools

The Smartphone used in the experiment was a Sony Xperia Z3. Figure 1 shows a Sony Xperia z3. The vibration app shock installed in the Smartphone was to measure the acceleration signal. The analysis and processing of acceleration signals were performed in Matlab.

Figure1 : Sony Xperia Z3

2.2 Procedure

The vibrations app shock is a software app. The app measures the acceleration in 3-directions; x, y and z. Figure 2 shows how the app measures the accelerations in 3 directions x, y and z.

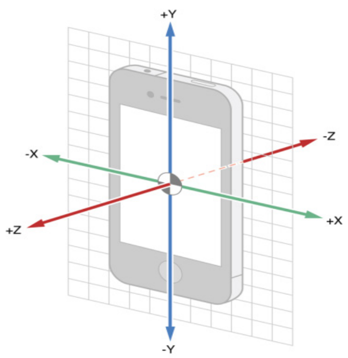

Figure2: The three direction in the Smartphone

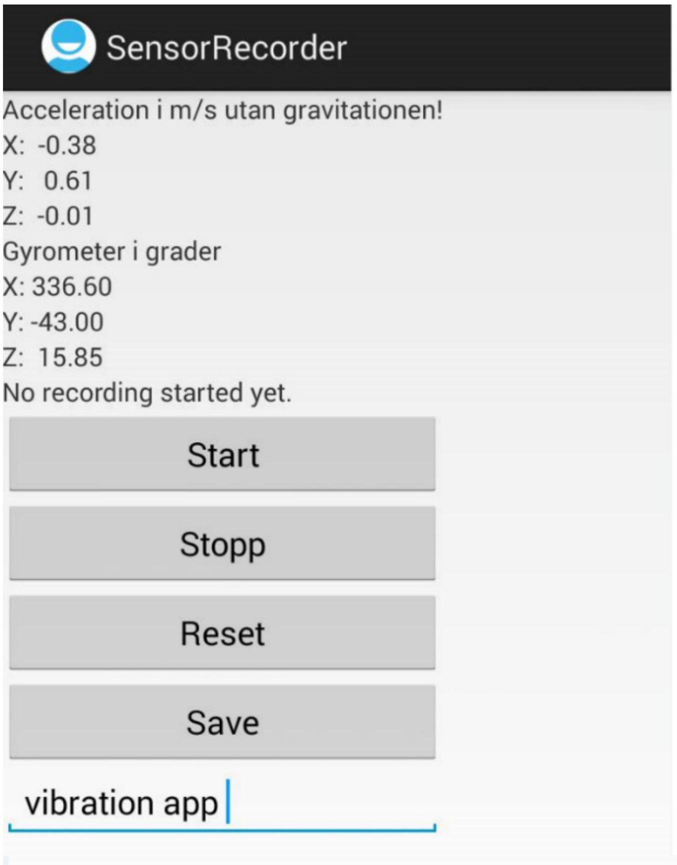

Figure 3: The vibration app in the smartphone

The software app implemented in the Smartphone is started to record the data before throwing the Smartphone on ground. After the shock between the Smartphone and the ground, the software app is stopped to record data. Figure 3 shows the interface of vibration app.

2.3 Data Transfer

After finishing the experiment with the Smartphone, the data stored in the Smartphone is exported to the laptop via a USB cable. Data is then exported into Maltab without changing data file type. The block diagram in figure 4 shows the steps for transferring data from the Smartphone to Matlab.

Figure 4 : The steps for transferring data from Smartphone to Matlab.

2.4 Signal Characteristics

Figure 5b shows the resultant acceleration of generated signal (module of acceleration). The resultant acceleration of generated data has two periods. The first period is the time falling period, and the second period is the period of time peaking and the two periods together are called the shock period. Figure 5b shows the time falling period started at 0.3 second and ended at 0.55 second and the time peaking period stared at 0.55 second and ended at 0.8 second.

Time falling period: This period starts when the Smartphone was thrown to the ground. The value of acceleration here was steady because the Smartphone was dropped in a free fall under gravity's influence.

Time peaking period: This period starts when the Smartphone touches the ground. Because the value of acceleration was changing in that time, we get a lot of peaks in this period. Figure 5b below shows this period as well.

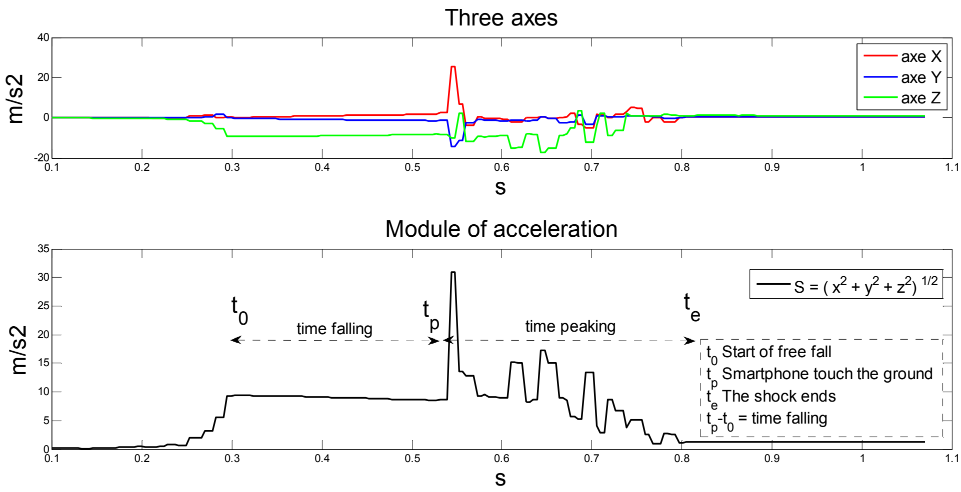

Figure5: a) The generated signals in x-y and z-directions. b) The figure show the sum of those signals which is used in this project to detect the shock.

2.5 Differentiating Between Shocks

We evaluated two types of shocks. In the experiments the smartphone is exposed to hard shocks and soft shocks.

A hard shock happens when the Smartphone is thrown toward an inflexible ground. Figure 6 below shows hard shock signal.

A soft shock happens when the Smartphone is thrown toward a flexible ground. Figure 6 below shows soft shock signal.

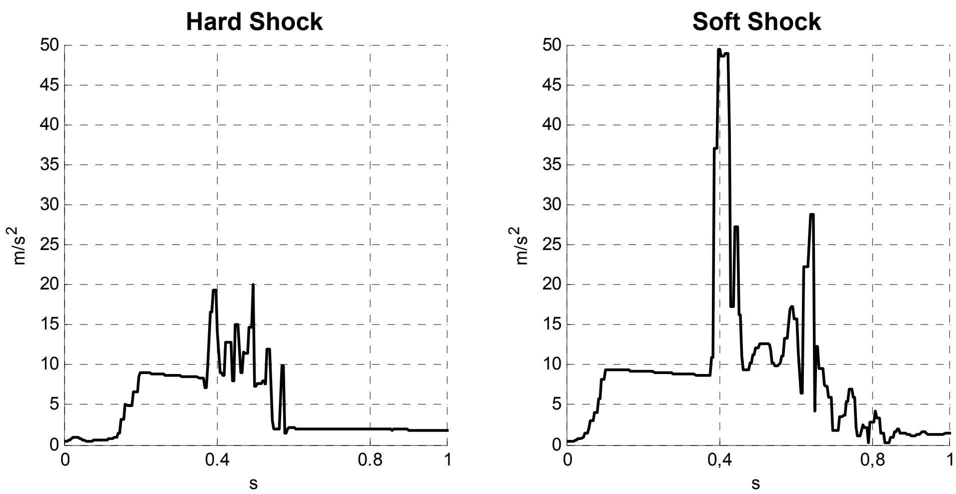

Figure6: Acceleration related to a hard shock, and a soft shock

We used four factors to know the differences between the hard shock and soft shock compared with falling height and those factors are:

1- Time peaking period.
2- Number of peaks.
3- Mean value of first peak.
4- Kurtosis function.

Falling height

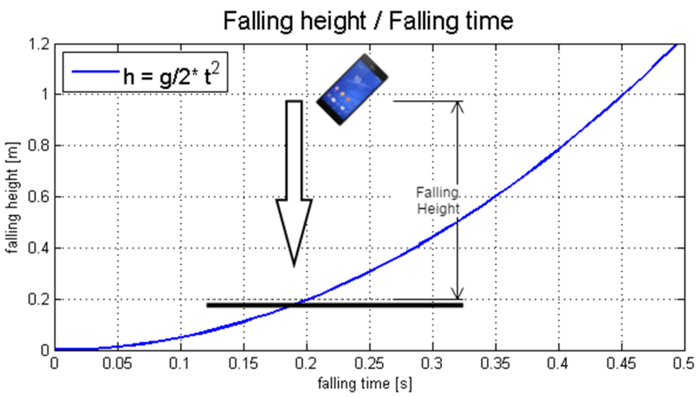

Figure 7: Falling height vs falling time

In figure 7 is shown the relation between the falling height and the falling time. The falling height of Smartphone, h, is obtained according to the gravitational force [4] explained in figure 8:

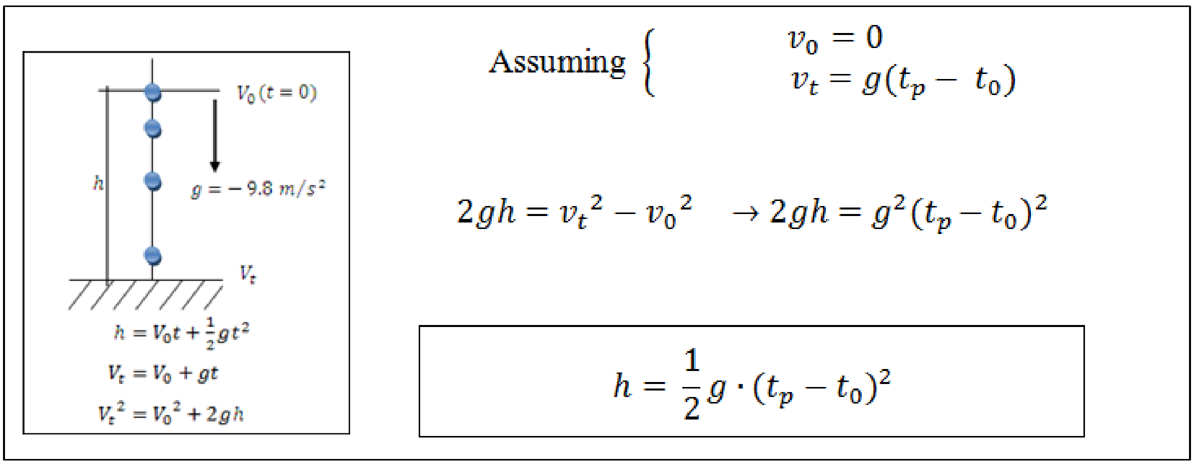

Figure 8: Falling height equations

In the figure 8 is shown a chart with useful equations to demonstrate the *free falling equation*. Where g is gravity value since the falling is under gravity influence (= 9.81m/s). The factors t_p and t_0 are the time of peak and the time of the fall beginning, both are represented in figure 5; the factor h is height of falling, v_0 is the velocity in the first moment of the fall (for this case $v_0 = 0$), and v_t is the velocity depending on the time.

Time peaking

The time peaking period started when the Smartphone touched the ground, until acceleration value falls to zero.

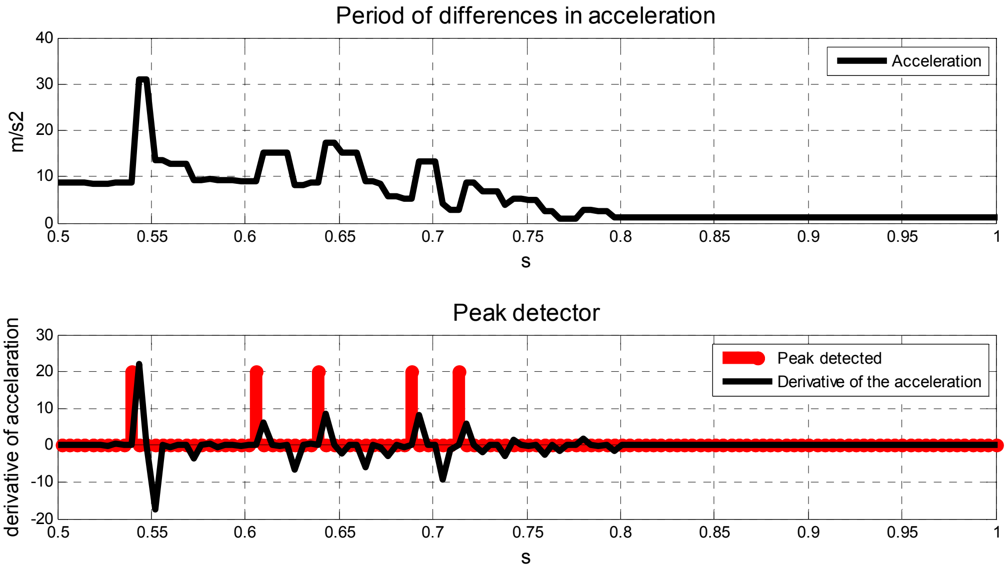

Figure 9: Peak detectors (number of peaks)

Number of peaks

As we can see from figure 9, we easily count the number of peaks during the second period by using the derivation function of this period. By deriving the signal, that describes this period, we get the peaks which are identified when the derivative is equal to zero and the slope is up.

Mean value of first peak

With this factor we get the mean value of the first peak, by calculating the value of samples within the first 0.1 seconds after the beginning of the first peak divided by the number of samples. It gives us an idea of the energy of the shock. Figure 10 shows the main value for a hard shock and a soft shock. In a hard shock all the energy goes from the smartphone to the floor, letting the phone stop quickly, but in a soft shock the energy does not disappear in the very beginning of the shock, giving back part of the energy to the phone, launching it up due to the elasticity of the surface.

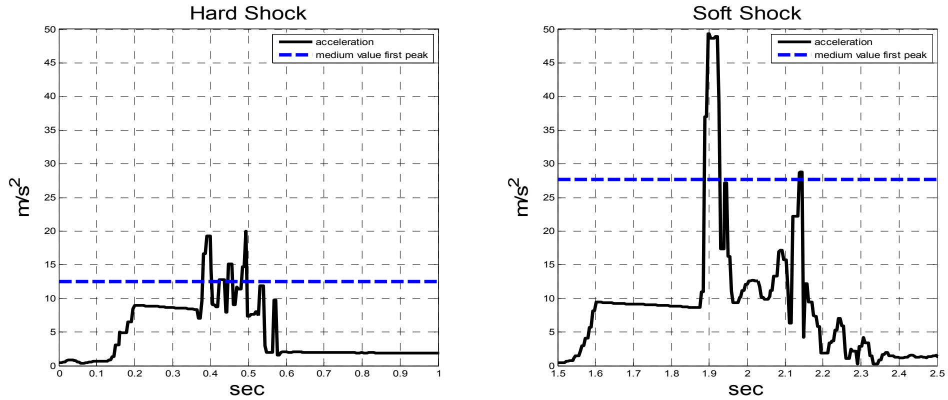

Figure 10: The mean values of first peaks for a hard and a soft shocks, respectively.

Kurtosis Function

Kurtosis is a function used in probability theory and statistics. Karl Pearson is the responsible for this function [5]. It gives an index to measure the shape of a signal depending on the variance. High kurtosis value means more values close to the mean value of the signal and smoother slopes after peak**.** Thus, small values of kurtosis means more differences between the peaks compared to the mean value of the signal and the sharper slopes after each peak .

For this project, we will measure two different values. The first value takes care 0.1 seconds before the first peak and 0.2 seconds after that, in order to get the kurtosis value for the very beginning of the shock. The second value takes care of the whole shock period, in order to get the value of whole shock.

The kurtosis of a distribution used by matlab is defined as

$$k = \frac{E[(x-\mu)]^4}{\sigma^4}$$

Where μ is the mean of x, σ is the standard deviation of x, and $E[(x-\mu)]^4$ represents the expected value of the quantity t.

It is possible to get more information from this equation in the manual of Matlab [6].

3. Experiments

We dropped the Smartphone 190 times in a free fall into the ground. In half of those attempts the Smartphone was thrown into a flexible ground (soft shock) like a sofa , and the other half of those attempts the Smartphone was thrown into an inflexible ground (hard shock) like a table . We compared the resulting shock signal using the four factors introduced previously.

3.1 Histogram

3.1.1 Time peaking

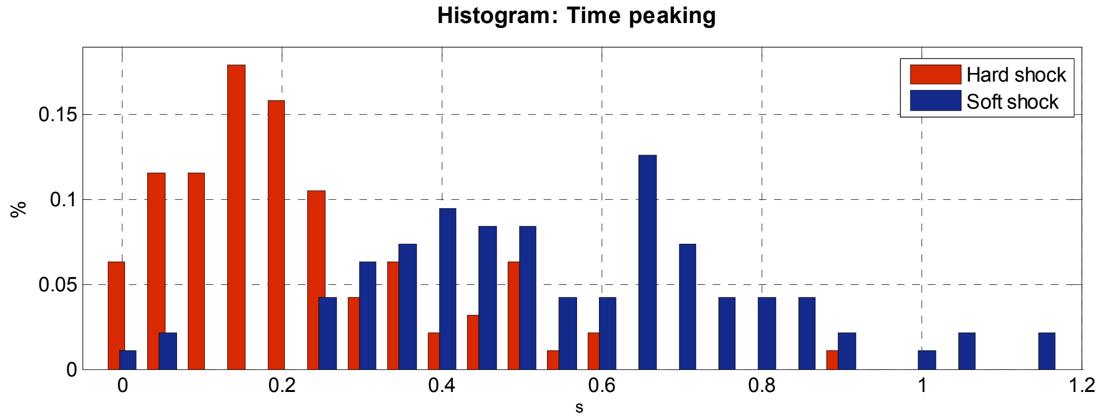

Figure 11 Histogram of time peaking for hard shocks and soft shocks

Figure 11 shows a histogram of time peaking for hard shocks and soft shocks, respectively.

The results show that the time peaking of hard shocks are concentrated between 0.1- 0.6second, but the time peaking of soft shocks are concentrated between 0.4-1.1seconds.

From statistically point of view, the hard shocks have shorter time peaking than the soft shocks.

3.1.2 Number of peaking

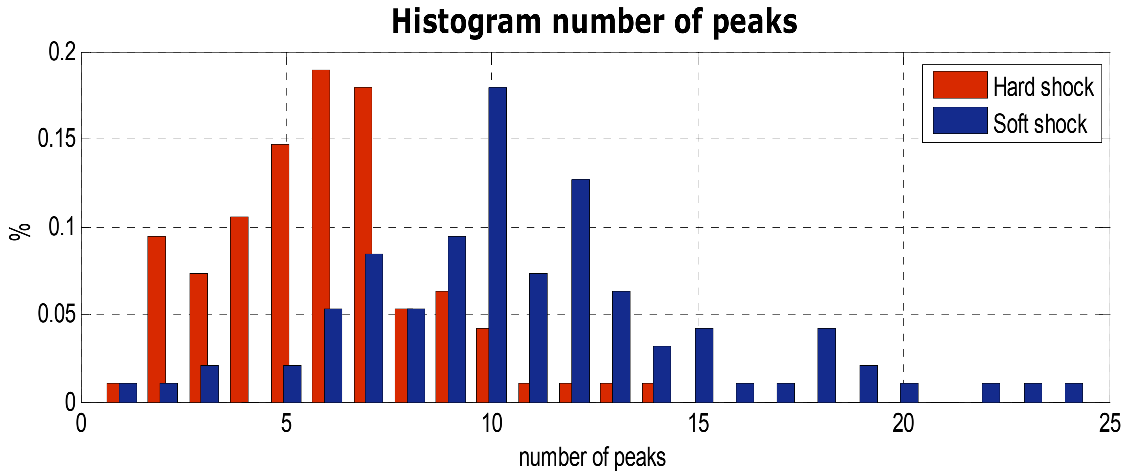

Figure 12 Histogram of number of peaks

Figure 12 shows a histogram of number of peaks in the second period of shock signal for the two types of shock: hard and soft.

A number of peaks for a hard shock are concentrated between two peaks to seven peaks but for soft shocks the number of peaks is concentrated between seven peaks to twenty peaks.

The results show that the hard shocks have less number of peaks in the second period than for soft shocks.

3.2 Relation

3.2.1 Relation between time peaking and height

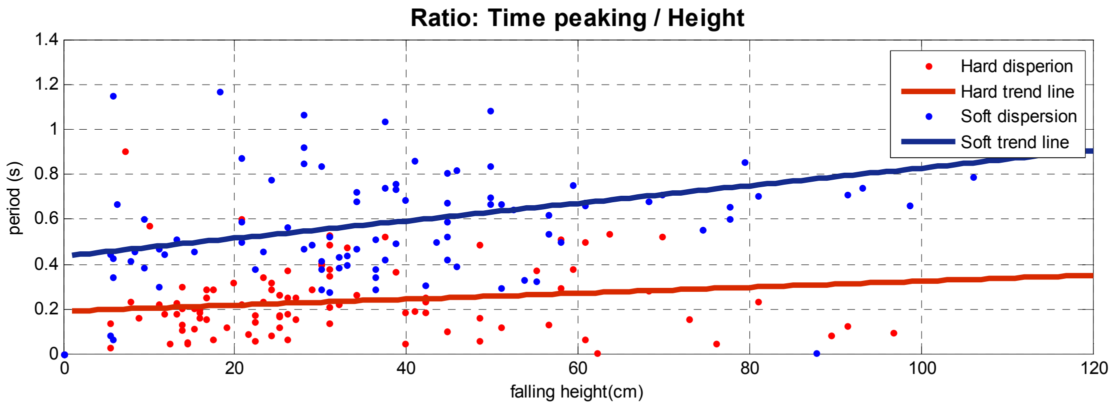

Figure13: Relation between times peaking and height for hard shocks and soft shocks

Figure 13 describes the relation between time peaking and falling height for hard shocks and soft shocks. In this experiment the falling height has been changed: 0-180cm.

Figure 13 above also shows the trend line of shock shocks and soft shocks. The trend line is a line of graph showing the general direction that a group of points seems to be heading [7].

The trend line for hard shocks shows that the hard shocks have shorter time peaking over all values of falling height. But, the soft trend line shows that the soft shocks have longer time peaking over all values of falling height.

3.2.2 Relation between number of peaks and height

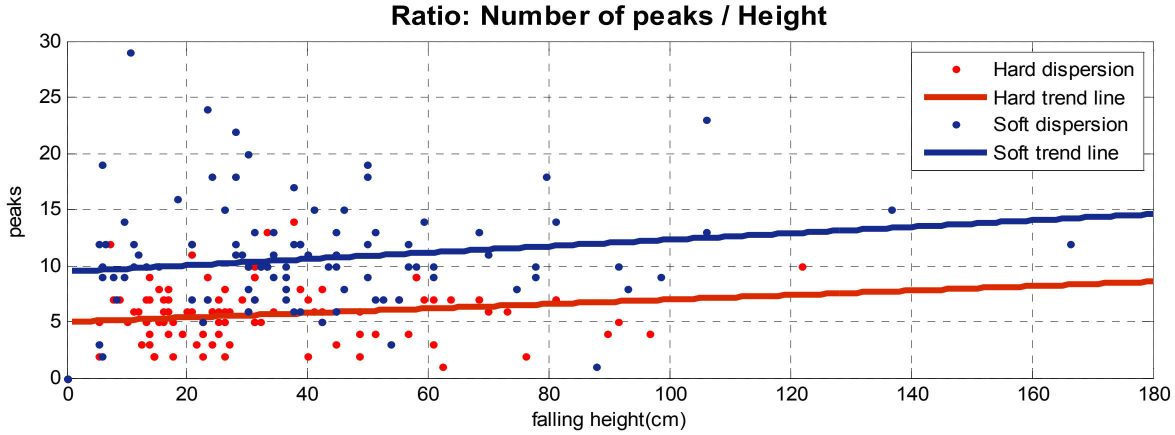

Figure14: Relation between numbers of peaks and height for hard shocks and soft shocks

Figure 14 describes the relation between number of peaks and falling height for hard shocks and soft shocks. The falling height is in the interval: 0-180cm. The figure also shows the trend line of hard shock and soft shock.

The results from this experiment are that the trend line for hard shocks shows lower number of peaks over all values of falling height. The soft shock trend line shows that the soft shocks have higher number of peaks over all values of falling height.

3.2.3 Relation between mean value of first peaks and height

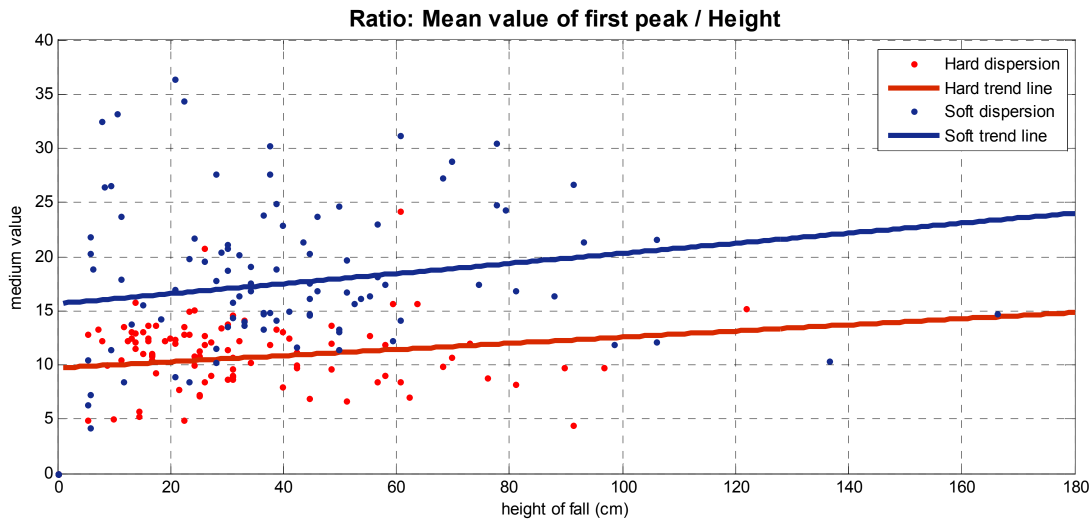

Figure15: Relation between the mean value of first peak and height for hard shocks and soft shocks

Figure 15 describes the relation between the average acceleration value after 0.1 second of the first peaks (mean value of first peaks) and falling height for hard shocks and soft shocks. In this experiment the falling height has been changed: 0-180cm.

The trend lines show that the hard shock has lower average acceleration value over all values of falling height.

3.2.4 Kurtosis function value for 0.3sec of time peaking period

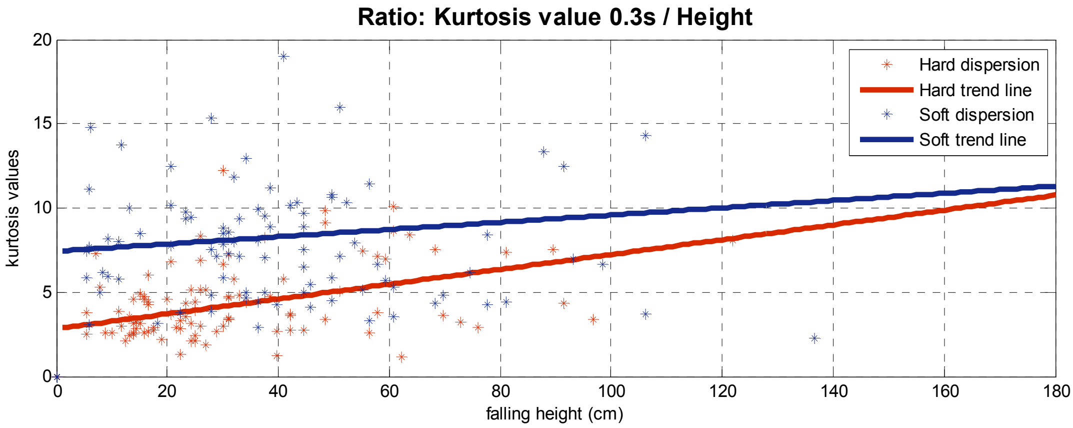

Figure 16: Kurtosis values during an interval of 0.3sec (0.1sec before the shock peak and 0.2 sec after the peak).

Figure 16 describes the relation between the kurtosis values over the first 0.3 seconds of the time peaking period and falling height for hard shock and soft shock. In this experiment the falling height has been changed 0-180cm.

The hard shock trend line shows that the hard shocks have lower kurtosis value over all values of falling height between 0-180cm, but for falling height above 180 cm the hard shock have higher kurtosis value.

3.2.5 Relation kurtosis function value full time and height

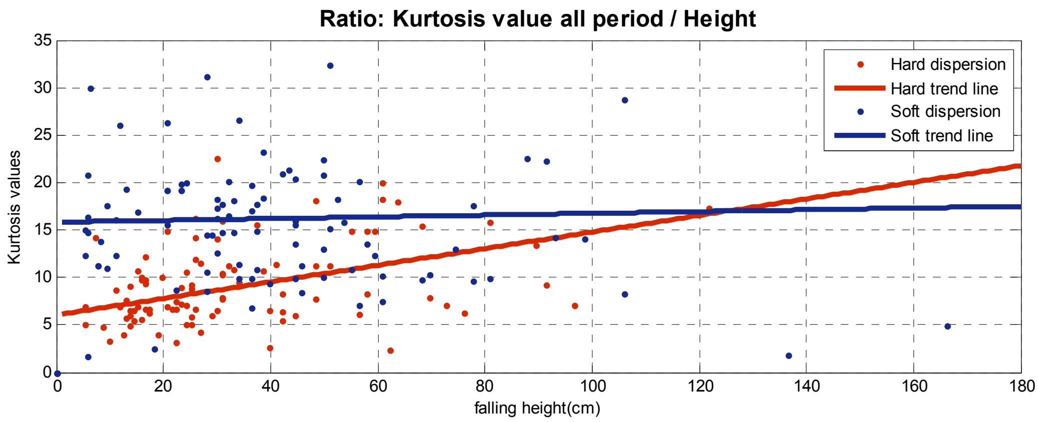

Figure 17: Kurtosis values over the whole period

Figure 17 describes the relation between the kurtosis values over the full time of the second period and falling height, for hard shock and soft shock. In this experiment the falling height has been changed.

The hard shock trend line shows that the hard shocks have lower kurtosis value between 10-120cm also shows that the hard shocks have higher kurtosis value for above falling height equal to 120cm. The result for the soft shock is the opposite.

4 Results

4.1 Template of decision

This section present the template of decision found in the experiments presented in chapter 3. The template is used to determine if the shock is hard or soft.

4.1.1 Histogram of time peaking (period of time peaking)

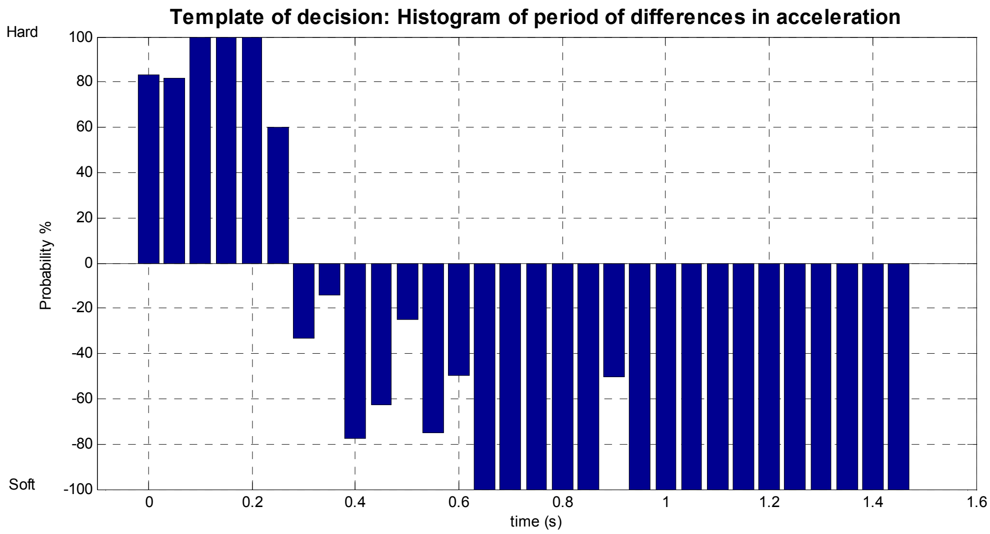

Figure 18: Probabilities of hard shock and soft shock for histogram of time peaking

Figure 18 shows the probabilities of hard shock and soft shock from the histogram of time peaking.

The hard shocks have probability between 0 to 100% and the soft shocks have probability between 0 to -100%.

The template of decision shows the probabilities of hard shocks are concentrated between 0.1- 0.3sec, and the probabilities of soft shocks are concentrated above 0.3sec.

4.1.2 Histogram of number of peaks

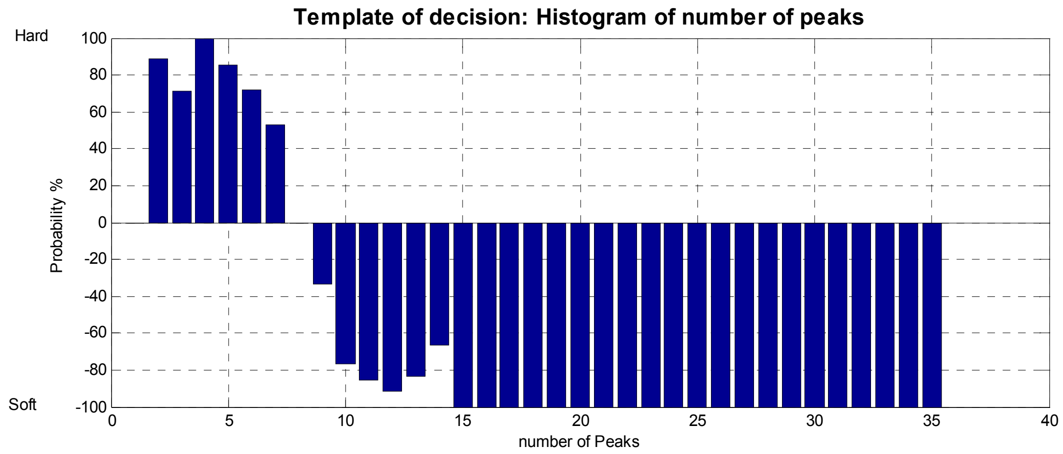

Figure 19: Probabilites of hard shock and soft shock for the histogram of number of peaks

Figure 19 shows the probabilities of hard shock and soft shock from the histogram of number of peaks.

The template of decision shows the probability of hard shocks are concentrated between 2 to 7 peaks and the template of decision shows the probability of soft shocks are concentrated above 8 peaks.

4.1.3 Relation between time peaking and height

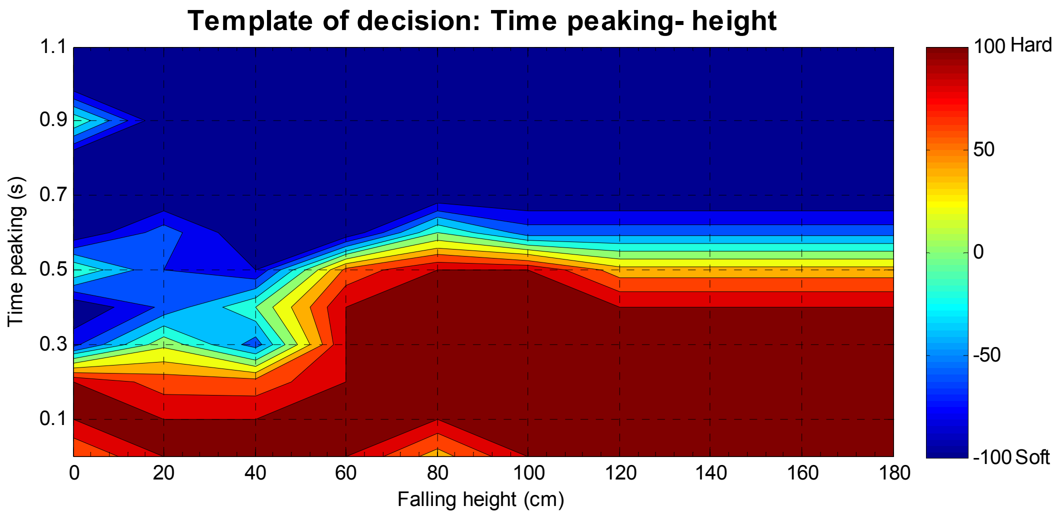

Figure20: Probabilites of hard hard shock and soft shock for relation between time peaking versus height

Figure 20 shows that the probabilities of hard shocks are concentrated between 0.1- 0.3sec over all values of height and also are concentrated between 0.3-0.5 second for height between60-180cm.

In the opposite, the results in the figure show the probability of soft shocks are concentrated above 0.5 sec over all values of height and also concentrated above 0.3sec for falling heights between 10- 60cm.

4.1.4 Ratio number of peak-height

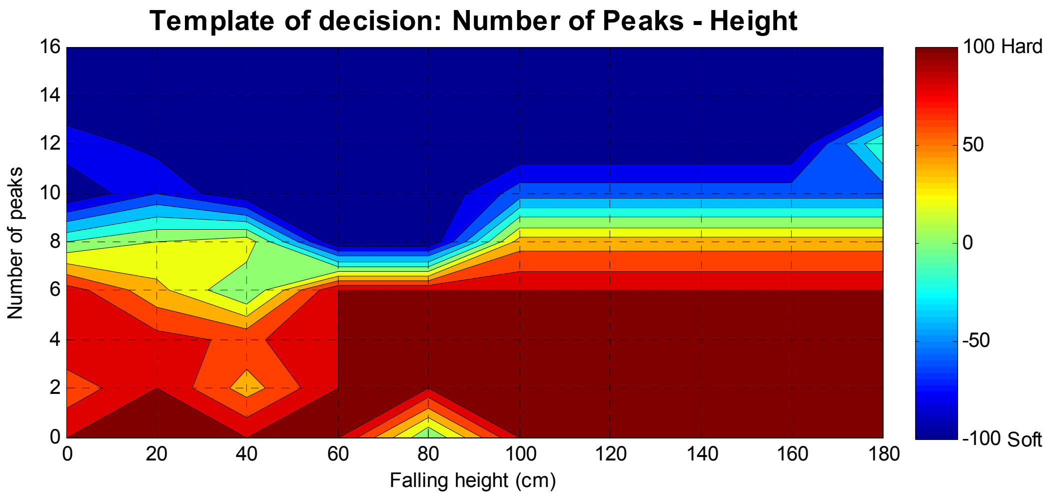

Figure 21: Probabilities of hard shock and soft shock for relation number of peak versus height

Figure 21 shows that the probability of hard shocks are concentrated between 1 to 6 peaks over all values of height and also are concentrated between 1 to 8 peaks for height between100-180cm.

In the opposite, the result in the figure 20 shows the probability of soft shocks are concentrated above 8 peaks over all values of height and also are concentrated above 6 peaks for height between 10-60cm.

4.1.5 Ratio mean value of first peak/height

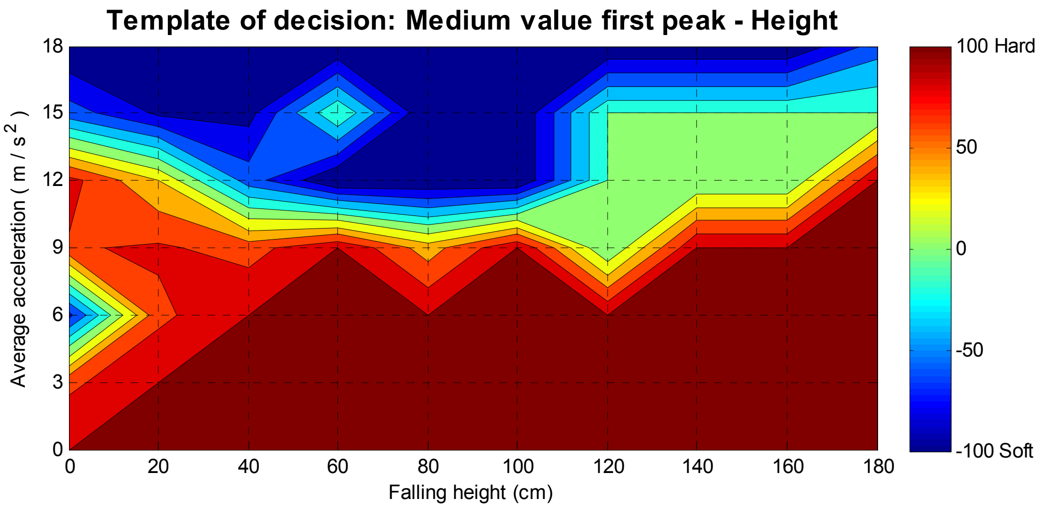

Figure 22 : Probabilites of hard shock and soft shock for mean value vesus height

Figure 22 above shows that the probabilities of mean value for hard shocks are concentrated between 0-12 units of accelerations over all values of height. But, the probability of mean value for soft shock concentrated above 12 units of acceleration over all values of height.

4.1.6 Kurtosis function value for 0.3sec of time peaking period

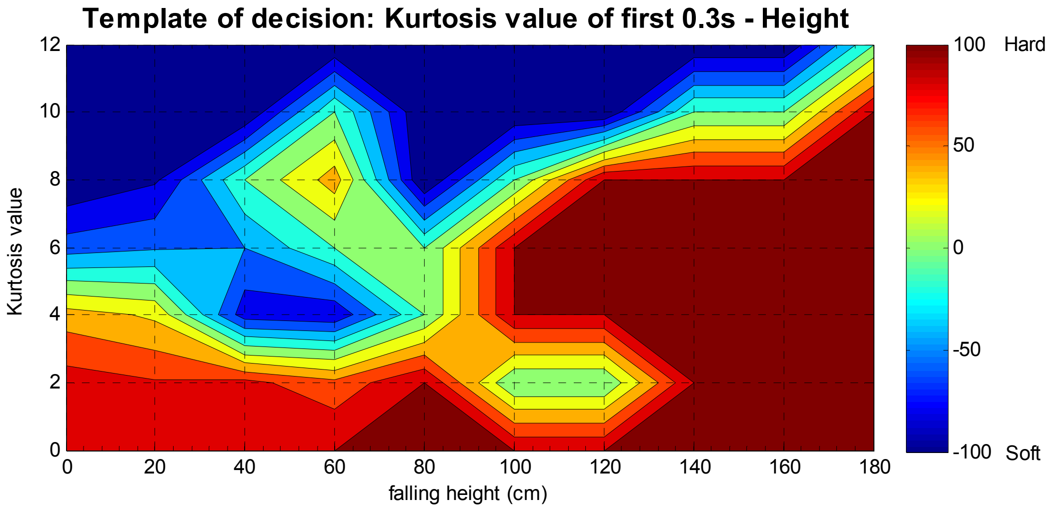

Figure 23: Probabilities of hard shock and soft shock over the first 0.3s of time peaking period

The result in figure 23 shows that the probability of hard shocks are concentrated between 1 to 4 units of kurtosis value over all values of height and also are concentrated between 1-10 units of kurtosis value for height between 100- 180cm.

In the opposite, the result shows the probability of soft shocks are concentrated above 4 units of kurtosis values over all values of height and also are concentrated above 10 units of kurtosis values for height between100- 180.

4.1.7 Kurtosis values for shock signal

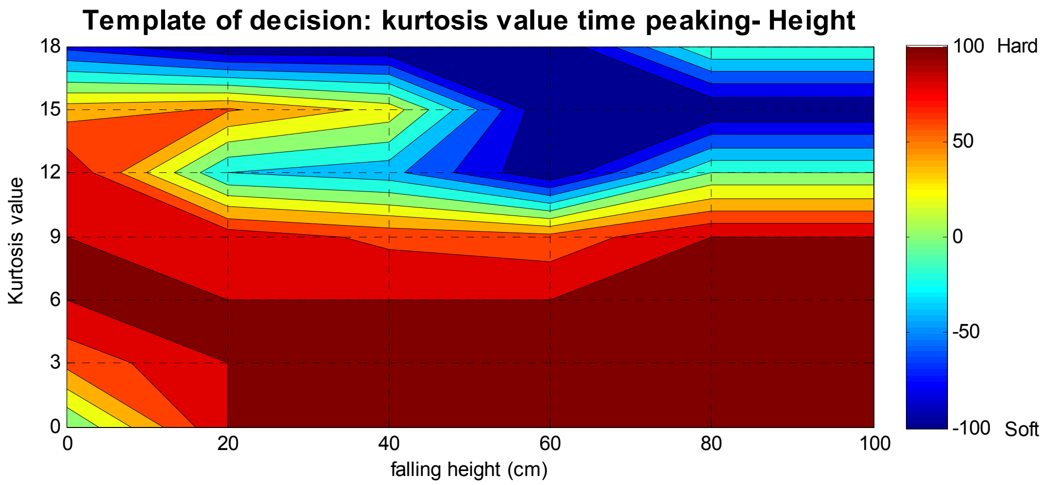

Figure 24 : Probabilities of hard shock and soft shock.Kurtusis value for whole period

Figure 24 shows that the probability of hard shock are concentrated between 1-11 units of kurtosis value over all values of height and also are concentrated between 1-15 units of kurtosis value for height between 10- 20cm.

In the opposite, the result in the figure 24 shows that the probability of soft shock are concentrated above 15 units of kurtosis values over all values of height and also concentrated above 10 units of kurtosis values for height between 60 to 100cm.

4.2 The decision maker

The data used in the decision is derived from statistical data calculated from the accelerometer signal in order to find out what kind of ground the Smartphone hits. Is the smartphone exposed to a hard or soft shock?

The decision maker evaluates each shock in the interval 100% to -100%, where 100% is the most probably of a hard shock (inflexible ground) and -100% is the most probably of a soft shock (flexible ground).

In order to get the best effectiveness possible, we prove it with all the decision templates mentioned before. The Table1 below shows the effectiveness of each decision templates separately while the percentage values are the average of the results for all the performed shock experiments, which are around 190 shocks.

Table 1: caption the effectiveness of each decision temples

	Histogram differensers in acceleration	Histogram Number Of peaks	Timepeaking /height	number of peaks /height	mean value first peak /height	Kurtosis 0.3sec / Height	kurtosis all time shocking /height
hard test	84%	51%	62%	57%	61%	49%	69%
soft test	24%	-47%	-64%	-54%	-52%	-45%	-3%

The table 1 shows that the ratio between time peaking, number of peaks, mean value of first peaks and kurtosis 0.3 sec, over different falling height are most effectiveness measurable data we could use it to detect the type of shock.

$$A = \frac{probability\ of\ (time\ peak + number\ of\ peaks + mean\ value + kurtosis 0.3\ \mathrm{sec})}{4}$$

Case 1: A > 0; the type of shock is <u>hard shock</u>

Case 2: A <0; the type of shock is <u>soft shock</u>

The decision maker was used to detect the hard shock and soft shocks in our hard test signal (95shocks) and soft test signal (95shocks) and the result obtained is presented in Table 2.

Table 2: The effectiveness of the decision maker.

	Total number of shocks	Test Result : Hard shock	Test Result : Soft shock	Effectiveness
Hard test	95	86	9	90%
Soft test	95	6	89	94%

Table 2 shows that the decision maker gives a good effectiveness for both shocks, the hard and soft shock. The result shows that we can use the decision maker to determine the type of shock and count the number of shocks happened in the Smartphone.

5. Summary

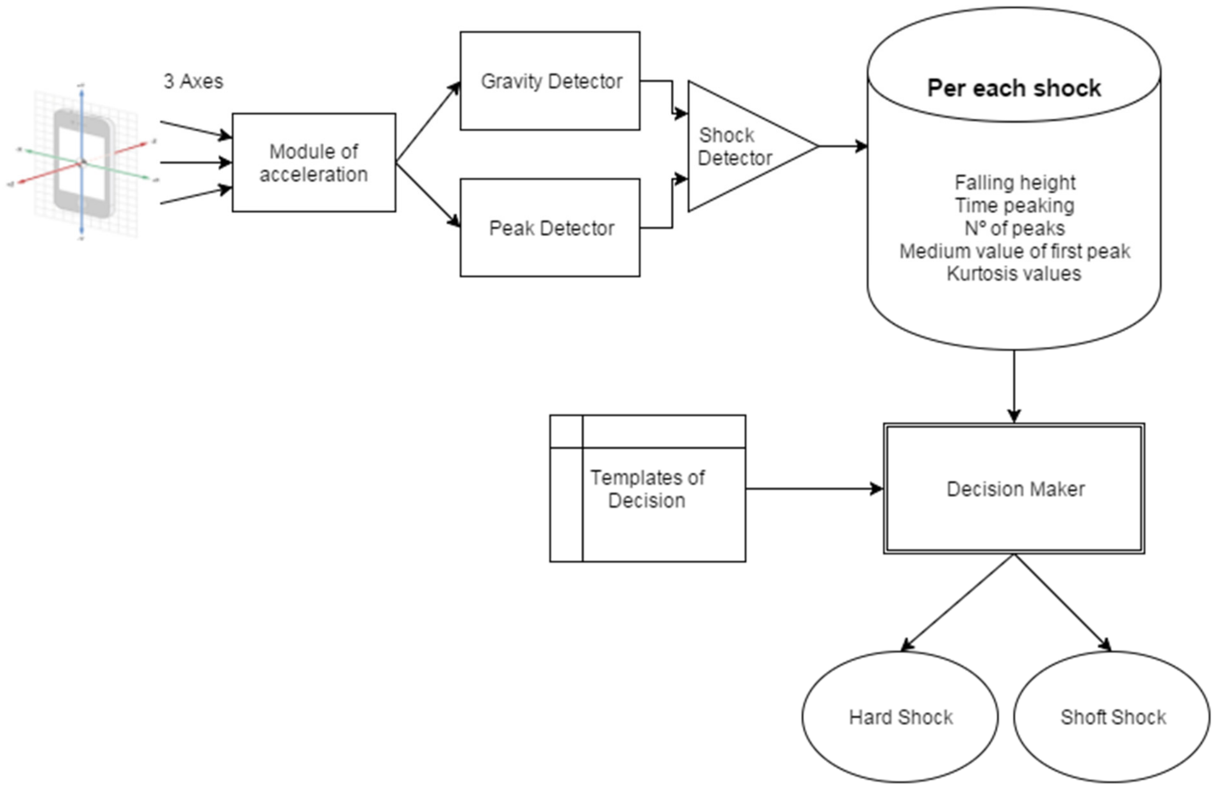

Figure 25 : The proccess used in the project

Figure 25 shows the process used in the project. The process was divided in following steps:

- Calculated the acceleration in 3 direction x, y and z by using software app implemented in the Smartphone.
- Found the shock signal by using shock detector.
- Found the differences between the hard shocks and soft shocks using four factors:
  1- Peaking period
  2- Number of peaks
  3- Mean value of first peaks
  4- Kurtosis function
- Found a temple of decision using statistical data in the differences.
- Found the Decision maker using the templates of decision.
- Found the effectiveness of the decision maker.

6. Conclusion

In conclusion, there are two types of shocks, soft and hard shocks. In order to determine whether the type of shock is hard or soft, several factors should be considered such as the peaking period, the number of peaks, and other factors shown in the table below.

Table 3: Shows the differences between hard shocks and soft shocks

Differences	Soft Shock	Hard Shock
Peaking period	long period (≈> 0.4 s)	short period (≈<0.5s)
Number of peaks	higher (≈> 10 peaks)	lower (≈<10 peaks)
Mean value first peak	higher (≈ 20 m/s^2)	lower (≈10 m/s^2)
Kurtosis 0.3 s	higher (≈ 10)	lower (≈ 4)
Kurtosis whole period	higher and constant	lower but increasing with the height

After determining what kind of shock and the number of shocks, the smartphone has been exposed to the manufacturers could find out whether the damage is from a careless user or malfunction from the manufacturing process.

7. References

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