**The process of the step algorithm**

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Contents

[1 The tendency analysis of the step patterns 2](#_Toc497930524)

[1.1 The natural walking pattern: (refer to references) 2](#_Toc497930525)

[1.2 Comparing the accelerations of different axes( X ,Y and Z axis) 3](#_Toc497930526)

[2 The features of X, Y and Z axis accelerations 6](#_Toc497930527)

[3 The conditions for judging the steps 9](#_Toc497930528)

[3.1 The analysis of there axes accelerations (refer to references) 9](#_Toc497930529)

[3.2 Peak of The acceleration Change 10](#_Toc497930530)

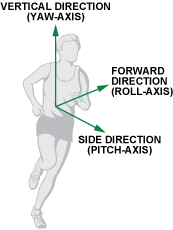
[3.3 Dynamic Threshold Judgement 12](#_Toc497930531)

# The tendency analysis of the step patterns

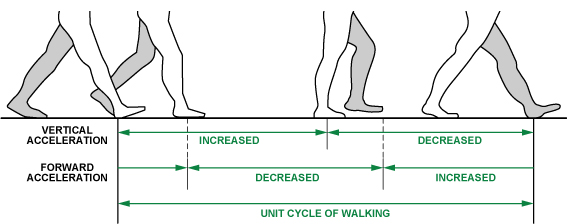
As everyone knows, during our daily lives there are a lot of different walking or movement pattern: seating, standing, sleeping, walking, cycling, running and so on. So first and foremost, let us check over all of those patterns and briefly analyze how the accelerometer is worked efficiently in different patterns.

## The natural walking pattern: (refer to references)

When a pedestrian is walking on the road, the accelerometer will divide the motion acceleration by three directions, as we can see in the picture below: Vertical Direction, Forward Direction and Side Direction, which can be also called: X, Y and Z Axis.



And two photos below, show the change state of the vertical acceleration and forward acceleration in one circle of a step.



***(\*\*\*This Picture is from online)***

## Comparing the accelerations of different axes( X ,Y and Z axis)

There are some charts below which show X, Y and Z axis acceleration data separately from Iphone 6s accelerometer. Every chart shows five states of movement in 30s, 50 Hz. *The detail in the form below:*

|  |
| --- |
| Accelerometer Data Record |
| Record Date:16/10/2017 |
| **Frequency: 50 Hz** |
| Time Interval Total: 2.5 Minutes |
| First 30s:Static |
| Second 30s:Walking in package |
| Third 30s:Wlaking in hand |
| Fourth 30s:Running in package |
| Fifth 30s:Running in hand |

The data record of the X-axis acceleration of Iphone 6S accelerometer in 2.5 minutes.

The data record of the Y-axis acceleration of Iphone 6S accelerometer in 2.5 minutes.

The data record of the Z-axis acceleration of Iphone 6S accelerometer in 2.5 minutes.

From those three charts, we can see the wave clearly. When the walk is static in the first 30s, there is no change in any axis it is always nearly 0. And in the next 60 s in walking state, there is a slowly change, but in last 60s, there is a dramatic fluctuation in charts. *What we can summarize is that the acceleration totally fluctuate with* ***amplitude of movement.***

Even we can get the regulation that there is a relationship between accelerations and amplitude of movement, we cannot actually use one axis to calculate the steps as pedestrians can walk or run in different directions, since in different directions the fluctuations of three axes accelerations are always changing. So how can we catch or summarize a correct regulation using the data of Iphone 6s accelerometer data? It will be explained in next chapter.

# The features of X, Y and Z axis accelerations

## Total acceleration concept

There is concept, total acceleration, should be maintained, and that will be explained in following paragraphs, and total acceleration can be computed using the equation below.

***(\*\*\* This format is from online )***

So what does this equation do? Exactly it integrates the accelerations of three axes values, X, Y and Z axis value of Iphone 6s accelerometer , to one value, which can represent or reflect the amplitude ***no matter which directions people walk or run to.***

There is a chart below, which shows the wave pattern of Axyz value, which are integrated from the last X, Y and Z axis data above in five states above of movement per 30s in 50 Hz. (Five states in 2.5 minutes data, First 30s: static, Second 30s:Walking Iphone in package, Third 30s:Walking Iphone 6s in hand, Fourth 30s:Running Iphone 6s in package, Fifth 30s:Running Iphone 6s in hand) .

From this chart we can see a very clear variation tendency and it is clear to distinguish every 30s the person walk in different states. For example, for third 30s, the person is walking and put the phone in hand, and then he start to run in after 30s, and the variation of data is more dramatic as the amplitude of the movement increases.

## Comparison between total acceleration with three axes

Here the chart below compares the separate there axes accelerations with the integrated one, so the blue line almost represent the overall trend of the other three lines data: X, Y and Z axis acceleration data.

# The conditions for judging the steps

(after getting the amplitude variation tendency chart above)

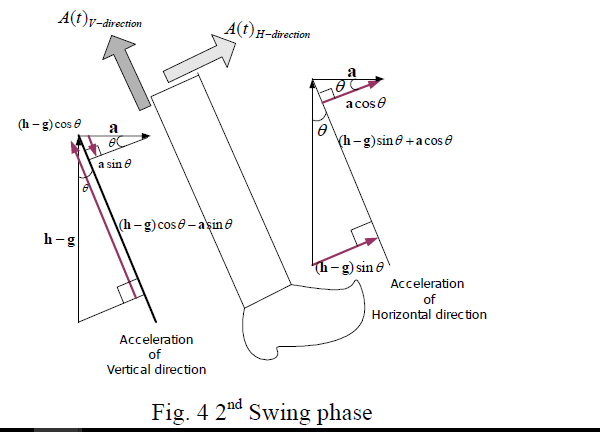
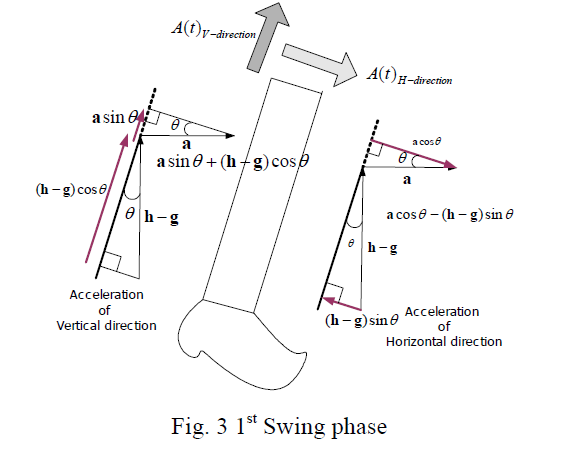
## Common sense of Waling speed

We assume that people can run as rapidly as five steps per second and walk as slowly as one step every two seconds. Thus, the interval between two valid steps is defined as being in the time window [0.2 s to 2.0 s]; all steps with intervals outside the time window should be discarded. According this rule, we catch the acceleration data from Iphone 6s in 50Hz Frequency, one value per 0.02 mS. As we all know the valid step period between 0.2 to 2 s, one step approximately occupies from 10 to 100 data.

Basing on this time window [0.2 s to 2.0 s], two features: Peak Values Of The Acceleration and Threshold Judgement, can be extracted from the charts above, and following those two standards we almost can use the code to catch the correct number of steps through the Axzy data.

## The analysis of there axes accelerations (refer to references just for introduction)

In this part, there are some pictures below show the analysis of the vertical and horizontal acceleration of the foot during one step of the walking, the signal pattern of walking behaviors is obtained. As we can see in two pictures below, where a , h , g means horizontal acceleration, vertical acceleration and gravity force, respectively.



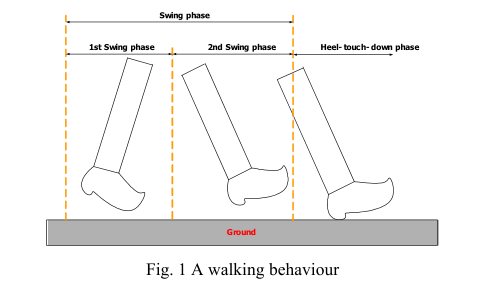
The strides of the walker are different according to the human parameters. The stride depends on several factors such as walking velocity, step frequency and height of walker etc.

The horizontal direction acceleration and vertical direction acceleration during the swing phase is denoted in equation below, where θ(t) is inclination angle of the leg at time t.

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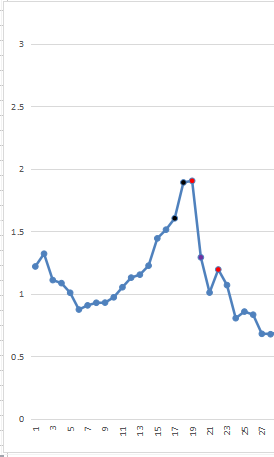
## Peak values of The acceleration

Considering about the posture of people walking, we can get a standard of the acceleration change. Combining the formulates above and some pictures below showing three phases of a step, so we can find there must have some peak values and bottom values of Axyz data, which are showed in the following chart.

***(\*\*\*This Picture is from online)***

This chart shows the total acceleration wave of walking in package during 2 seconds from the 2.5 minutes above chart. From the diagram, we can mark some positive and negative peak values, and there are some rules for judging whether peak values are available or not:

Rule 1: Before the positive peak value, there must have two increase changes happened before and one decrease happened after, so we can see the picture below (a part of the last picture above), which shows two black values increase continuously before the first red peak value and one purple value after decrease dramatically. And the follow red positive peak value should be discarded because of having only one increase value before it.



Rule 2: And the negative peak is very simple to judge, which includes one increase value after it and one decrease before. After following this two rules, we can discard several invalid data, which become to normal blue color from red color, comparing with the first one to find the difference.

## Dynamic Threshold Judgement

### The format of threshold

After extracting some alternative positive and negative peak, we can see there are still some obvious invalid values showed in the chart above, so how can we discard those invalid value? Here, we introduce a ***threshold value***, only when the positive peak value is larger than the threshold, it can be considered about as a valid peak value. In a word, how to decide the exact value of threshold of acceleration is a key point.

The threshold value = (Peak\_value + Bottom\_value)/2

From the chart above, there is trend of threshold value, we can compare the peak values with the threshold value to flite the invalid data.

### The dynamic threshold conception

As anyone known, different patterns of movement have different amplitudes of acceleration Axyz data, we should update the threshold in real time. There is a strategy for referred, we can calculate an average of four threshold values. There are some charts below, comparing the walking pattern with running pattern.