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Forums / Data Analysis Assignment 2

Background on accelerometers, gyros and FFTs

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David T Wilcox · 25 days ago

Since I've seen several threads where people have confusion over the variables used and what an accelerometer is versus a gyroscope, and why there are some variables prefixed with t and others with f, I thought I'd write up a simple explanation based on what I've inferred from reading through the data set docs and my past experiences.

I do have a background in Wii and iOS game development using accelerometers and gyroscopes. Not an expert, but I have a little experience dealing with them.

DISCLAIMER I am a student in this course and have nothing to do with the data set (hopefully that's obvious). I could be completely wrong about how the authors of the data set labelled their variables. I am also not an expert on FFTs. Everything I write from here on out should be reviewed thoroughly by the reader, considered alongside the reader's own research and not considered official in any manner. Also, I've made every attempt to abide by the course honor code and forum rules, but if I've unintentionally said anything that breaks the code, please inform me immediately and I'll be happy to edit or remove my post.

Accelerometers and Gyroscopes

An accelerometer measures movement along a particular axis (up and down, left and right, forward and backward). In the case of an Android smartphone like the Samsung Galaxy S II used to gather this data, it can measure movement along all three of the X, Y and Z axes.

The measurements can have positive and negative values to indicate the direction of movement along the axis. Two measurements with the same absolute value indicate the same acceleration, but could be in opposite directions. Note that in the data set, the data has been normalized to a [-1, 1] scale, so the sign of the value no longer has the same meaning as in the raw data provided by the accelerometer. In the data set, -1 corresponds to the minimum value and 1 to the maximum value for that variable.

The X, Y and Z axes are based around the default orientation of the phone. *They do not change* relative to the phone when the phone orientation changes, but they *do change* relative to you. If you hold the phone at arm's length so the screen is facing towards you and the top of the phone (the part you hold to your ear when talking) is pointed towards the sky, then the X-axis runs from your left to your right, with positive values being towards your right; the Y-axis

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runs up and down, with positive values being towards the sky; and the Z-axis runs front and back, with positive values being closer to you and negative values being away from the phone.

Since the axes don't change when you re-orient the phone, this can be tricky. If you turn the screen away from you and the phone upside-down, the axes are still oriented the same, but the positive / negative directions are flipped for the Y- and Z-axes. Likewise, if you point the screen towards the ground, the Z-axis is now oriented up and down, rather than front and back.

A gyroscope will tell you the orientation of the phone and how quickly it is changing orientation. For example, if your phone is laying face up on your desk, the gyroscope will tell you it is oriented that way. If you flip it over, the gyroscope will tell you not only that it was flipped over, but how quickly and in which direction it was rotated.

The gyroscope axes are the same as the accelerometer axes. Positive values indicate counter-clockwise rotation around the axis and negative values indicate clockwise rotation around the axis.

As a final note, acceleration measures the change in velocity of the phone; jerk measures the change in acceleration. Both could be useful.

Time Domain vs Frequency Domain

The original data set docs reported the sensor data was sampled at 50 Hz (50 times per second) and then filtered to remove noise. That data is stored in the variables with a "t" prefix to indicate time domain data.

Some of the variables were then processed using a Fast Fourier Transform to change the time domain data to frequency domain data.

What's the difference between time domain and frequency domain data? Time domain data is data sampled over time - widgets sold per day, accelerometer samples taken per 1/50 second, etc. Frequency domain data shows how much of a value is present within each frequency band over a range of frequencies. *What?*

Edited example Let's say you have widget sales data. The widget sales are recorded daily for 91 days (13 weeks, or a fiscal quarter). Sales per day is time domain data, the kind you normally work with. Applying a Fourier Transform to this converts this time domain data to frequency domain data. This will show the frequency components of the sales data, which can be used to determine the number of sales cycles present in the data and how often they occur. If you see a spike in the frequency component corresponding to 13 cycles, that would indicate a weekly sales cycle. This is 91 samples (days) / 13 cycles = cycle every 7 days.

In this data set, there are 64 frequency bands per sample representing the energy value. Based on their docs, energy is equal to the sum of the squares of velocity measurements per axis, divided by the number of values. *My interpretation* is that the frequency band with the largest magnitude (value) represents the energy value band that occurred most often, which would indicate a cycle in the total energy (such as the phone moving back and forth while walking).

Conclusion

Obviously, whether or not any of this is meaningful to a prediction model will have to be

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determined through analysis. Hopefully this helps other students understand this better than I did initially. If anyone smarter on these subjects, or a TA or Prof. Leek, can shed more light or correct me, please do so.

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Jeff Jetton COMMUNITY TA · 25 days ago

Nice job, David. Thanks for the post!

Just to add to one point that confused me a tiny bit on first read... when you change the position of the phone, the x/y/z axes do not change *relative to the phone*. They *do* change relative to you, the stationary observer, right?

5

David T Wilcox · 25 days ago

Thanks. I noticed the bad wording after I posted, but the post controls didn't let me edit until now. I've made the correction to clarify.

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+ Add New Comment

Anne Paulson COMMUNITY TA · 25 days ago

Great post! Thanks.

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+ Add New Comment

David T Wilcox · 25 days ago

My initial example of frequency domain data was bugging me and I realized it wasn't entirely correct. I've edited the example to be more correct and explanatory and also edited the section in the next paragraph applying the frequency domain data definition to this data set.

My apologies if my first example confused or misled anyone. Discrete Fourier transforms can be a bit to wrap your mind around.

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Michele Mendel · 24 days ago

Thanks for your post. I'm learning as much from people like you as I do from the course. I have been looking at all the sensor data (see post "561 box plots"). The limits are -1 to 1, but it's not clear to me what they measure. At first I thought that a reading at either limit means a strong movement in either direction of an axis (or an angular movement in case of readings from the gyroscope) and zero means no movement, but it looks like -1 is no movement and 1 is maximum movement. Do you know if this i true and if there is a difference in the time vs the frequency domain?

Example:
tBodyAcc-max()-X: laying -0.8, walkdown 0.5
fBodyAcc-max()-X: laying -1, walkdown -0.1

5

David T Wilcox · 24 days ago

The UCI documents state the data was normalized on a [-1, 1] scale, so -1 would represent the smallest value across all samples for that variable and 1 is the largest value. That applies to all of the numeric values, whether measured in a time or frequency domain.

I have no idea how you'd interpret those values to determine direction of movement along the axis. A naive assumption would be that 0 could be treated as no value, so that -1 and 1 indicate movement in opposite directions. That may be a reasonable enough assumption for our purposes. However, if the original data for movement on the X-axis, for example, ranged from -100 to 200, then the normalized value indicating no movement would be slightly above 0.

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Eoin P Sharkey · 24 days ago

Hi David,

a very interesting post.

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I think (at least my assumption) is to try to build the predictor function/model *without* too much domain-specific knowledge. Your post has provided just the right level of detail.

It would be great if you can "publish" it somewhere so I can reference it properly in my write-up. (The course wiki would do I guess ?)

I am also wondering - based on your experience - can you give any pointers toward resources that would describe benchmarks or evaluation parameters for predictor functions. Like is accuracy more important than speed, what is a reasonable level of accuracy (60% 90%)

Thanks again.

ES

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+ Add New Comment

 Daniel Gutierrez · 22 days ago

Is it as simple as thinking of the phone's Newtonian kinematics like this: the gyroscope represents the 1st derivative in motion or velocity whereas the accelerometer represents the 2nd derivative in motion, or rate of change of velocity? Jerk sounds like the 3rd derivative?

^ 5 v

Anonymous · 22 days ago

you are right http://en.wikipedia.org/wiki/Jerk_(physics)

^ 0 v

Anonymous · 22 days ago

the link is bad above.

^ -2 v

 David T Wilcox · 22 days ago

Correct

^ 0 v

Chris Stehlik · 21 days ago

The jerk physics link just needs the last ')' added to it and it will work.

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Suzanne Kiihne · 18 days ago

The gyroscope data is not just the rate of motion, as it would be in normal Newtonian physics. This is because the gyroscope and the accelerometers are separate pieces of hardware that measure different things. The accelerometer is sensitive to the forces on the phone. The mass of the phone is constant, so measuring the force in a direction will give the acceleration, F=ma. The gyroscope is measuring angular velocity. If you move forward in a straight line, you have no angular velocity. If you turn pirouettes on a spot like a ballet dancer, you have angular velocity, but no forward velocity. And there's more confusion. In physics, the direction of angular velocity is funny. Since the angle is changing, you can't just draw an arrow in the direction of movement. The direction is defined as perpendicular to the plane of motion. So if you are standing in the middle of a typical graph and facing along the x-axis and then you contemplate turning to the left, toward the y axis, the angular velocity will be upwards, along positive z. This is described by the 'right hand rule'. Curl your right hand along the direction of motion and your thumb will point along the velocity direction.

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+ Add New Comment

Anonymous · 22 days ago

This may be a silly question, but is there a real-world reason to predict the phone data? In other words, the Netflix prediction could make Netflix work better. Or is this just a cool assignment to do?

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Anonymous · 22 days ago

What if you wanted to write an app that tracked how much time you spent running, walking, sitting, sleeping, etc? Or maybe estimate how many calories you burned during the day? Seems like it could be interesting information.

4

Rose Kudlac · 20 days ago

This thread is about a Kaggle competition using similar data to predict Parkinson's disease. That sounds pretty useful. https://class.coursera.org/dataanalysis-001/forum/thread?thread_id=1416

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Predictiing activity could taken as a first step.

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Kristin · 20 days ago

For health studies, it can be useful to know how much time subjects spend doing different kinds of physical activity and also what the intensity of that activity is.

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Suzanne Kiihne · 18 days ago

There's a lot of ongoing research using phones to track motion. Have a look at http://www.activelivingresearch.org/node/12638. Obesity and diabetes are huge problems (no pun intended). There is a lot of health research into understanding when and where people are active. There is a push to understand how to increase physical activity and how to promote better habits of activity. Tracking physical activity during the day can be a baseline monitoring, or it could be used to send an encouraging SMS reminder to an overweight patient.

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Diego F. Pereira-Perdomo · 22 days ago

Nice! Thank you!

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+ Add New Comment

Anonymous · 21 days ago

Thanks David for your help!

Ps. You (American?) guys are obsessed by honour codes!! Looks like when in Middle Ages people were scared of writing because they could be taken for heretics :)

-3

David T Wilcox · 21 days ago

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Not obsessed, but no sense running afoul of the rules unintentionally. The gray area between helping other students and doing some of the work for them can differ for each instructor and TA, hence the disclaimer.

1

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Rodrigo Fernandez-Vizarra · 20 days ago

David,

thanks for sharing this valuable information. I have a doubt about one of your statements.

"Two measurements with the same absolute value indicate the same velocity, but could be in opposite directions"

Shouldn't that be "[...] indicate the same *acceleration*, but could be in opposite directions". You state that the accelerometers measure change in speed in a latter paragraph, and being called accelerometers it makes sense that they measure changes in speed.

Thanks again, your post helped me to understand the data in the dataset. Rodrigo

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David T Wilcox · 20 days ago

Correct and good catch. I fixed the original post to reflect what I meant to say, but didn't write.

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Tabitha Post · 18 days ago

Thanks David! This really helped to understand the data!!

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Will Traves · 16 days ago

I'm starting to doubt the validity of the dataset. First I wondered what "normalized to [-1,1]" meant. It seems reasonable to interpret this as -1 for the min value of the observed variable and 1 for the max value. However, when I was going through the data looking for outliers I tried

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the following:

xval=as.factor(samsungData[which(samsungData[,562]==25),563])
yval=samsungData[which(samsungData[,562]==25),1] plot(xval,yval,pch=19)
names(samsungData)[1]

The code plots a boxplot of subject 25's mean-x-acceleration doing each of 6 activities. The values for "laying" are both the smallest and the largest (by far). I can't see how this can be interpreted at all. Does anyone have any ideas for how to interpret this?

Will

▲ 2 ▼

Hibai Unzueta · 15 days ago

I agree with Will, at least I find it difficult to interpret some of the values I see. Sitting may have acceleration values if the subject is sitting on a moving vehicle, for example but what about laying?

▲ 0 ▼

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