DELSYS

The following Delsys tutorial focuses on analyzing one's gait solely through the use of Trigno™ Wireless sensors. It guides one through sensor setup, data collection and post-processing analysis of the recorded data sets. EMG measurements were taken from several muscles and processed cyclically in accordance with tibial angular velocity measurements.

HARDWARE PRESENT

Trigno™ IM sensors

Trigno 4-contact FSR sensor

Trigno Standard sensors

SOFTWARE PRESENT

Delsys' EMGworks

C-Motion's Visual3D

We encourage users to recognize the useful principles present here and apply and expand them as needed to other tasks or applications.

Acknowledgement: Delsys thanks Professor Jim Richards and the University of Central Lancashire for creating this tutorial and providing permission to share on its website.

DELSYS-VISUAL3D TUTORIAL 2

Gait Analysis

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Data Collection
Gait Analysis

SENSORS REQUIRED

Sensor 1 EMG on Right Tibialis Anterior

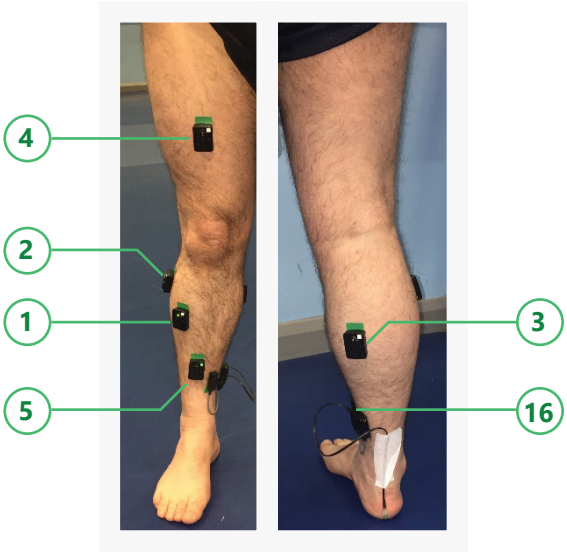
Sensor 2 EMG on Right Peroneus Longus

Sensor 3 EMG on Right Gastrocnemius

Sensor 4 EMG on Right Rectus Femoris

Sensor 5 EMG/IMU on the front of Right Tibia

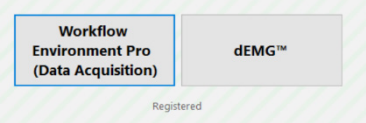
Sensor 16 Footswitch



SETTING UP THE SOFTWARE

Open EMG works Acquisition

Open Workflow Environment Pro



Import note: Where does the data go?

Please follow the few points below to ensure you're able to locate the data sets after collection.

When starting a new session click on **"Application"** and **"Options"** under "**Default Sample Data Folder**" click on **"Browse"** and select where you want this project data to go.

c:\....\Delsys Tutorial\Gait

For individual participants you will have the chance to make a folder within this later.

Open Test Configuration Gait EMG IMU Footswitch

Click "Import" and locate the file "Gait EMG IMU Footswitch.emtc" then "Open" This loads the Gait EMG IMU Footswitch test configuration file from the download package of this tutorial into EMGworks. The sensors in this tutorial were placed in the following locations (see image above for reference):

EMG Sensor	Location	Sensor	Location
1	R Tibialis Anterior	EMG+IMU 5	Front of R Tibia
2	R Peroneus Longus	FSR 16	R_Foot_Switch
3	R Gastrocnemius		
4	R Rectus Femoris		

If you wish to use EMG/IMUs then the Test Configuration will need to be modified slightly.

It is worth reviewing the sensitivity settings of these sensors each time you use the Test Configuration. This is particularly relevant when you are recording IMU data (acceleration, angular velocity and magnetometer data).

Import note: sensitivity

For this Configuration, set these sensors to the least sensitive and therefore highest range, giving us the greatest range at the expense of sensitivity.

- Failure to select the correct sensitivity could reduce the sensitivity of the accelerometers (acceleration) and gyroscopes (angular velocity) measures
- Or worse clip the data so you do not record the full range, this data is then lost

EXPERIMENTAL WORKFLOW

Open Experimental Workflow. Within Experimental Workflow there are several items we can do and display. Selected here is a "Signal Preview" template and a series of different "Plot and Store" experimental conditions.

Signal Preview

This is useful to check if you are getting signals from the sensors and to visually check a) the quality of the EMG signals, the sensitively setting of the IMU data (acceleration, angular velocity and magnetometer data), FIGURE 1. You have to select a sensor for feedback, however all channels will be displayed, FIGURE 2.

Plot and Store Gait

The next steps are to perform a series of experiments/data collection. This workflow focuses on a 20-30 meter long Gait Trial walking in a lab setting.

Within Plot and Store you can choose what you would like displayed and how you would like it displayed.

If you click on options you can select which signals you would like displayed in the collection, although all channels will be collected so if you change your mind what you want to look at all the data will be available in analysis. We have also selected showing the data on 3 columns.

For these tasks, we've selected EMG only on R Tibialis Anterior, R Peroneus Longus, R Gastrocnemius, R Rectus Femoris, angular velocity (Gryo) from the R_Tibia, and the R_Foot_Switch, FIGURE 3.

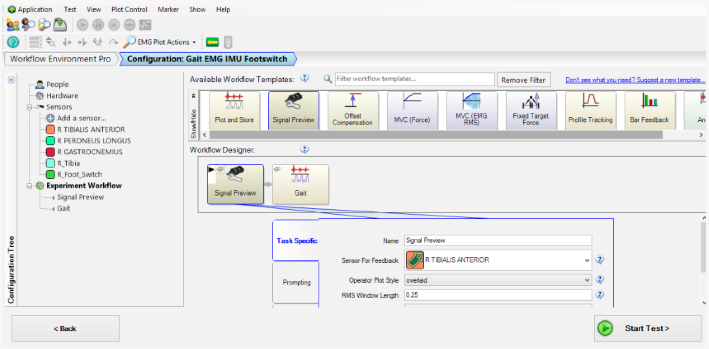


Figure 1 – Setting up Signal Preview

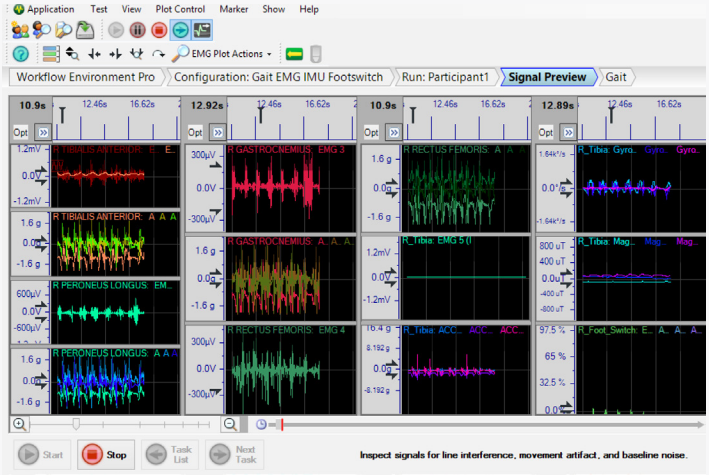


Figure 2 – Preview window

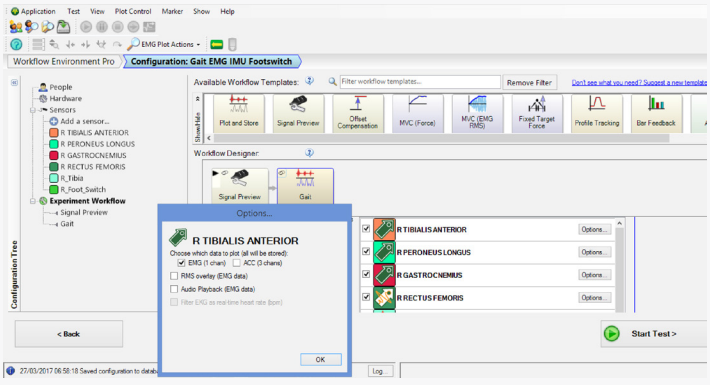
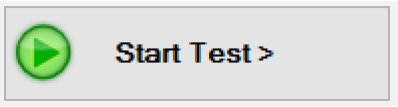


Figure 3 – Setting up Plot and Store

STARTING A TEST

Click on



You now have a chance to name the data session, here we have called this "Participant1", FIGURE 4.

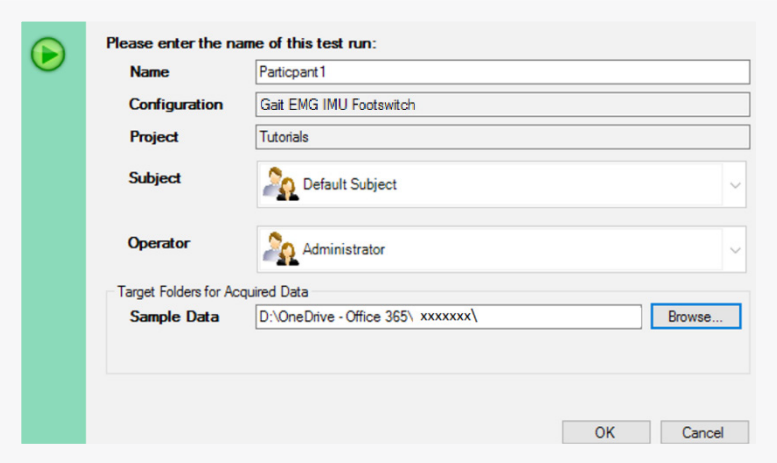


Figure 4: Session Data Name

Create a folder for that data session, by clicking on "**Browse**" and **"Make New Folder"** again making sure that you are selecting a sensible folder, FIGURE 5.

In this case we have created a folder within ...\Gait**Participant1**

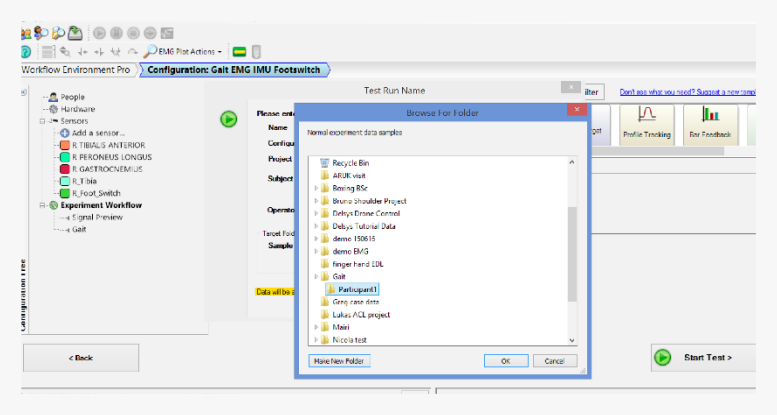


Figure 5: Session Data Name and Location

Import note: Return to Test Configuration

If you want to **"Return to Test Configuration"** this will now revert to the "**Default Sample Data Folder**" so you will need to point the data to the correct folder again when you click on **"Start Test"**

Data Collection

RUNNING A TASK

A task is part of the test configuration and in this case we have **"Signal Preview"**, **"Gait"**

If you click on **"Run Task"** the software will increment through the tasks one by one, alternatively you can Double Click on the test Icons and do in any order which is useful if you are wanting to randomise the conditions. In "Signal Preview" you will need to click stop before you can run the next task.

PROTOCOL

This "Gait" protocol aims to look at the muscle activity the Tibialis Anterior, Peroneus Longus, Gastrocnemius and Rectus Femoris during gait.

Ask your participant to start walking and then click "**start**" and click "**stop**" just before they reach the end of the walkway. In this way you will avoid collecting the gait initiation and the period of slowing down which will produce variations in the EMG signals.

Saving the Data

The data is automatically saved on the completion of each task in the location selected above. This can now be analyzed in a number of ways including EMGworks Analysis and Visual3d.

Data Analysis of Gait in EMGworks Analysis

CREATING A WORKSPACE

Open **EMGworks Analysis**

Select **"Create new workspace"**

The workspace name usually suggest this is the same as the participant data file, in this case **Participant1** and Browse to the **Participant1** folder.

You can now add the different trial files to this workspace by clicking on "Add Data" in the "Data" Window.

For the purpose of this tutorial we will consider one file **Participant1_Gait**

Plotting the data

At this point we have to be clear on what we are trying to achieve. For this test, we're interested in:

1) Tibial angular velocity
2) Tibial linear acceleration
3) Phasic muscle activity during gait

The first thing to do is visually inspect the data. To do this we need to select the channels we are most interested in, namely **R Tibialis Anterior EMG 1, R Peroneus Longus EMG 2, R Gastrocnemius EMG 3, R Rectus Femoris EMG 4, R_Tibia ACC Z 5 (IM),** and the **R_Foot_Switch EMG 16.**

To select, hold down the **Ctrl key** and **select the channels**. Then **right hand mouse click** and select plot as **Subplots**. FIGURE 6.

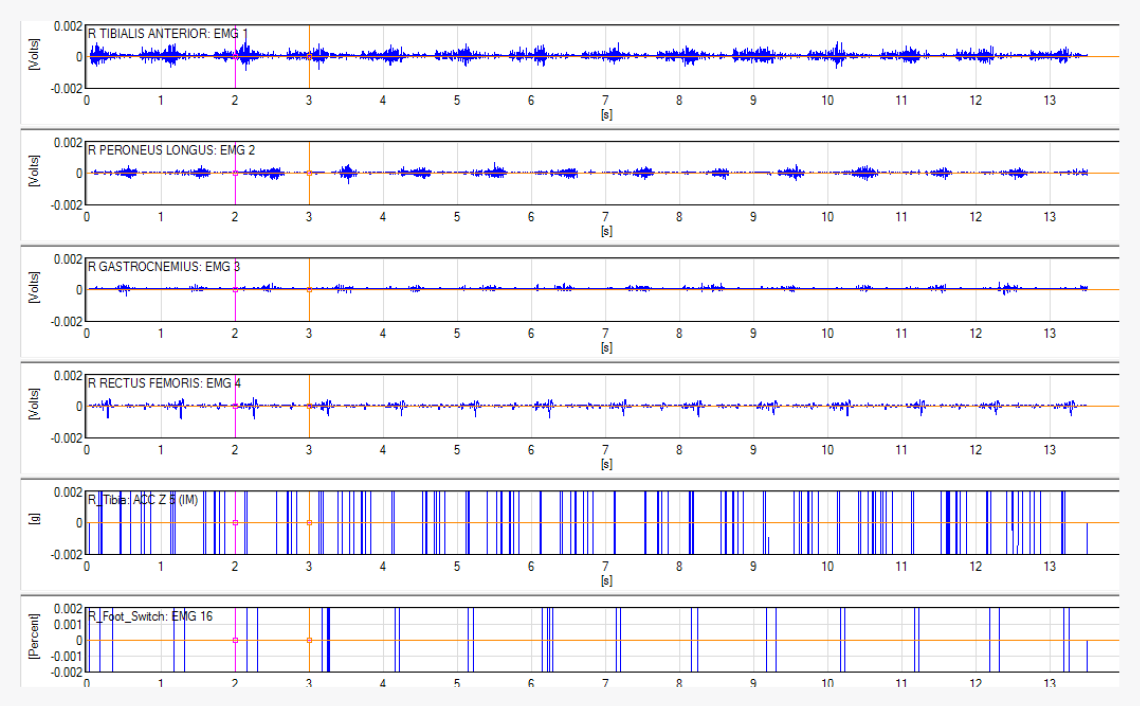


Figure 6: visual inspection of the data

Now unlock the screen by clicking the icon in the red circle. Then **right hand mouse click** and **Auto Scale All Y**, FIGURE 7

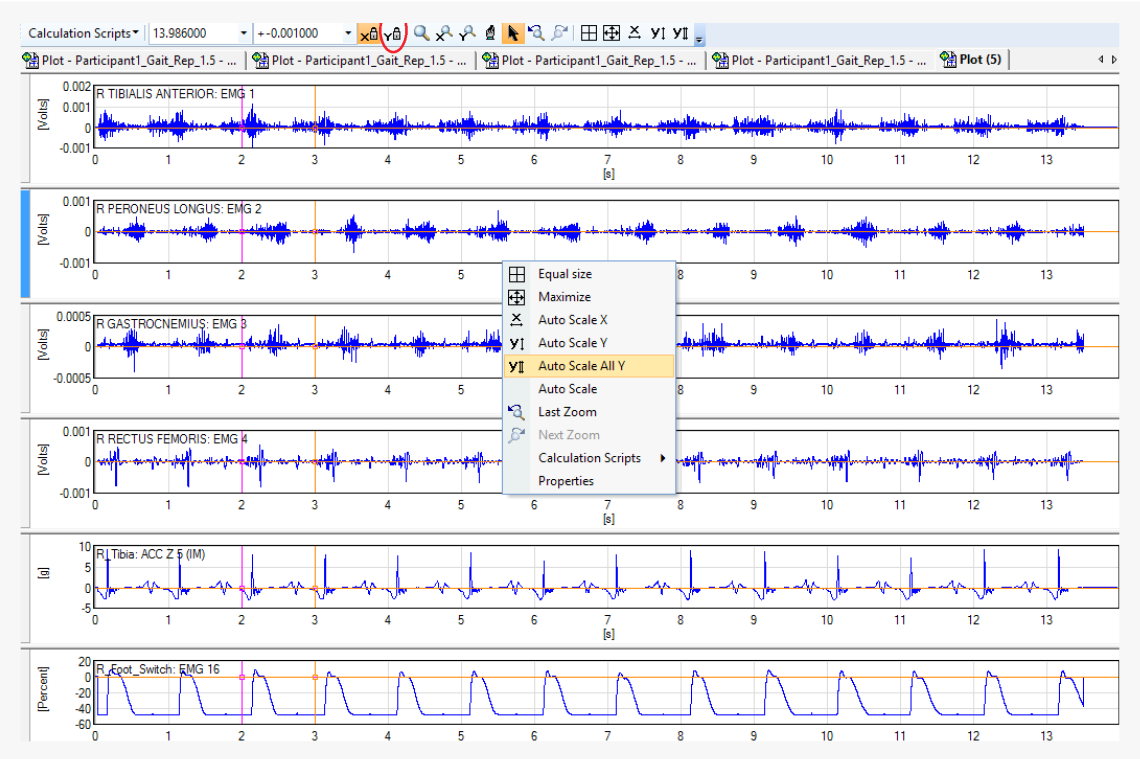


Figure 7: Rescaling the Y axes

Removing offsets on EMG signals

You should be able to see there is a slight (DC) offset on the EMG that we need to get rid of.

To do this hold down the **Ctrl key** and select the channels **R Tibialis Anterior EMG 1, R Peroneus Longus EMG 2, R Gastrocnemius EMG 3 and R Rectus Femoris EMG 4**

Then **right hand mouse click** and select **Calculation Scripts** and **Remove Mean** and plot as **Subplots**, FIGURE 8 A B.

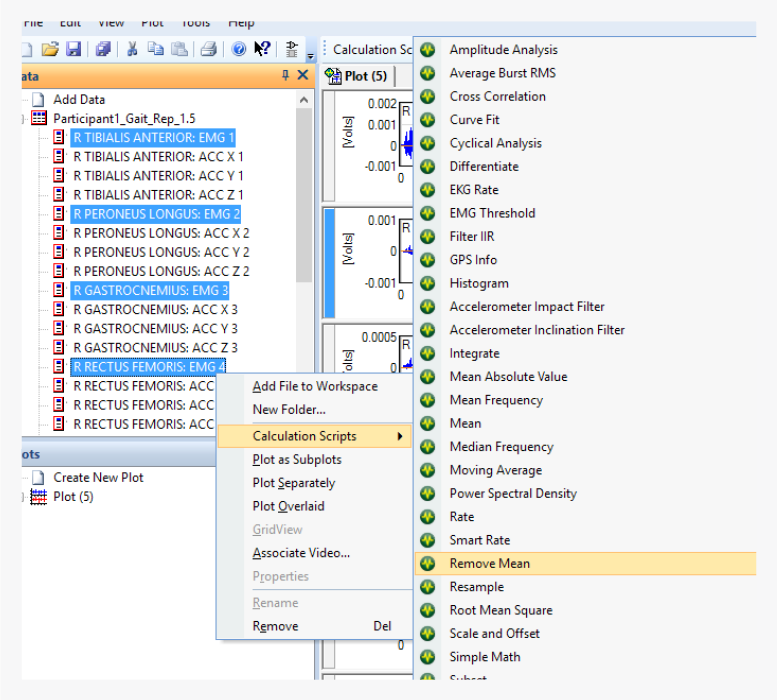


Figure 8a: Remove mean from data

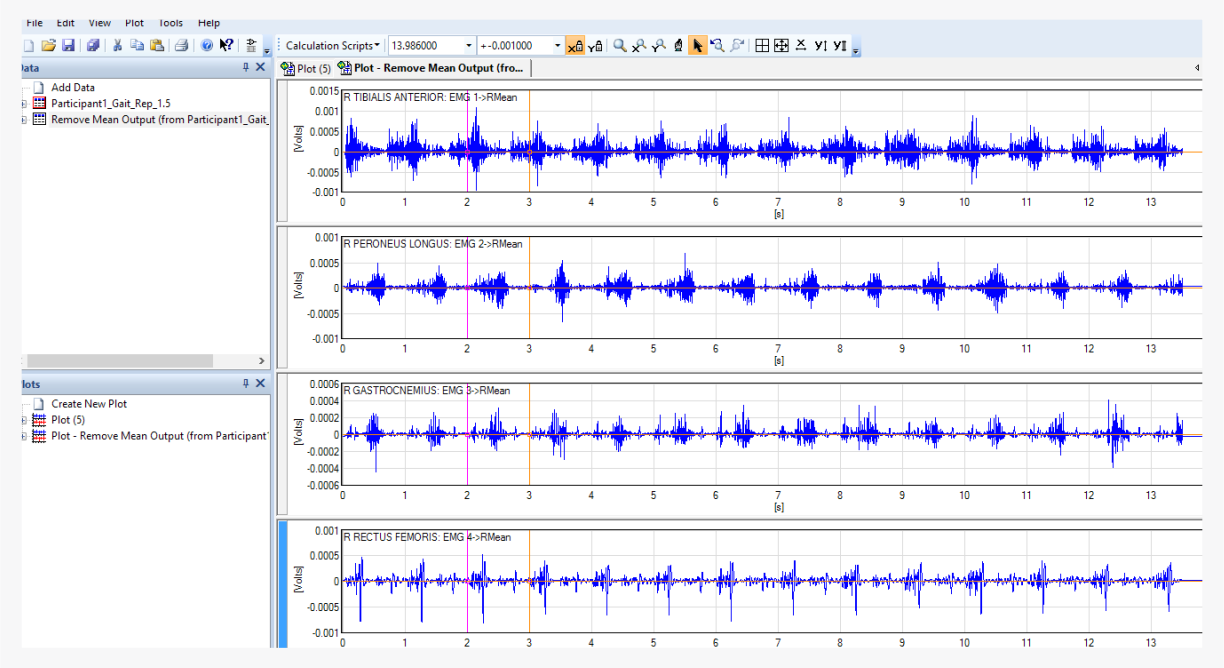


Figure 8b: Plotting remove mean data

Enveloped EMG signals

To produce an Enveloped EMG we will now run a Root Mean Square (RMS) calculation. To do this hold down the **Ctrl key** and select the channels in **Remove Mean Output**

Then **right hand mouse click** and select **Calculation Script** then **Root Mean Square**

And then plot **Root Mean Square Output** as **Subplots**, FIGURE 9.

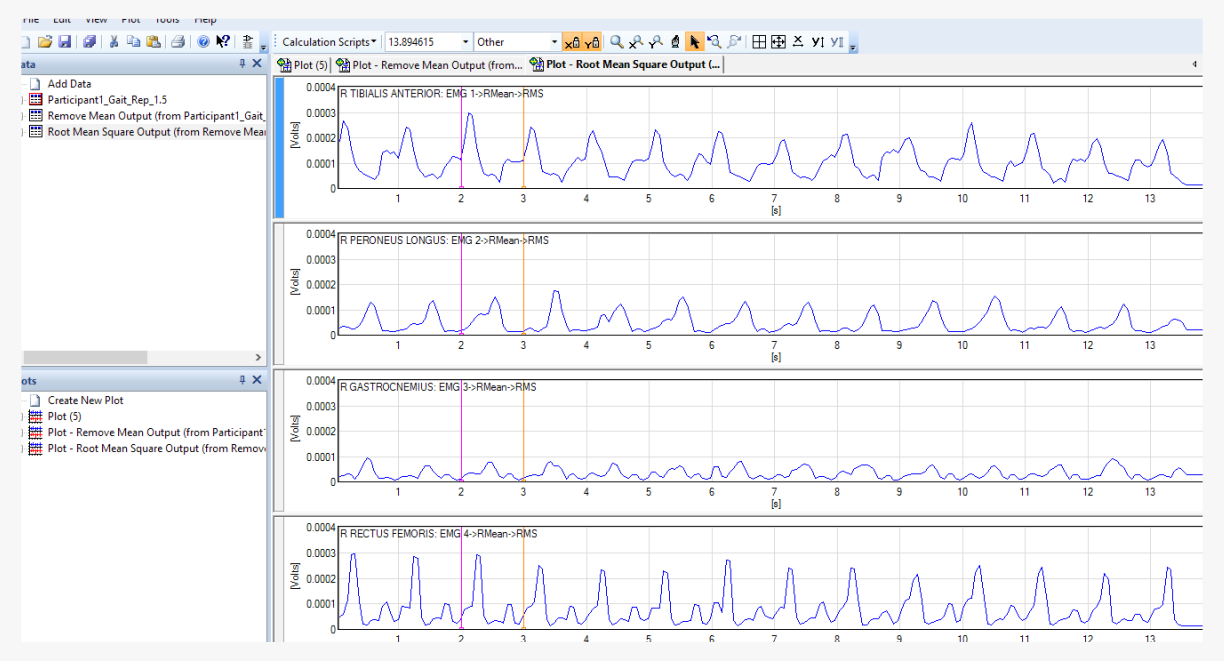


Figure 9: Plot of Root Mean Square EMG signals

Cyclical Analysis

Cyclical analysis is a way of defining events which can then be used to plot the mean and standard deviation of multiple cycles. In this case, flexion extension.

If we plot the footswitch data we can see clear heel strike events.

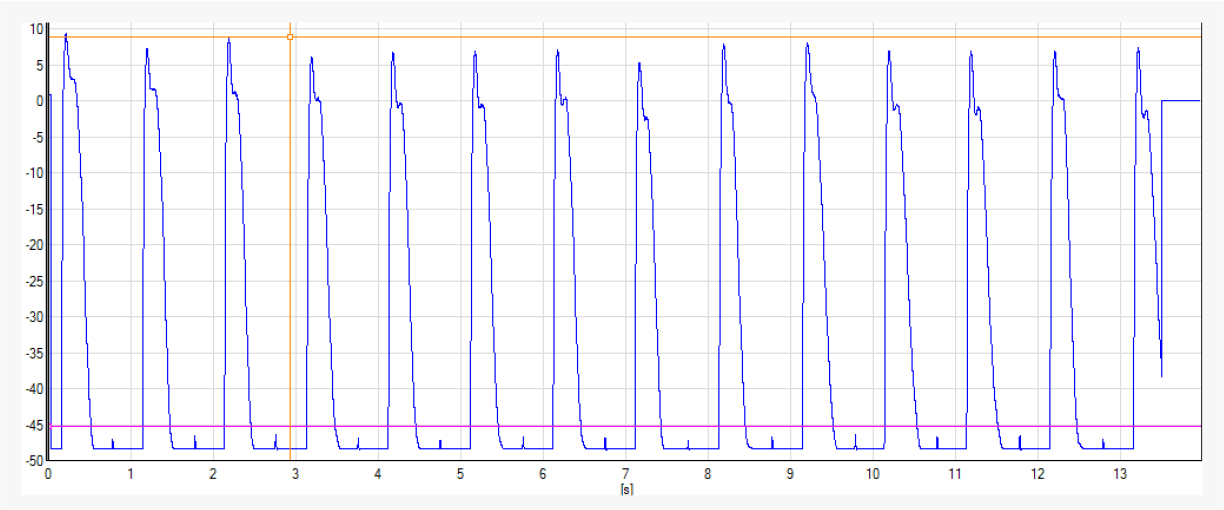


Figure 10: Identifying threshold for heel strike events

Select the signals you wish to include. Here, we have included the R_Foot_Switch and the RMS of the EMG signals, FIGURE 11.

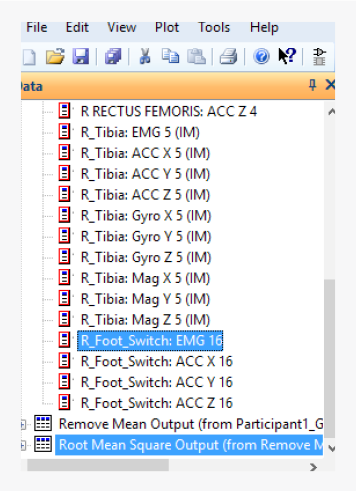


Figure 11: Selecting R_Foot_Switch and the RMS EMG signals

Then **right hand mouse click** and select **Calculation Script** then **Cyclical Analysis**

For this data we have selected Fixed R_Foot_Switch with a threshold of -45 (which can be used to define heel strike), FIGURE 12.

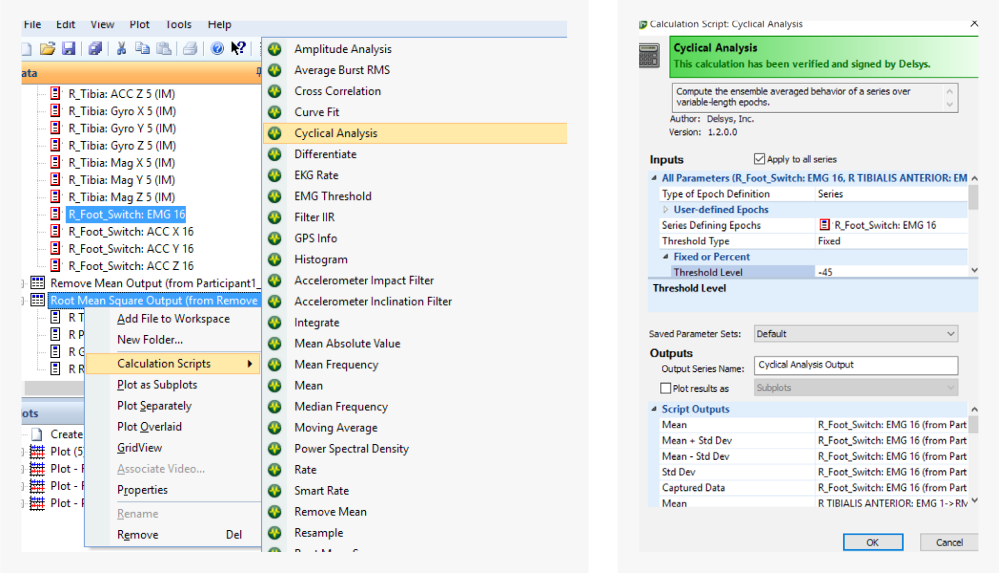


Figure 12: Cyclical Analysis set up

It is now possible to plot the mean and standard deviations of these signals, by selecting and then **right hand mouse click** and select **Plot Overlaid**, FIGURE 12-14.

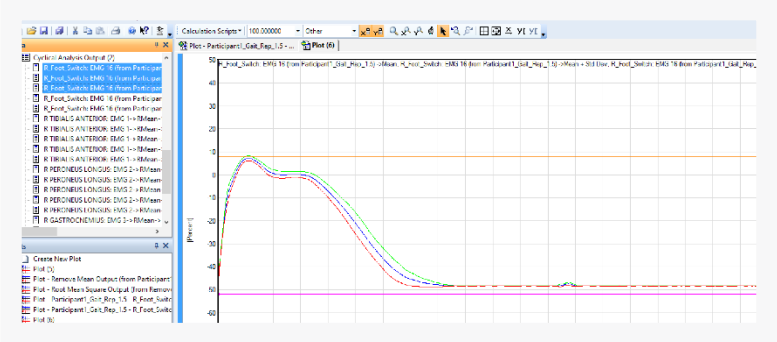


Figure 13: Footswitch mean and standard deviation

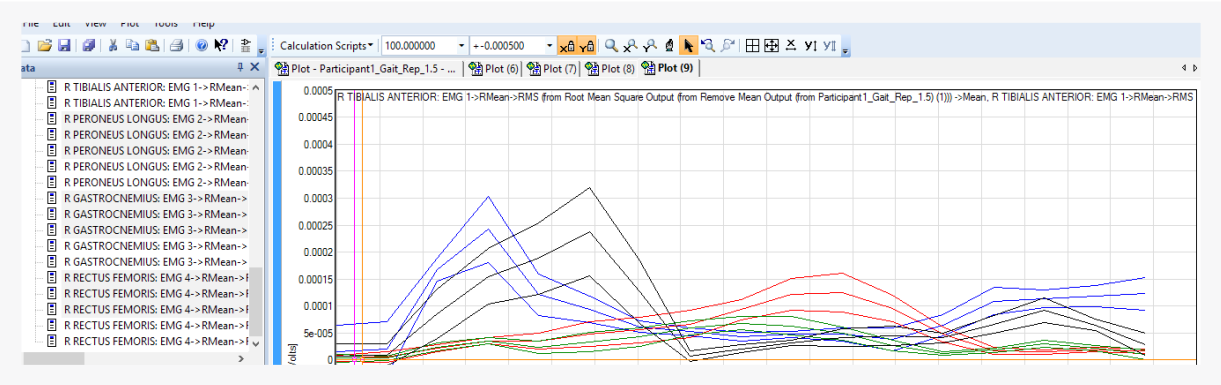


Figure 14: RMS mean and standard deviation

Data Analysis of Gait in Visual3d

EXPORTING THE DATA

Open the Delsys File Utility – this is a separate program that can be found in your program list, FIGURE 15.

Select the .hpf file that you are wanting, in this case "Participant1_Gait_Rep_1.5.hpf"

Tick C3D and UPSample hpf to .c3d, this will up sample all channels to the highest recorded in this case 1111 Hz as this is the highest frequency from the EMG from the Delsys IM sensors.

This will generate a file "Participant1_Gait_Rep_1.5_1925_926Hz_part1.c3d"

You could shorten this name without affecting the files in EMGworks, but we will continue to use as is for consistency.

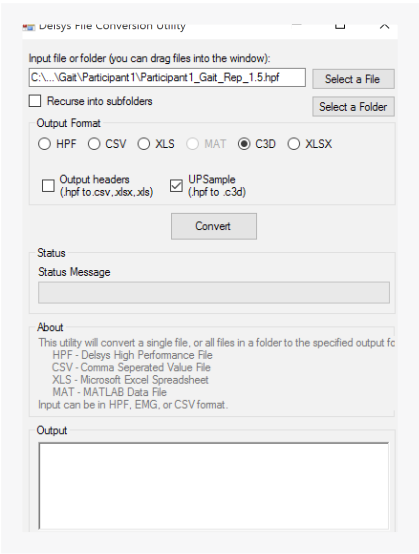


Figure 14: Export to c3d using Delsys File Utility.

BRINGING THE DATA INTO VISUAL3D

Open Visual3D

Go to – **File** – **Open** – and select "Participant1_Gait_Rep_1.5_1925_926Hz_part1.c3d".

RUNNING A PIPELINE IN VISUAL3D

A "pipeline" which contains a series of operations.

Click on **Pipeline** – Open Pipeline... – and click on "**Gait IMU EMG.v3s**", FIGURE 15A.

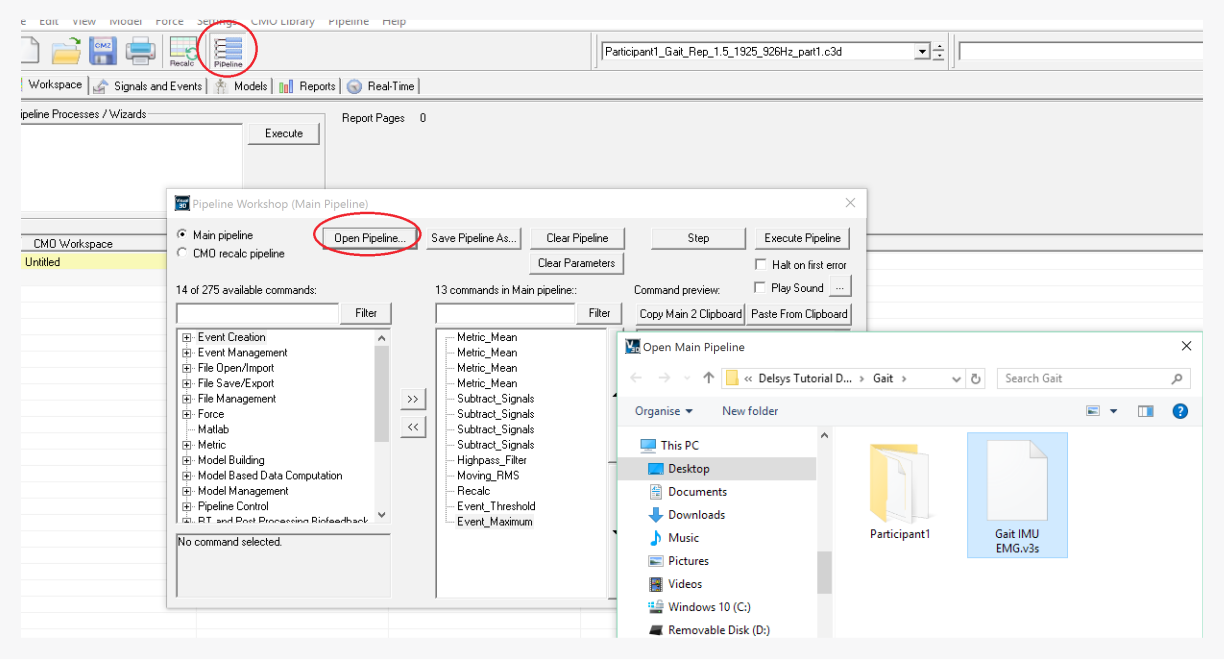


Figure 15: a) Opening and Running a pipeline in Visual3D

Figure 15b shows a pipeline to calculate the mean values "**Metric_Mean**" for the four EMG channels, then subtracts the mean from these "**Subtract_Signals**" signals which performs the same operation as remove mean in EMGworks.

Next, we've applied a "**Highpass filter**" with a cut off frequency of 20 Hz which can be increased if you have any movement artefacts, and a "**Moving RMS**" in this case with a window length on 23, or 0.021 seconds. This performs the same operation as RMS in EMGworks.

Finally, and most importantly we have created "Events". In this case we've used a threshold of -45 on the Footswitch data, and I have also added a peak event from the anterior-posterior acceleration of the Tibia "**R_ Tibia: ACC Z 5_IM**".

These create the events Right Heel Strike "**RHS**" and "**RHSaccZ**" which should approximate to Right Heel Strike.

Click on "Execute Pipeline"

RUNNING A REPORT TEMPLATE IN VISUAL3D

We are now able to bring in a report.

Click on the **Reports** tab, then and select "Gait IMU EMG.rgt", FIGURE 16.

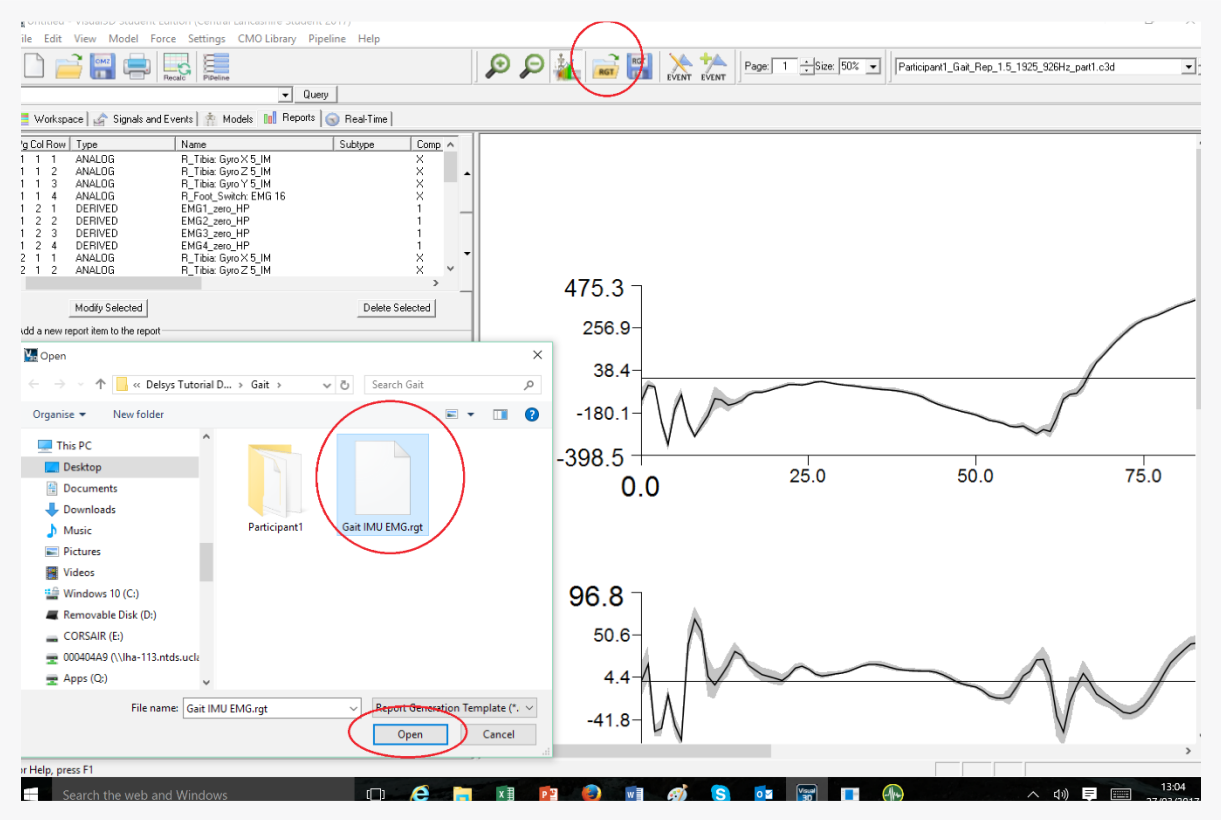
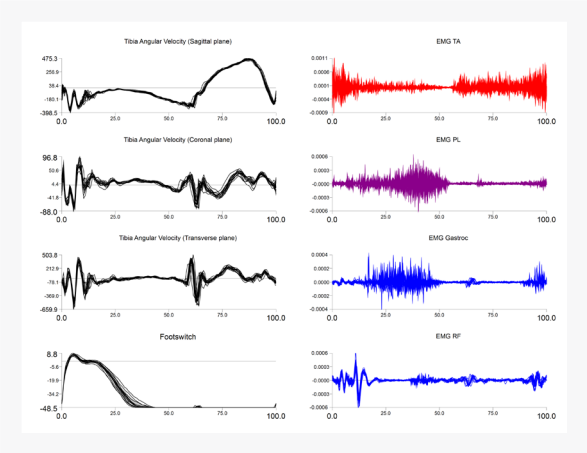
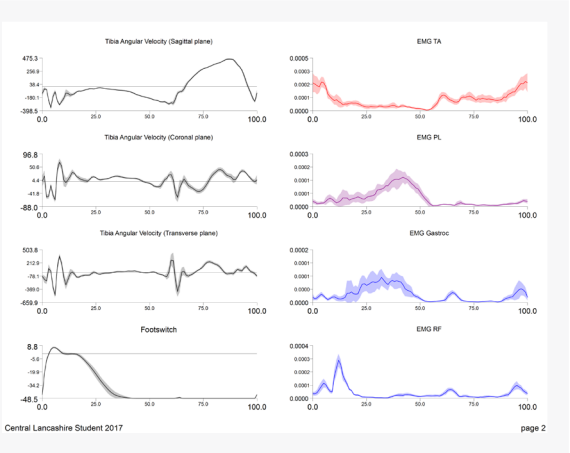


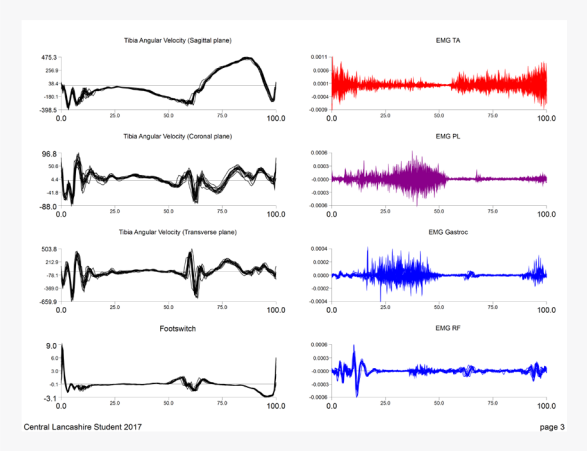
Figure 16: Running a Report Template in Visual3D

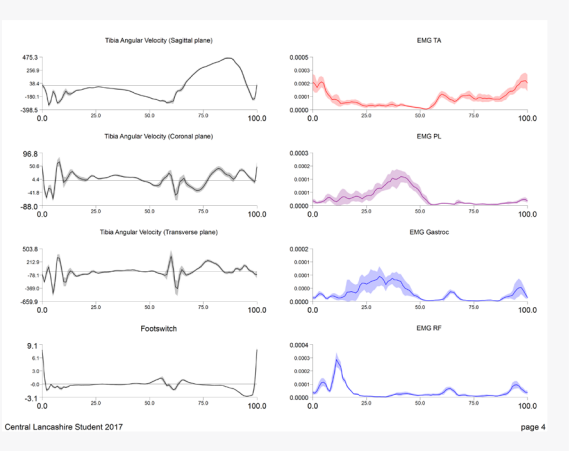
This is a simple report that will use the "**RHS**" and "**RHSaccZ**" events We can now review the report and view Page 1 where we can see the individual repetitions and Page 2 the Mean and Standard Deviation using the events from the Footswitch "**RHS**".





Pages 3 where we can see the individual repetitions and Page 2 the Mean and Standard Deviation using the events from the Tibia accelerometer "**RHSaccZ"**.





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