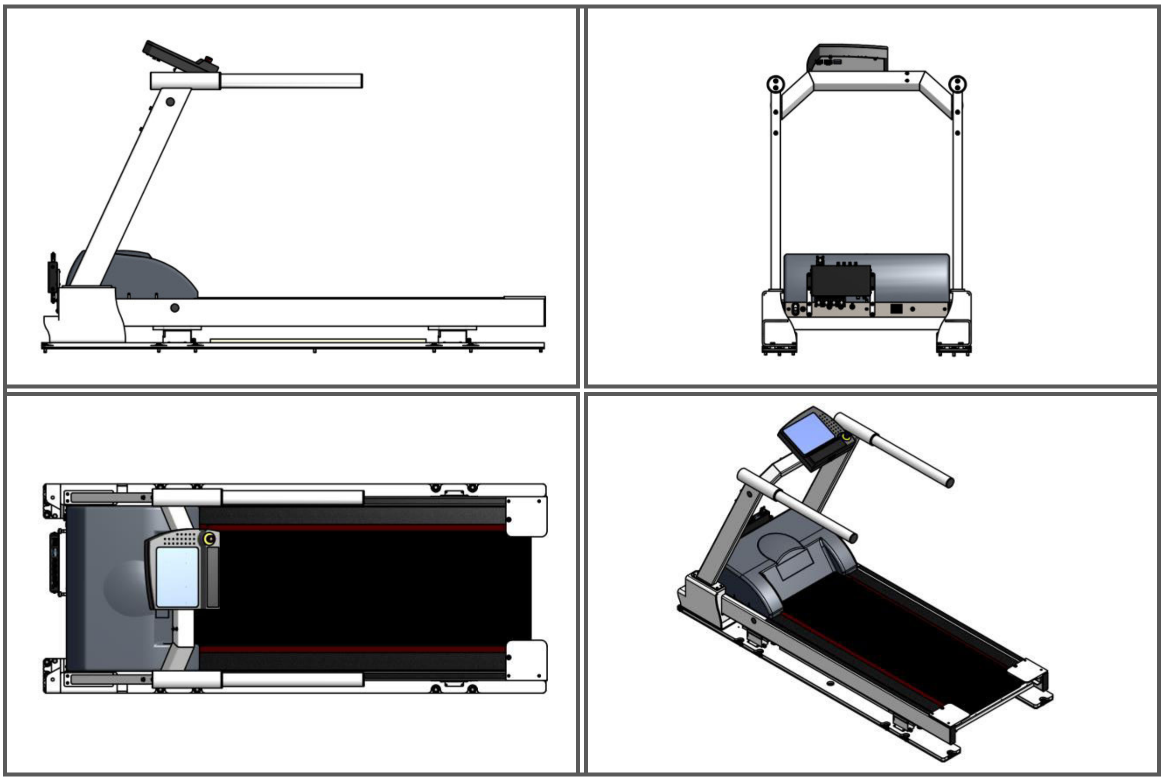
Gaitway 3D analog force output signals interpretation



gaitway-3D treadmill manufacturer:
h/p/cosmos: sports & medical gmbh
Am Sportplatz 8
DE 83365 Nussdorf-Traunstein
Germany
phone +49 86 69 86 42 0
fax +49 86 69 86 42 49
service@hpcosmos.com
www.hpcosmos.com

gaitway-3D Instrumentation manufacturer:
Arsalis SRL
Chemin du Moulin Delay, 6
B-1473 Glabais
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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. Introduction

This document is intended to provide support to customers willing to acquire the force signals of a gaitway 3D instrumented treadmill using the analog force output interface. This document describes the interface to the gaitway 3D analog force signals and the calculations to convert the signals into three-dimensional forces and moments.

2. Device description

This technical note applies to the gaitway-3D device illustrated in Figure 1. The gaitway-3D is an instrumented treadmill based on the h/p/cosmos treadmill, equipped with three dimensional ground reaction force measurement sensors. The gaitway-3D instrumentation components include four transducers supporting the treadmill and the force amplifier fixed in front of the treadmill, as shown in Figure 1.

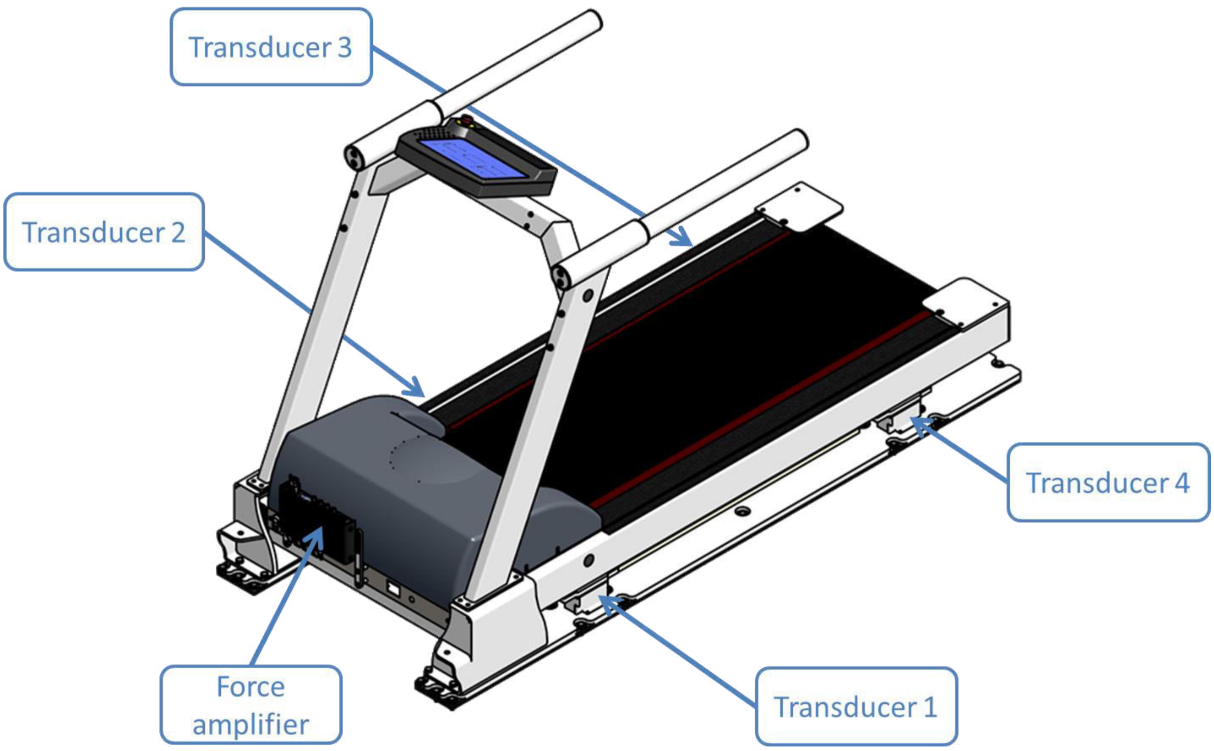


Figure 1. gaitway-3D overview.

2.1. Gaitway-3D amplifier description

The force amplifier is mounted on two brackets located in front of the treadmill motor compartment (see Figure 1). The force amplifier provides interface connectors on the top and bottom panels as described in next sections.

2.1.1. Amplifier bottom panel

The bottom panel provides connection for the internal components of the gaitway 3D instrumentation, i.e. the four transducers, the treadmill speed sensor and the power supply input to the instrumentation, see Figure 2.

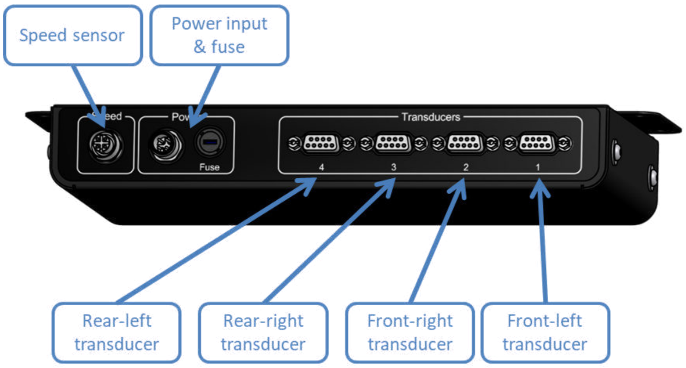


Figure 2. gaitway-3D amplifier bottom panel.

2.1.2. Amplifier top panel

The top panel, shown in Figure 3, provides connection for user interfaces to the gaitway 3D instrumentation. User interfaces include visual LED indicators, Ethernet interface connector, digital I/O BNC connectors and Analog Force output connector. The digital I/O interface connectors are used exclusively with the Ethernet data interface and are not described further in this document.

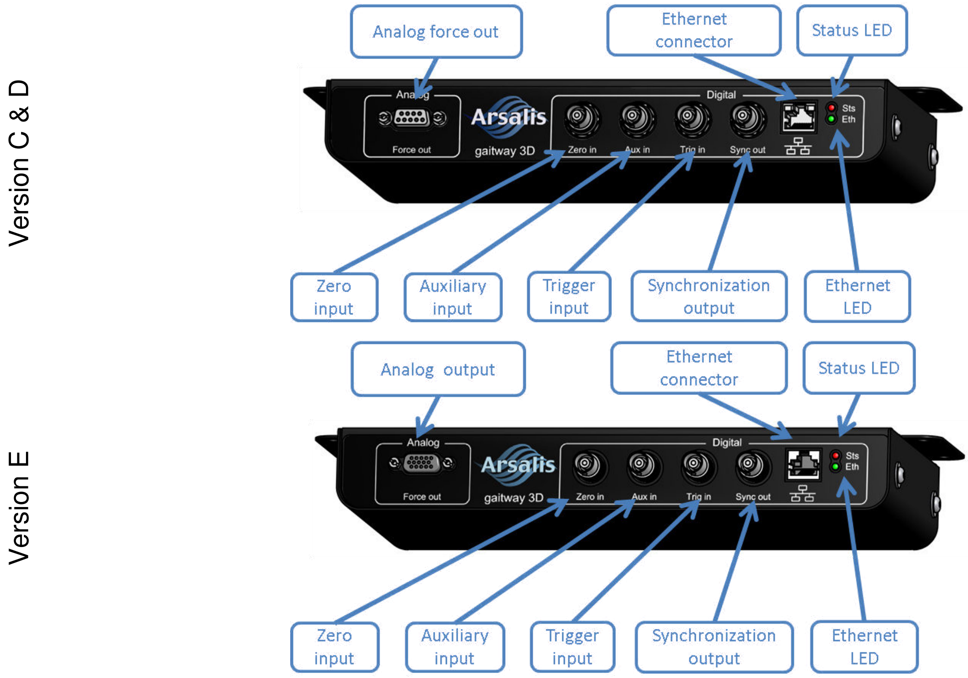


Figure 3. gaitway-3D amplifier top panel

2.1.3. Status LED

The status LED (Sts) shows the status of the gaitway-3D instrumentation via a RED LED according to the states described in Table 1.

Table 1. Status LED state description.

Status RED LED state	Description
LED is OFF	The gaitway-3D instrumentation is not powered.
LED blink at 1Hz with a duty cycle of 1/8	The gaitway-3D instrumentation is operational and no error is logged.

2.1.4. The Zero input

The 'Zero In' digital input is dedicated to resetting the baseline analog output when no load is applied on the instrumented treadmill (see Table 2). The 'Zero In' is activated by pulling the input low or by driving it low. The 'Zero In' digital input is isolated and rated for 5V digital operation with standard TTL/CMOS logic levels. It has a weak pull-up resistor that sets the default input to a high state. A falling edge must be detected to enable the baseline reset; i.e. the 'Zero In' must be reset high between successive baseline reset commands. The baseline reset operation lasts approximately 350 milliseconds and during this period the analog outputs are not valid. Note that the analog output baseline is reset automatically at system power-up. Therefore, the gaitway-3D instrumented treadmill may be used without interaction with the Zero-In digital input.

Table 2. gaitway-3D digital I/O special functions.

Channel	Special function	Default state
Zero in	Pulling the Zero input low resets the baseline output voltage to the default value for each direction (Z direction = 1.2Volts; Y & X direction = 5Volts).	Normally high

- The "Zero in" function should be activated when the patient is not on gaitway-3D treadmill and when no object is touching the treadmill.
- The Analog Force outputs are not valid while the analog signal baselines are being reset.

2.1.5. Analog Force output

The Analog Force output connector is used to provide an analog copy of the eight force signals measured by the force transducers (version C, D and E) and of the treadmill speed (version E only). The voltage output for each signal is ground referenced, within a range of 0 to 10 V and is rated 10 mA for version C & D1 and 1 mA for version D2 and E and has an impedance of 100 Ohm. The internal analog ground of the amplifier is separated from the external ground (GNDIO) with a 100 Ohm resistor. The connector pin-out is presented in Table 3 and in Figure 4.

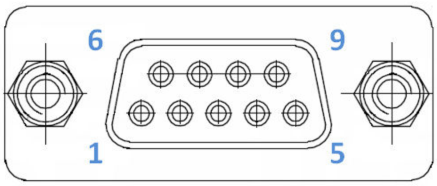
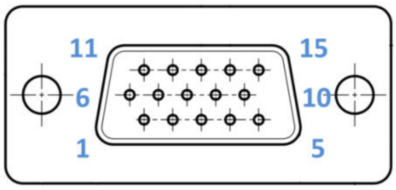
Version C & D	Version E
	

Figure 4. Analog force out connector front panel pin-out view

Table 3. Analog force out connector pin-out (version C, D and E).

Pin number		Signal	Type	Description
version C&D	**version E**			
1	1	EX34	Filtered analog signal	Sum of Rear Left and Rear Right force sensors in the X direction
2	2	EX12	Filtered analog signal	Sum of Front Left and Front Right force sensors in the X direction
3	3	EY23	Filtered analog signal	Sum of Front Right and Rear Right force sensors in the Y direction
4	4	EY14	Filtered analog signal	Sum of Front Left and Rear Left force sensors in the Y direction
5	5	EZ4	Filtered analog signal	Force in Z direction on Rear Left force sensor
6	6	EZ3	Filtered analog signal	Force in Z direction on Rear Right force sensor
7	7	EZ2	Filtered analog signal	Force in Z direction on Front Right force sensor
8	8	EZ1	Filtered analog signal	Force in Z direction on Front Left force sensor
NA	10	SPEED	Filtered analog signal	Analog treadmill speed
9	15	GNDIO	External ground	External ground for signal reference
Shield	Shield	Chassis	PE	Connected to chassis of amplifier

2.1.6. Programmable gain

The gaitway 3D force amplifier offers programmable gain amplification (PGA). The default PGA is set to 16 in the vertical direction (allowing a nominal range of 2600 N for each EZ channels) and to 64 for the fore-afterwards and medio-lateral directions (allowing a nominal range of 640 N for each EY and EX channels). The default PGA is set at system power up.

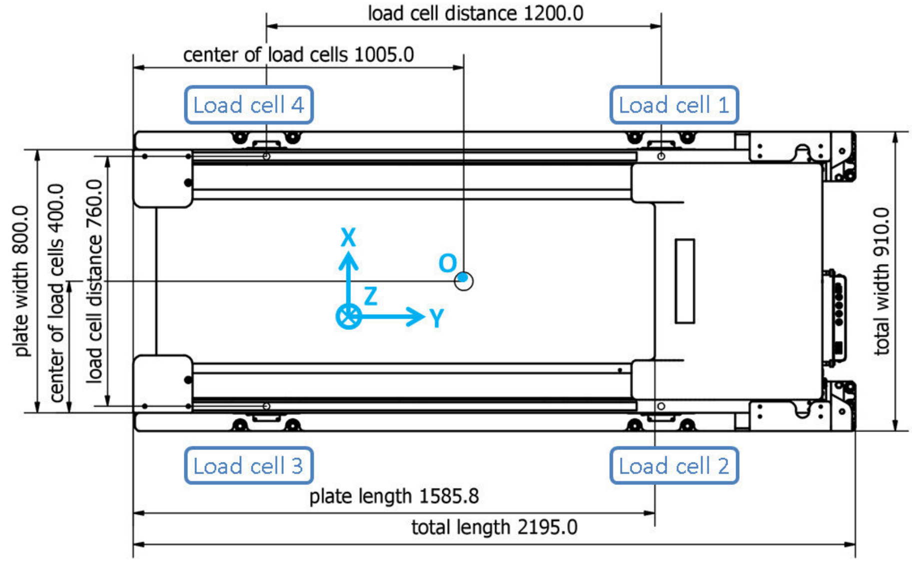
3. Treadmill reference frame

The sensors measure the three-dimensional forces applied to the treadmill. These forces are expressed by the amplifier in the reference frame presented in Figure 5.

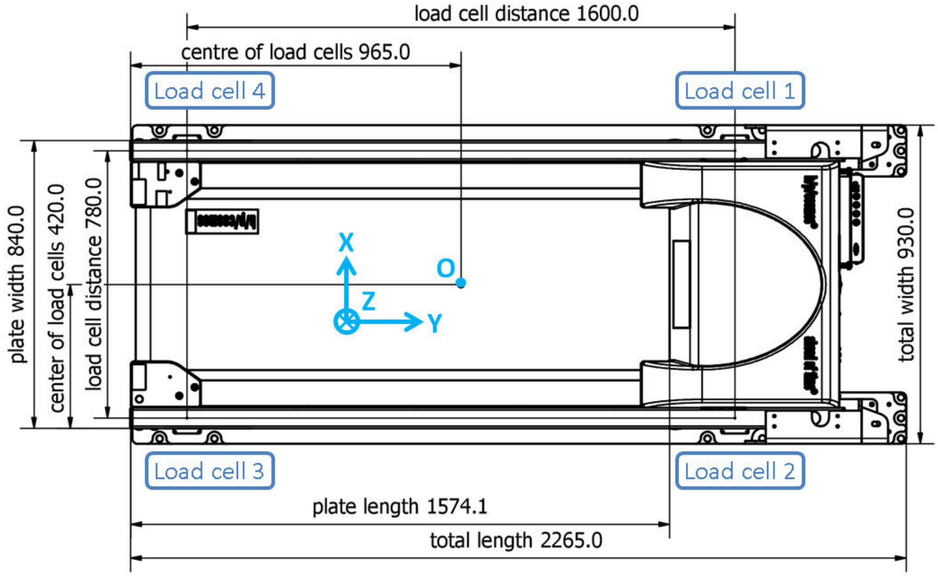
A transducer is mounted at each corner of the treadmill (transducer 1 to 4 in Figure 5). The origin of the reference frame (O in Figure 5) is located at the geometrical center of the rectangle defined by the four transducers. The location of the origin relative to the treadmill chassis can also be determined from the dimensions presented in Figure 5 (all dimensions are expressed in millimeters). The three orthogonal components of the applied force (not the ground reaction force) are reported as follows:

- vertical component along the Z-axis, positive downwards;
- fore-afterwards components along the Y-axis, positive forwards;
- medio-lateral component along the X-axis, positive left.

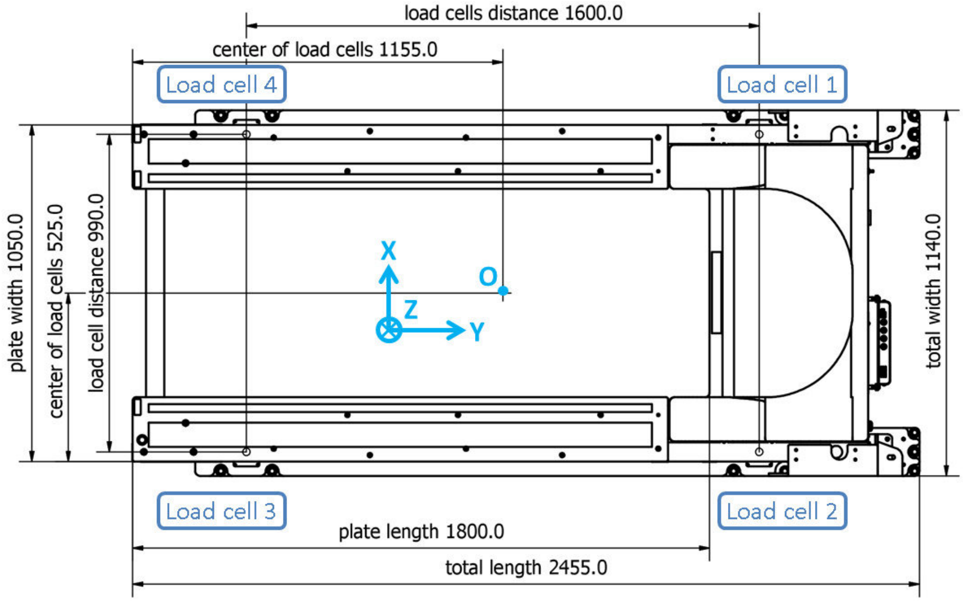
gaitway-3D 150/50 with mercury or stratos treadmill, SN: cos30000va



gaitway-3D 150/50 with mercury or stratos treadmill, SN: cos30000-02



gaitway-3D 170/65 with quasar or stellar treadmill, SN: cos30003



gaitway-3D 190/65 with pulsar treadmill, SN: cos30004

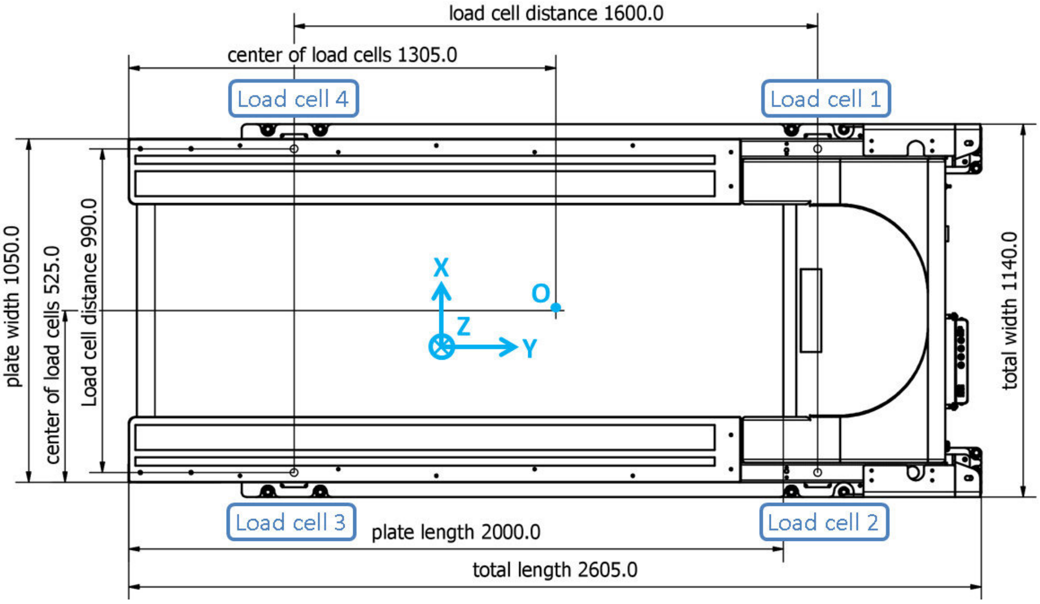


Figure 5. Treadmill top view and reference frame.

4. Analog signals acquisition scenario

A typical acquisition scenario includes the steps described in Table 4.

Table 4. Analog signal acquisition scenario.

Step	Description
1	Power up the gaitway-3D
2	Optional: Reset the baseline analog output when no load is applied on the instrumented treadmill (see section 2.1.4)
3	Measure the analog channels baseline values when no load is applied on the instrumented treadmill and store them as BZ_1, BZ_2, BZ_3, BZ_4, BY_{14}, BY_{23}, BX_{12}, BX_{34}
4	Measure the analog signals EZ_1, EZ_2, EZ_3, EZ_4, EY_{14}, EY_{23}, EX_{12}, EX_{34}
5	Compute resultant forces and moments using the equations provided in Table 5.

5. Parameters calculation

The force and moment signals are calibrated according to the calculations described in Table 5. For each channel, the calibrated force or moment (in N or Nm) is computed from:

- the voltages read from the channels (e.g. EZ_1, in mV);
- the baseline measured from the corresponding signal when no load is applied on the instrumented treadmill (e.g. BZ_1, in mV);
- the calibration matrix CM for the corresponding signal, specified for default PGA, in N/mV or Nm/mV, according to the calibration certificate delivered with

each device.

$$CM = \begin{bmatrix} GZ1_{FZ} & GZ2_{FZ} & GZ3_{FY} & GZ4_{FY} & GY14_{FZ} & GY23_{FZ} & GX12_{FZ} & GX34_{FZ} \\ GZ1_{FY} & GZ2_{FY} & GZ3_{FY} & GZ4_{FY} & GY14_{FY} & GY23_{FY} & GX12_{FY} & GX34_{FY} \\ GZ1_{FX} & GZ2_{FX} & GZ3_{FX} & GZ4_{FX} & GY14_{FX} & GY23_{FX} & GX12_{FX} & GX34_{FX} \\ GZ1_{MX} & GZ2_{MX} & GZ3_{MX} & GZ4_{MX} & GY14_{MX} & GY23_{MX} & GX12_{MX} & GX34_{MX} \\ GZ1_{MY} & GZ2_{MY} & GZ3_{MY} & GZ4_{MY} & GY14_{MY} & GY23_{MY} & GX12_{MY} & GX34_{MY} \\ GZ1_{MZ} & GZ2_{MZ} & GZ3_{MZ} & GZ4_{MZ} & GY14_{MZ} & GY23_{MZ} & GX12_{MZ} & GX34_{MZ} \end{bmatrix}$$

Table 5. Calculations for dynamic signals.

Param.	**Calculation** [1]	**Description**
FX_{tot}	$(EZ_1 - BZ_1) \cdot GZ1_{FX} + (EZ_2 - BZ_2) \cdot GZ2_{FX} + (EZ_3 - BZ_3) \cdot GZ3_{FX} + (EZ_4 - BZ_4) \cdot GZ4_{FX} + (EY_{14} - BY_{14}) \cdot GY14_{FX} + (EY_{23} - BY_{23}) \cdot GY23_{FX} + (EX_{12} - BX_{12}) \cdot GX12_{FX} + (EX_{34} - BX_{34}) \cdot GX34_{FX}$	Total force in X-direction, medio-lateral
FY_{tot}	$(EZ_1 - BZ_1) \cdot GZ1_{FY} + (EZ_2 - BZ_2) \cdot GZ2_{FY} + (EZ_3 - BZ_3) \cdot GZ3_{FY} + (EZ_4 - BZ_4) \cdot GZ4_{FY} + (EY_{14} - BY_{14}) \cdot GY14_{FY} + (EY_{23} - BY_{23}) \cdot GY23_{FY} + (EX_{12} - BX_{12}) \cdot GX12_{FY} + (EX_{34} - BX_{34}) \cdot GX34_{FY}$	Total force in Y-direction, anterior-posterior
FZ_{tot}	$(EZ_1 - BZ_1) \cdot GZ1_{FZ} + (EZ_2 - BZ_2) \cdot GZ2_{FZ} + (EZ_3 - BZ_3) \cdot GZ3_{FZ} + (EZ_4 - BZ_4) \cdot GZ4_{FZ} + (EY_{14} - BY_{14}) \cdot GY14_{FZ} + (EY_{23} - BY_{23}) \cdot GY23_{FZ} + (EX_{12} - BX_{12}) \cdot GX12_{FZ} + (EX_{34} - BX_{34}) \cdot GX34_{FZ}$	Total force in Z-direction, vertical
$M_{X,O}$	$(EZ_1 - BZ_1) \cdot GZ1_{MX} + (EZ_2 - BZ_2) \cdot GZ2_{MX} + (EZ_3 - BZ_3) \cdot GZ3_{MX} + (EZ_4 - BZ_4) \cdot GZ4_{MX} + (EY_{14} - BY_{14}) \cdot GY14_{MX} + (EY_{23} - BY_{23}) \cdot GY23_{MX} + (EX_{12} - BX_{12}) \cdot GX12_{MX} + (EX_{34} - BX_{34}) \cdot GX34_{MX}$	Moment of measured forces around the X-direction at the coordinates origin
$M_{Y,O}$	$(EZ_1 - BZ_1) \cdot GZ1_{MY} + (EZ_2 - BZ_2) \cdot GZ2_{MY} + (EZ_3 - BZ_3) \cdot GZ3_{MY} + (EZ_4 - BZ_4) \cdot GZ4_{MY} + (EY_{14} - BY_{14}) \cdot GY14_{MY} + (EY_{23} - BY_{23}) \cdot GY23_{MY} + (EX_{12} - BX_{12}) \cdot GX12_{MY} + (EX_{34} - BX_{34}) \cdot GX34_{MY}$	Moment of measured forces around the Y-direction at the coordinates origin
$M_{Z,O}$	$(EZ_1 - BZ_1) \cdot GZ1_{MZ} + (EZ_2 - BZ_2) \cdot GZ2_{MZ} + (EZ_3 - BZ_3) \cdot GZ3_{MZ} + (EZ_4 - BZ_4) \cdot GZ4_{MZ} + (EY_{14} - BY_{14}) \cdot GY14_{MZ} + (EY_{23} - BY_{23}) \cdot GY23_{MZ} + (EX_{12} - BX_{12}) \cdot GX12_{MZ} + (EX_{34} - BX_{34}) \cdot GX34_{MZ}$	Moment of measured forces around the Z-direction at the coordinates origin
OP_X	$- M_{Y,O} / FZ_{tot}$	X coordinate of the COP[2], relative to the coordinates origin
OP_Y	$M_{X,O} / FZ_{tot}$	Y coordinate of the COP[2], relative to the coordinates origin
OP_Z	0	Z coordinate of the COP[2], relative to the coordinates origin
T_Z	$M_{Z,O} + OP_Y * FX_{tot} - OP_X * FY_{tot}$	Free moment of measured forces around the Z-direction at the coordinates of the COP

Notes:
(1) O = coordinates origin, fixed at the projection of the geometric center of the 4 sensors in the locomotion surface plane;
(2) COP = center of pressure; defined as the point on the locomotion surface plane where the moment is equal to zero.

6. Analog interface of gaitway 3D with Vicon Nexus software

6.1. Integration philosophy

The integration of gaitway 3D with Vicon Nexus 2.x software described here concerns an interconnection of analog outputs of gaitway 3D, sampled by a Vicon Lock device. The gaitway 3D hardware settings (signals, calibration matrix, position, etc) need to be configured in Nexus for proper data acquisition and interpretation. Once acquired, the force applied by the subject can be decomposed between the left and right foot via a Matlab routine called from Nexus in post processing. To do so, two force plates are actually configured in Nexus: a real force plate that is assigned with the recorded signals (i.e. the total resultant force applied on the gaitway 3D) and a virtual force plate that is exactly superimposed to the real one and is assigned dummy signals. After the decomposition, the real force plate is assigned with the force at the left side and the virtual force plate is assigned with the force at the right side. Once recorded (and decomposed if needed) the gaitway 3D force signals can be used in any post processing pipeline in Nexus since it is part of the Nexus trial data.

6.2. Software requirements

In order to integrate the gaitway 3D signals into Vicon Nexus 2.x software according to the philosophy described above, the following software components need to be setup and running on the same computer:

- gaitway 3D software, version 1.5.0 or later, is used to control the treadmill and allow the left/right force decomposition in post processing;
- Nexus, version 2.X, is used as the user interface to record and interpret gaitway 3D and kinematic signals.
- Matlab, R2016a or later, is used to decompose the force applied on gaitway 3D between the left and right side during walking or running.

6.3. Connection of gaitway 3D analog outputs into Vicon Lock device

The analog outputs of the gaitway 3D force amplifier are connected to the Vicon Lock device. The Vicon and gaitway 3D need to be powered off during this operation. Plug the gaitway 3D analog output cable to the analog output connector of the gaitway 3D (see Figure 3). Connect the ground signal wire (grey wire for amplifier ver. C or ver. D, red & white wire for amplifier ver. E) to one ground connection of the Vicon (top row of each connector of Figure 6). Each other wire is connected to the bottom row of the connector in the order of Table 6. Depending on availability, other pins can be used. Finally, connect the PE wire to a screw of the Vicon Lock as in Figure 7.

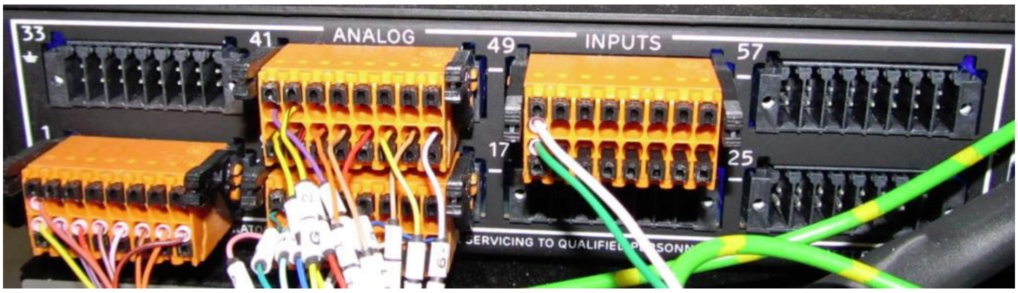


Figure 6. Vicon Lock analog input connections (wire colors are not representative).

Table 6. Analog input connections to Vicon Lock.

Vicon Lock pin	Vicon Lock row	Signal	Analog cable for amplifier ver. C&D (RD 4)	Analog cable for amplifier ver. E (RD 5)
1	bottom	EZ1	purple	purple
2	bottom	EZ2	blue	blue
3	bottom	EZ3	green	green
4	bottom	EZ4	yellow	yellow
5	bottom	EY14	orange	orange
6	bottom	EY23	red	red
7	bottom	EX12	brown	brown
8	bottom	EX34	black	black
GND	top	GND	grey	red & white
9	bottom	Speed	NA	white
PE screw	NA	PE	green & yellow	green & yellow

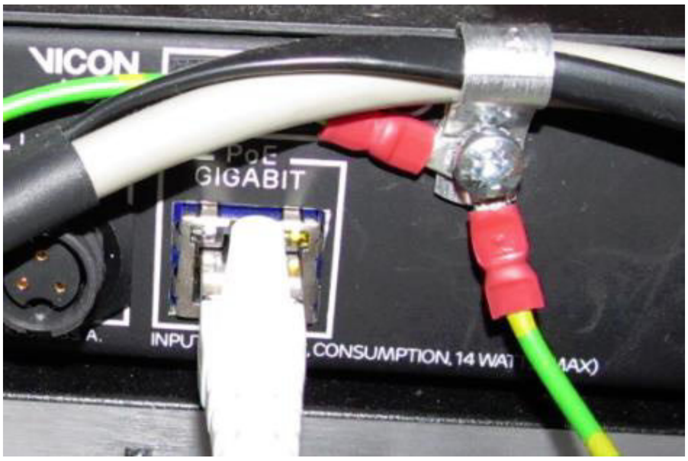


Figure 7. Analog cable PE connection to Vicon Lock.

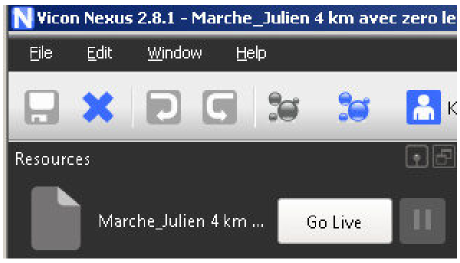
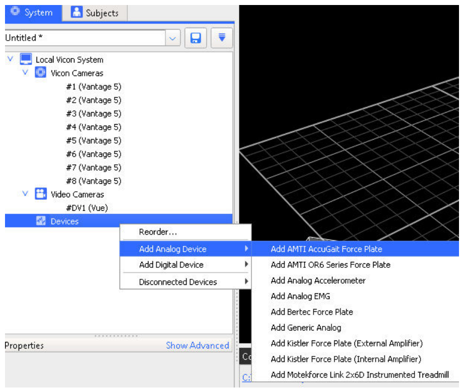
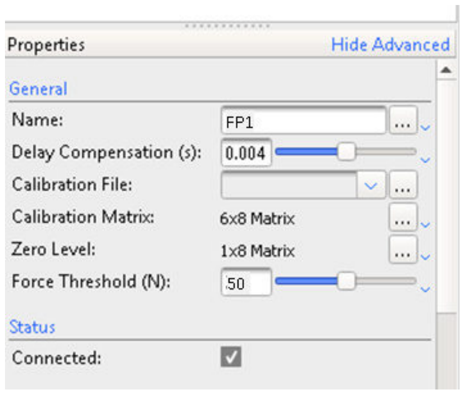
6.4. Configuration to integrate gaitway 3D signal into Nexus 2.x

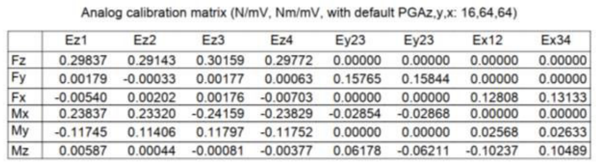
The following configuration procedures are required to allow the integration of gaitway 3D analog outptus into Vicon Nexus 2.x. These procedures will allow the configuration of a real force plate to record the gaitway 3D signals, an additional input for the optional treadmill speed signal, a ‘virtual’ force plate to decompose left and right forces, the signals filtering in Nexus 2.x and of the left/right force decomposition.

6.4.1. Configuration of Nexus to read gaitway 3D force signals

The gaitway 3D is configured as a force plate in the Vicon Nexus 2.x software as described in Table 7.

Table 7. Nexus configuration to read gaitway 3D forces.

Step	Description	Illustration
1.	Click on ‘Go Live’	
2.	– Right click on ‘Devices’. – Select ‘Add analog device’ – Select ‘Add AMTI Accugait force plate’	
3.	– Click on ‘Show advanced’. – Enter a name to the force plate, e.g. “FP1” – Enter the Delay Compensation (0.004s) – Skip the setting of the zero level for now. – Set the Force Threshold to 50N	

<table>
<tr><th>Step</th><th>Description</th><th>Illustration</th></tr>
<tr><td>4.</td><td>Click on ‘Calibration Matrix’ then enter the sensitivities for all analog force channels from the gaitway 3D calibration certificate under the heading ‘Analog calibration matrix (N/mV, Nm/mV, with default PGAz,y,x: 16,64,64)’:
– Multiply all values by 1000.
– Enter values in the following order for rows 1 to 6: Fx, Fy, Fz, Mx, My, Mz.</td><td>
Analog calibration matrix (N/mV, Nm/mV, with default PGAz,y,x: 16,64,64)
<table>
<tr><th></th><th>Ez1</th><th>Ez2</th><th>Ez3</th><th>Ez4</th><th>Ey23</th><th>Ey23</th><th>Ex12</th><th>Ex34</th></tr>
<tr><td>Fz</td><td>0.29837</td><td>0.29143</td><td>0.30159</td><td>0.29772</td><td>0.00000</td><td>0.00000</td><td>0.00000</td><td>0.00000</td></tr>
<tr><td>Fy</td><td>0.00179</td><td>-0.00033</td><td>0.00177</td><td>0.00063</td><td>0.15765</td><td>0.15844</td><td>0.00000</td><td>0.00000</td></tr>
<tr><td>Fx</td><td>-0.00540</td><td>0.00202</td><td>0.00176</td><td>-0.00703</td><td>0.00000</td><td>0.00000</td><td>0.12808</td><td>0.13133</td></tr>
<tr><td>Mx</td><td>0.23837</td><td>0.23320</td><td>-0.24159</td><td>-0.23829</td><td>-0.02854</td><td>-0.02868</td><td>0.00000</td><td>0.00000</td></tr>
<tr><td>My</td><td>-0.11745</td><td>0.11406</td><td>0.11797</td><td>-0.11752</td><td>0.00000</td><td>0.00000</td><td>0.02568</td><td>0.02633</td></tr>
<tr><td>Mz</td><td>0.00587</td><td>0.00044</td><td>-0.00081</td><td>-0.00377</td><td>0.06178</td><td>-0.06211</td><td>-0.10237</td><td>0.10489</td></tr>
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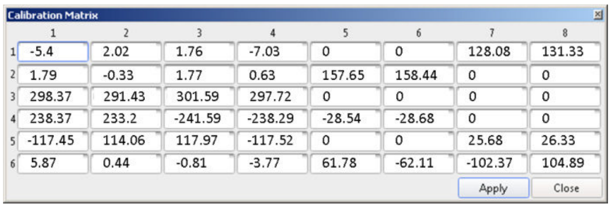
Calibration Matrix
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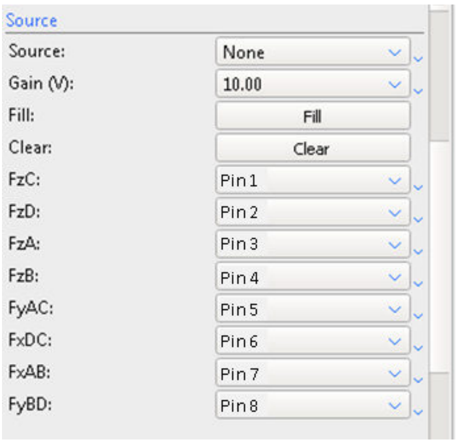
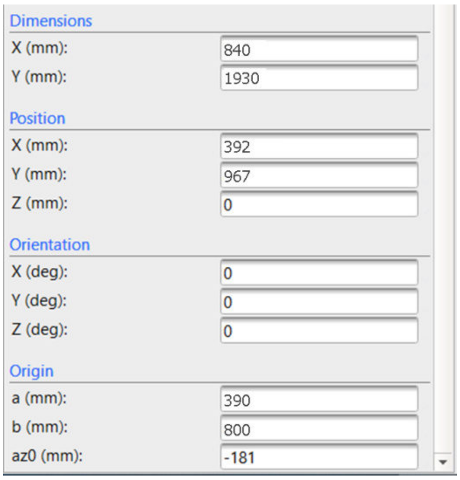
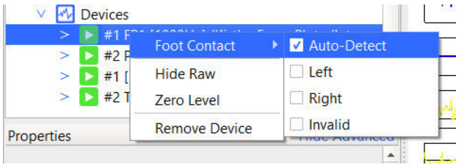
<tr><td>3</td><td>298.37</td><td>291.43</td><td>301.59</td><td>297.72</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>4</td><td>238.37</td><td>233.2</td><td>-241.59</td><td>-238.29</td><td>-28.54</td><td>-28.68</td><td>0</td><td>0</td></tr>
<tr><td>5</td><td>-117.45</td><td>114.06</td><td>117.97</td><td>-117.52</td><td>0</td><td>0</td><td>25.68</td><td>26.33</td></tr>
<tr><td>6</td><td>5.87</td><td>0.44</td><td>-0.81</td><td>-3.77</td><td>61.78</td><td>-62.11</td><td>-102.37</td><td>104.89</td></tr>
</table>
</td></tr>
<tr><td>5.</td><td>– Select the correct Vicon Lock device slot as the force plate signal source.
– Enter the Gain (V) as 10.00.
– Select the analog force signals according to the analog input connections listed in Table 6 with the mapping given hereunder:
FzC ← EZ1 (pin1)
FzD ← EZ2 (pin2)
FzA ← EZ3 (pin3)
FzB ← EZ4 (pin4)
FyAC ← EY14 (pin5)
FxDC ← EY23 (pin6)
FxAB ← EX12 (pin7)
FyBD ← EX34 (pin8)</td><td>
</td></tr>
</table>

Step	Description	Illustration
6.	Enter the Dimensions of the force plate (Dimension illustrated on the 3D view) **Nexus** **S/N cos30000va** X (mm) 800 Y (mm) 2010 **Nexus** **S/N cos30000-02** X (mm) 840 Y (mm) 1930 **Nexus** **S/N cos30003** X (mm) 1050 Y (mm) 2310 **Nexus** **S/N cos30004** X (mm) 1050 Y (mm) 2610 Enter the Position of the force plate (position of plate center in Vicon reference) **Nexus** **S/N cos30000va** X (mm) 392 Y (mm) 967 **Nexus** **S/N cos30000-02** X (mm) 412 Y (mm) 927 **Nexus** **S/N cos30003** X (mm) 517 Y (mm) 1117 **Nexus** **S/N cos30004** X (mm) 517 Y (mm) 1267 The position of the force-plate set here corresponds to the position of the wand illustrated at step 1 of Table 12. Enter the Origin of the force plate (distance from plate center to load-cell) **Nexus** **S/N cos30000va** a (mm) 380 b (mm) 600 az0 (mm) -163 **Nexus** **S/N cos30000-02** a (mm) 390 b (mm) 800 az0 (mm) -181 **Nexus** **S/N cos30003** a (mm) 495 b (mm) 800 az0 (mm) -185 **Nexus** **S/N cos30004** a (mm) 495 b (mm) 800 az0 (mm) -185	

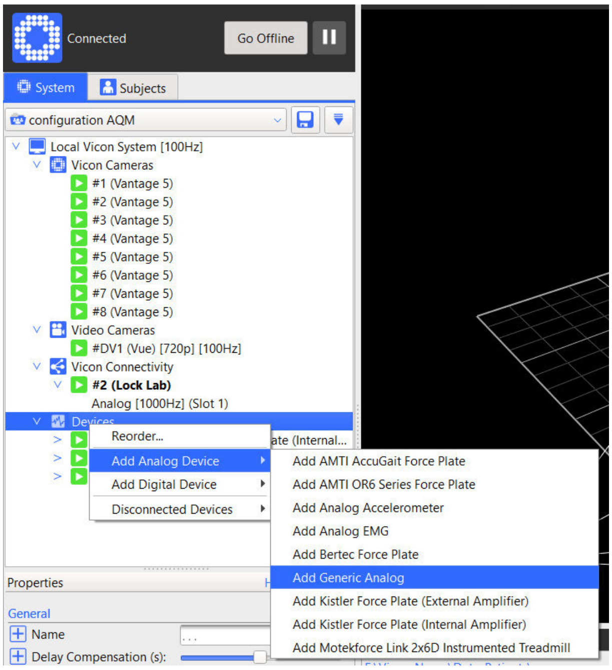
Step	Description	Illustration
7.	Right click on the device then select ‘Foot Contact’ → ‘Auto-Detect’	

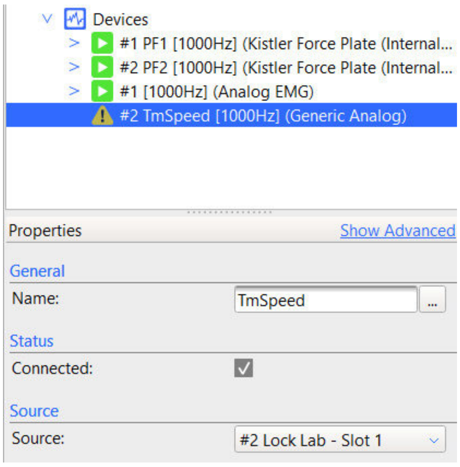
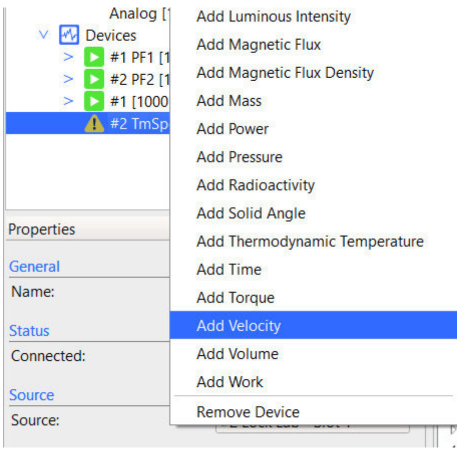
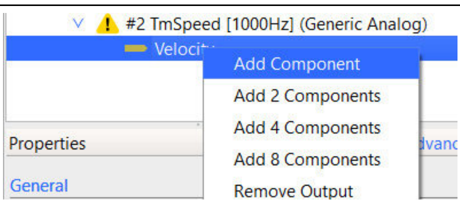
When the force plate is configured and the zero level is set, Nexus will measure the resultant force applied by the subject on the gaitway 3D in each direction (Fx, Fy and Fz). It computes the resultant moments applied by the subject on the gaitway 3D with respect to the force plate origin and also the global center of pressure in the Vicon reference frame.

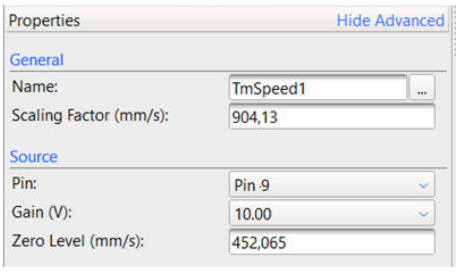
6.4.2. Configuration of Nexus to read gaitway 3D treadmill speed signal

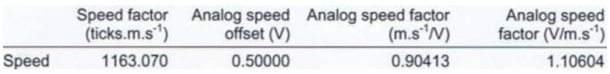
When using a gaitway 3D amplifier version E (see Figure 3), the gaitway 3D treadmill speed can also be read as an analog input into the Vicon Nexus 2.x software. A new analog input needs to be declared in Nexus as described in Table 8.

Table 8. Nexus configuration to read gaitway 3D treadmill speed.

Step	Description	Illustration
1.	When online, in the ‘System’ tab, select ‘Device’ then ‘Add Analog Device’ then ‘Add Generic Analog’.	

Step	Description	Illustration
2.	Enter the new device a name, e.g. ‘TmSpeed’.	
3.	Right click on the device and select ‘Add Velocity’.	
4.	Right click on the device and select ‘Add Component’.	

<table>
<tr><th>Step</th><th>Description</th><th>Illustration</th></tr>
<tr><td>5.</td><td>
– Click on ‘Show advanced’ to access all settings.
– Enter the ‘Scaling Factor’ as specified in the gaitway 3D calibration certificate for the 'Speed’ channel, as follows:
<u>Nexus</u> — <u>Gaitway 3D calibration</u>
Scaling Factor (mm/s) — 1000* Analog speed factor ($m.s^{-1}/V$)
– Enter the pin of the treadmill speed input signal according to the analog input connections listed in Table 6.
– Enter the ‘Gain’ value of 10.00.
– Enter the ‘Zero level’ as specified in the gaitway 3D calibration certificate for the 'Speed’ channel, as follows:
<u>Nexus</u> — <u>Gaitway 3D calibration</u>
Zero Level (mm/s) — Analog speed offset (V) * 1000 * Analog speed factor ($m.s^{-1}/V$)
</td><td>


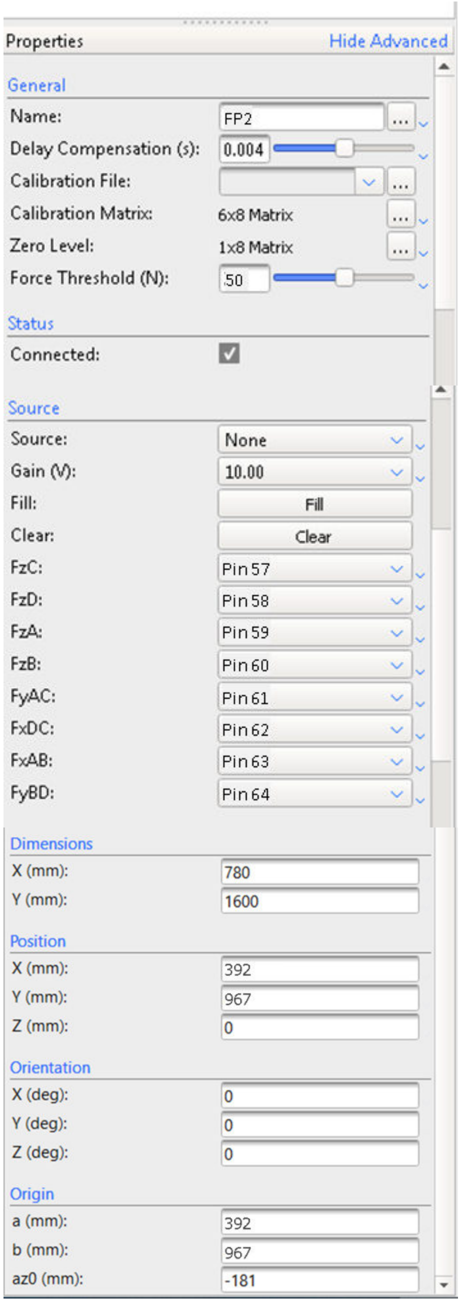


</td></tr>
</table>

6.4.3. Configuration of virtual force plate for left/right force decomposition

Configure a new 'virtual' force plate into Nexus environment to allow the left/right decomposition of the force applied by the subject. The virtual force plate should have identical characteristics as the real force plate (e.g. "FP1"), as described in Table 9.

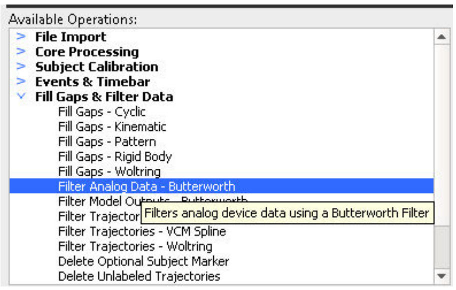
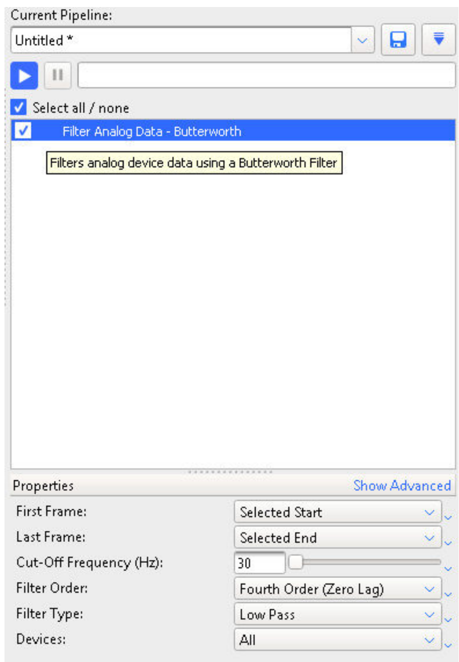
Table 9. Nexus configuration of virtual force plate.

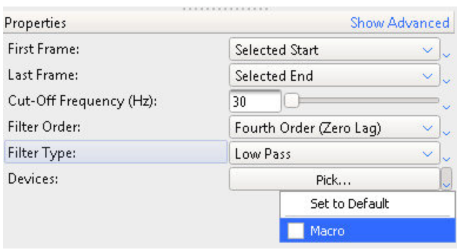
Step	Description	Illustration
1.	– Configure a new force plate according to Table 7, with the modifications listed below. – Enter a different name for the virtual force plate, e.g. "FP2". – Set very large sensitivities for the virtual force plate analog inputs, e.g. 1000, to hide any noise on the unused analog inputs. – Select unused analog inputs for the source of signals of the virtual force plate – Set the virtual force plate with the same physical dimensions as the real force plate, to have both force plates exactly superimposed in Nexus.	

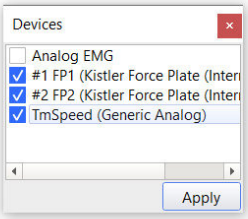
6.4.4. Filtering configuration

Configure the filter for the force and treadmill speed signals as described in Table 10.

Table 10. Nexus configuration of filtering.

Step	Description	Illustration
1.	In the ‘Tools’ tab, select ‘Pipeline’.	
2.	– In ‘Available Operations’, select: ‘Fill Gaps & Filter Data’ – Then select: ‘Filter Analog Data - Butterworth’	
3.	In the current pipeline, select the filter operation then: – Define ‘First Frame’ as ‘Selected Start’ – Define ‘Last Frame’ as ‘Selected End – Set the ‘Cut-Off Frequency’ as 2/3 of vibration frequency (i.e. 30Hz). – Set ‘Filter Order’ as ‘Fourth Order (Zero Lag)’ – Set ‘Filter Type’ as ‘Low Pass’. – ‘Devices’ can be set to ‘All’ if no other devices are connected.	

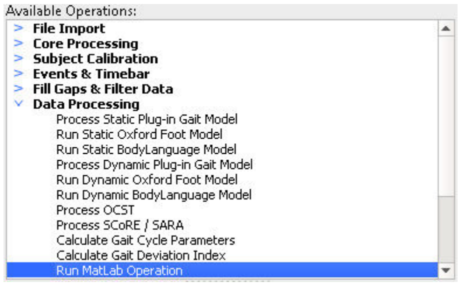
<table>
<tr>
<td>4.</td>
<td>– If other devices are connected, disable ‘Macro’ with the small arrow at the right side of the ‘Device’ menu.
– Click on ‘Pick’ and select the two force plates and the analog speed channel if connected (amplifier version E in Figure 3).</td>
<td>

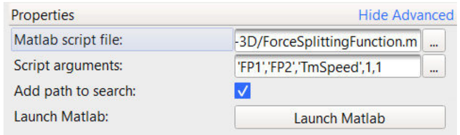

</td>
</tr>
</table>

6.4.5. Configuration of left and right force decomposition

Configure the Matlab function 'ForceSplittingFunction' as described in Table 11. This function will overwrite the original data in the real force plate 'FP1' with left foot forces, moments and COP while the right foot data will be written into a second, virtual force plate 'FP2'. With the forces separated in this way, Nexus is ready to compute the joint moments by the inverse dynamic process. Before the force splitting, the Matlab function also has the option to remove the average force value in fore-aft and transverse directions and also to adjust the average vertical force to the body weight declared in subject parameter 'Bodymass' in kg.

Table 11. Configuration of LEFT vs. RIGHT force decomposition.

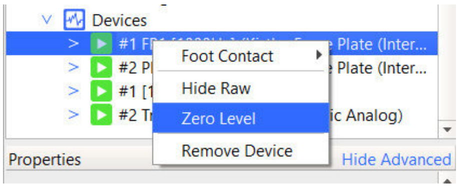
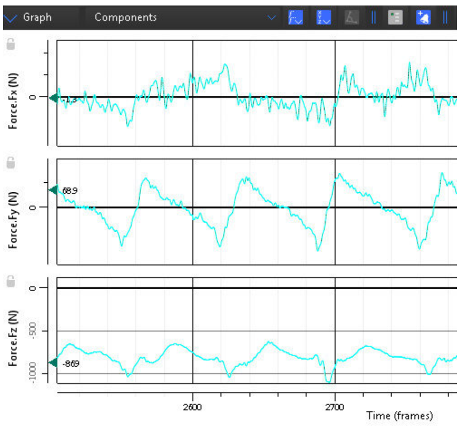
Step	Description	Illustration
1.	Go to the Pipeline tab and add an item 'Run Matlab Operation' from the 'Data Processing' operations	

2.	– Select the Matlab Script File 'Program Files (x86)\Gaitway-3D\ForceSplittingFunction.m'.
	– Write the Matlab script arguments separated by comma:
	  – 'FP1',
	  – 'FP2',
	  – 'TmSpeed' if speed channel available or write speed average value (km/h) if no speed sensor is connected,
	  – belt direction (1 if the subject is heading towards the motor, -1 if the subject is heading away from the motor),
	  – average force rectification (1 to enable, 0 to disable). This set the average of forces Fx,Fy,Fz to 0,0,BodyWeight. This option may be helpful only in case a small offset on the force records is present but errors on the COP measure remains if offsets in vertical forces were important. In addition, an entire number of steps needs to be selected as 'Region of interest' when using this option.
		

6.5. Data recording

The important operations to perform before each recording in order to have useable data are described in Table 12.

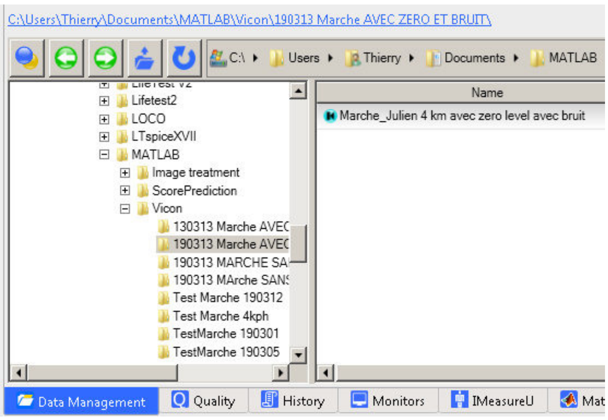
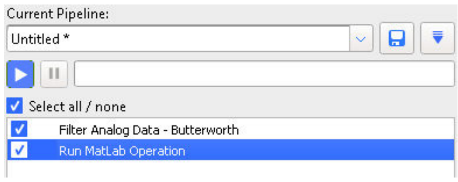
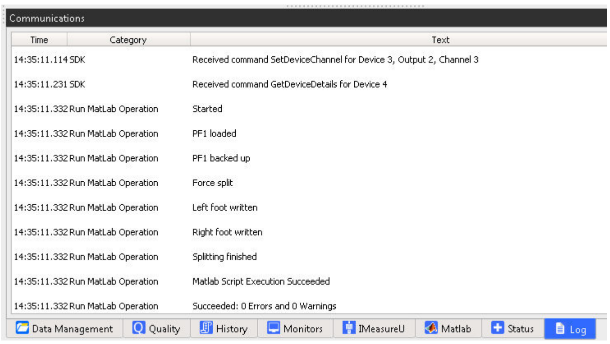
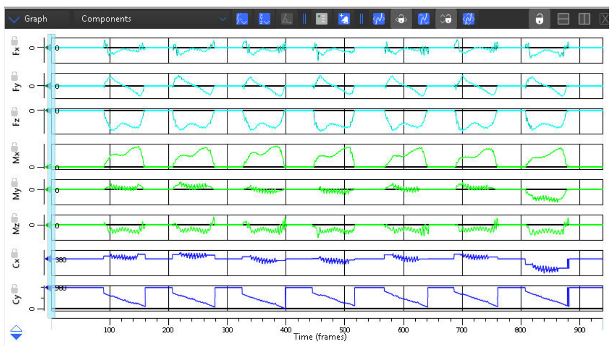
Table 12. Data recording.

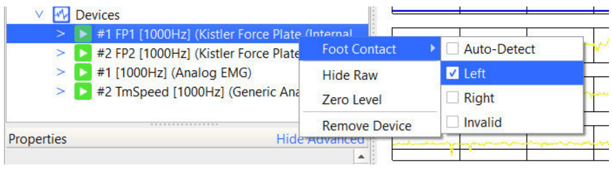
Step	Description	Illustration
1.	– When performing the Vicon calibration, place the Vicon wand at the left side of the treadmill, aligned with the rear side of treadmill frame. ⚠ The position of the wand illustrated here corresponds to the settings at step 6 of Table 7.	
2.	– Before instructing the subject to go on the treadmill, ensure that nothing touches the treadmill and right click on the devices 'FP1'. – Select 'Zero Level'. ⚠ Forgetting this step will result in unusable data	
3.	While the subject is walking on the treadmill, switch to graph visualization of forces on 'FP1' then check that the average fore-aft and lateral forces are about zero and that the average vertical forces is about the bodyweight.	

6.6. Processing of recorded data

The operations to perform the data filtering and the force splitting on recorded data are described in Table 13.

Table 13. Processing Application to recorded data.

Step	Description	Illustration
1.	In the ‘Data Management’ panel, select the record on which the decomposition algorithm needs to be applied and double click on the trial to decompose the Left and Right foot force.	
2.	Run the pipeline by clicking on the Play button	
3.	Wait until ‘Matlab Script Execution Succeeded’ message is given in the Nexus Log. This can take up to two minutes the first time, when Matlab needs to be loaded.	
4.	The force-plate forces, moments and center of pressure are now decomposed between the real force plate ‘FP1’ that contains the left foot data and the virtual force plate ‘FP2’ that contains the right foot data. The originally acquired data are saved into a new model output of the subject. Note that if a ‘region of interest was defined, the splitting is only done during this period.	

5.	Set the real force plate ‘FP1’ to detect LEFT foot contact and the virtual force plate ‘FP2’ to detect RIGHT foot contact.	

6.7. Troubleshooting

A number of error messages can be generated by the decomposition routine. Any error message will be listed in the Nexus Log panel and the corresponding solution is described in Table 14.

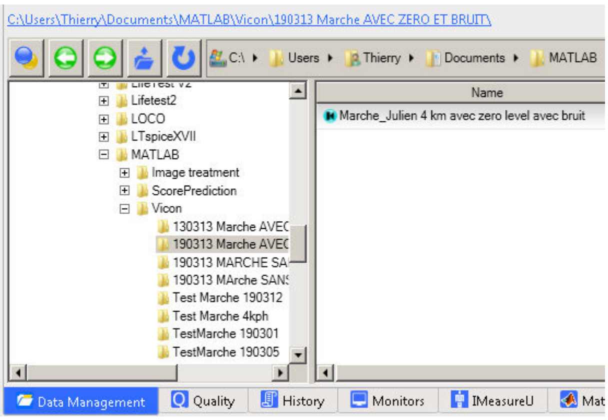
Table 14. Error messages and solutions.

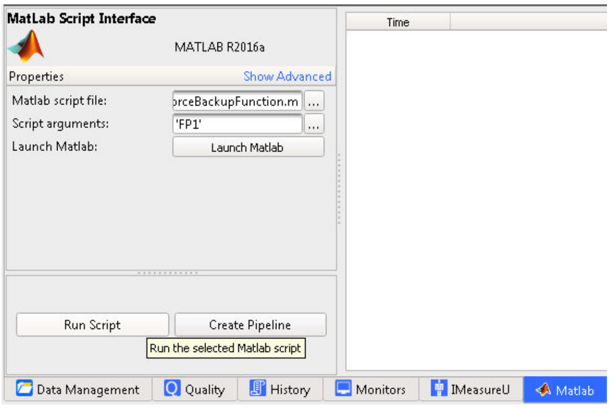
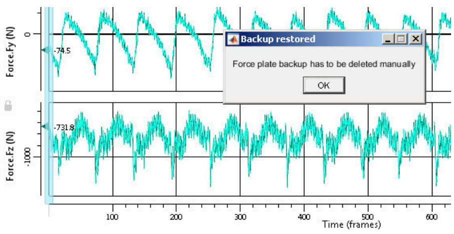
Error message	Solution
“The Matlab function ‘ForceSplittingFunction’ cannot be found.”	The gaitway-3D software cannot be found at the location specified in step 2 of Table 11 or older than version 1.5. Install gaitway-3D software and specify its location at step 2 of Table 11.
“The source file could not be found.” or “Unable to remove old input/output files.”	The file '%public%\Documents\Vicon\Arsalis\DataInFile.txt' or the file '%public%\Documents\Vicon\Arsalis\DataOutFile.txt' is not accessible to the Matlab or Gaitway-3D software. Grant read and write access to both files.
“The sample rate specified in the arguments is out of bounds.”	Specify a sample rate between 100Hz and 10000Hz for the recording of gaitway-3D analog signals.
“The treadmill belt direction is not specified correctly in the arguments.”	Specify a value of 1 if the subject is heading towards the motor and of -1 if the subject is heading away from the motor for the 4th argument of the Matlab function (see step 2 of Table 11).
“The gaitway-3D device could not be accessed or the Force Split Algorithm option is not activated for your device.”	In order to enable the force decomposition, the license for this option needs to be installed and the gaitway-3D force amplifier needs to be accessible on the Ethernet network.
“The system could not find out if it is a walking or a running gait.”	The data are not walking or running data or the number of steps is too small to identify the type of gait. Select a longer record or a longer region of interest to allow the decomposition.

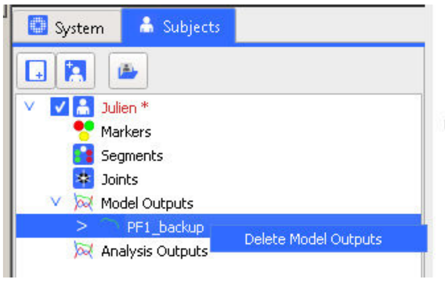
Error message	Solution
“*Force-plate-name* loading error.”	The data of the force plate named ‘Force-plate-name’ cannot be read from Nexus. Check that the correct name of the force plate is entered in the argument of the Matlab function (see step 2 of Table 11) and that the data are present.
“A subject name is needed for force backup.”	The original force data are always backed-up before the decomposition into the subject model output. Specify a name for the subject in order to allow the backup.
“Restore force backup then delete force backup before splitting again.”	The force plate data backup already exist, indicating that the forces have already been decomposed for this trial. Restore the original force data according to the procedure in Table 15 to apply a new decomposition to the trial.
Any other message from the Matlab execution.	Check that the arguments of the ‘ForceSplittingFunction’ are defined as explained in Section 6.4.5 and separated by commas. Name arguments (force-plate and speed channel) should be between quotes.
The center of pressure on the force plate does not match the foot position from kinematic data.	Verify the following specifications to ensure an accurate measurement form Vicon and from gaitway 3D: - Verify that the Vicon system is calibrated as recommended in the user manual. - Verify that the offset of applied force is lower than 10N when no load is applied on the gaitway-3D. - Make sure the ‘Zero level’ has been done when no load was applied to the gaitway-3D (see step 2 of Table 12). - Verify that the Force-plate is configured as described in sections 6.4.

When applying the decomposition to recorded data, the original data of PF1 are backed up before assigning the data of the left and right foot to separate force plate. The presence of this backup is used to determine whether the decomposition has already been applied to any particular trial. In case a backup is found, an error message will be generated (see above). In order to apply the decomposition anew, the backup needs to be restored according to the procedure described in Table 15.

Table 15. Restoring the force backup.

<table>
<tr><th>Step</th><th>Description</th><th>Illustration</th></tr>
<tr><td>1.</td><td>In the ‘Data Management’ panel, select the record for which the original force data should be restored and double click on the trial to restore the original forces.</td><td>
</td></tr>
<tr><td>2.</td><td>- Select the Matlab Script File ‘Program Files (x86)\Gaitway-3D\RestoreForceBackupFunction.m’.
- Write the force plate name as Script argument: ‘FP1’.
- Click on ‘Run Script’

Note that a pipeline can also be configured to automate the restore as described in section 6.4.5.</td><td>
</td></tr>
<tr><td>3.</td><td>Wait until the Matlab popup indicates that the forces have been restored and that the backup can be deleted.</td><td>
</td></tr>
<tr><td>4.</td><td>- In the ‘Subjects’ panel, select the ‘Model outputs’ then right-click on the force backup.
- Select ‘Delete Model Outputs’.

After these operations, the force decomposition can be performed again if needed.</td><td>
</td></tr>
</table>

7. Analog interface of gaitway 3D with Qualisys QTM software

7.1. Integration philosophy

The integration of gaitway 3D with Qualisys QTM software version 2019 described here concerns an interconnection of analog outputs of gaitway 3D, sampled by a Qualisys analog to digital converter. The gaitway 3D hardware settings (signals, calibration matrix, position, etc) need to be configured in QTM for proper data acquisition and interpretation.

7.2. Connection of gaitway 3D analog outputs into Qualisys analog to digital converter

The gaitway 3D analog outputs are connected to the BNC inputs of the Qualisys analog-to-digital converter, using the pinout given in section 2.1.5. An Arsalis Analog-to-BNC cable can be used. Any unused analog input of the Qualisys ADC can be used, depending on the other devices already connected, but in this example we will use the pins starting from number 17. It is recommended to connect the channels in the order given in Table 16.

Power off the gaitway 3D and Qualisys systems to connect and disconnect cables.

Table 16. gaitway 3D connection to Qualisys

gaitway 3D channel	Qualisys analog input
EZ1	17
EZ2	18
EZ3	19
EZ4	20
EY14	21
EY23	22
EX12	23
EX34	24
Speed (if applicable)	25

The noise on the Analog channels can be very important if a bad grounding configuration is used. It is recommended to connect the gaitway 3D plug and the Qualisys plug on sockets that are on the same circuit to have the shortest Earth connection. The use of a shielded cable with shielding connected to the backshell of the analog output connector on gaitway 3D cable extremity and connected on the GND of signals on the Qualisys cable side usually improves noise rejection also.

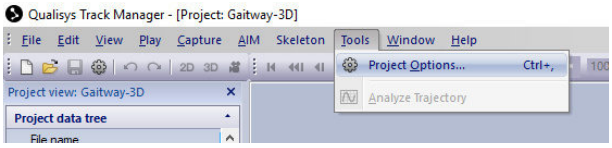
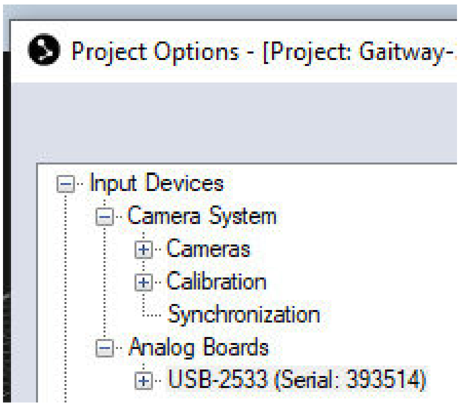
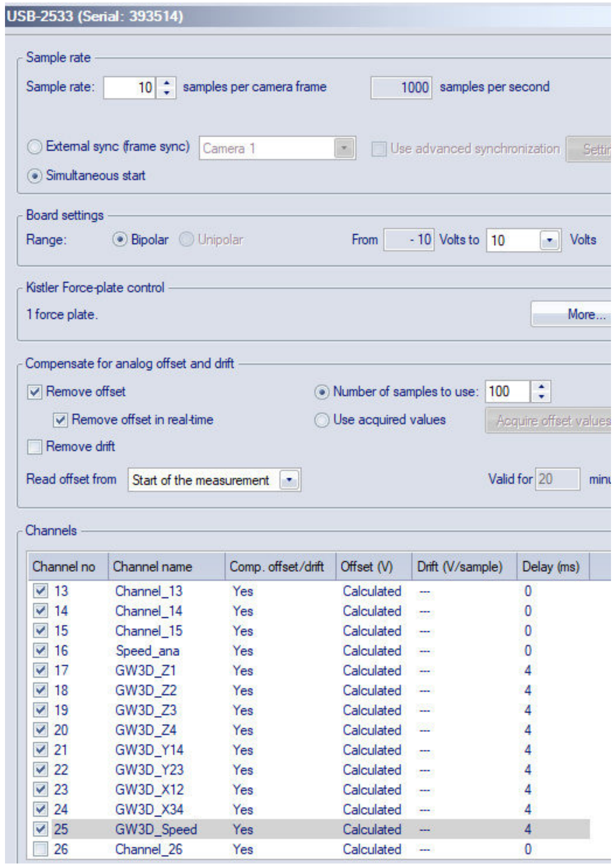
7.3. Configuration to integrate gaitway 3D signal into QTM

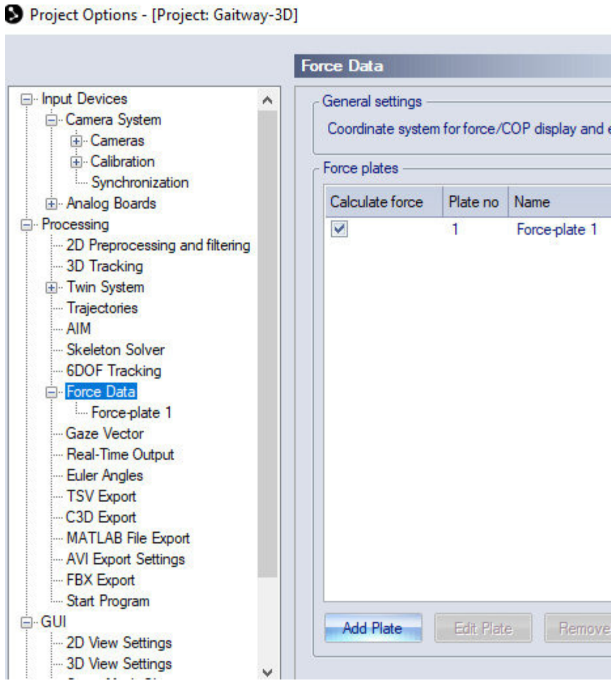
The following configuration procedures are required to allow the integration of gaitway 3D analog outputs into Qualisys QTM. These procedures will allow the configuration of a force plate to record the gaitway 3D signals and the optional treadmill speed signal.

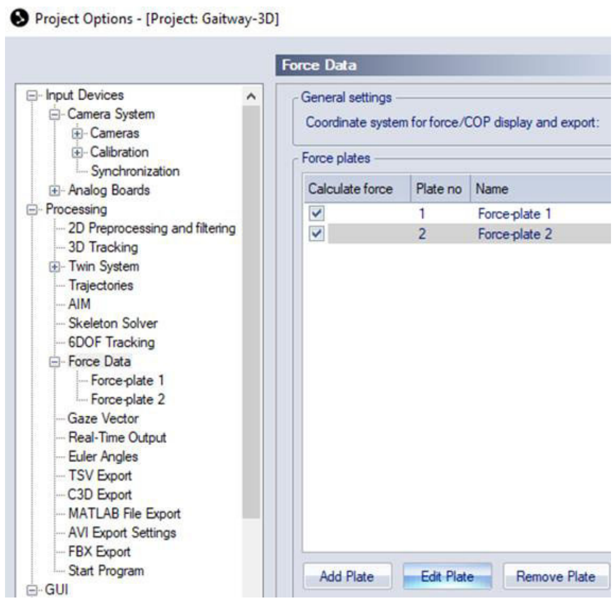
7.3.1. Configuration of QTM to read gaitway 3D force signals

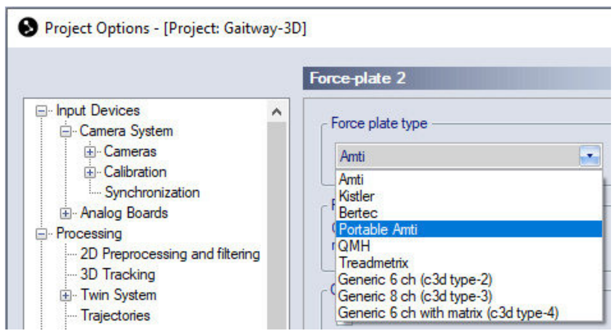
The gaitway 3D is configured as a force plate in the Qualisys QTM software as described in Table 17.

Table 17. QTM configuration to read gaitway 3D forces.

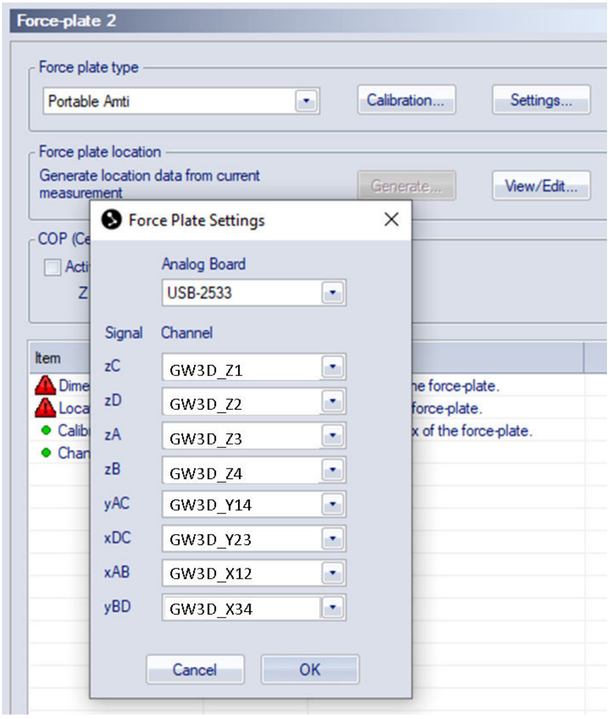
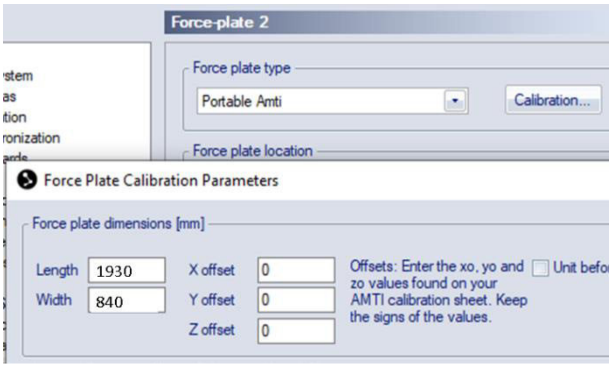
<table>
<tr><th>Step</th><th>Description</th><th>Illustration</th></tr>
<tr><td>1.</td><td>Click on ‘Project Options’</td><td>
</td></tr>
<tr><td>2.</td><td>Click on the Analog to digital converter in the menu under ‘Input Devices’ and ‘Analog Boards’.</td><td>
</td></tr>
<tr><td>3.</td><td>– Adjust the sample rate to the desired value.
– Select ‘Simultaneous start’.
– Select ‘Range’ of at least 0 to 10V, here: ‘Bipolar -10Volts to 10 Volts’.
– Select ‘Remove offset’.
– Select ‘Remove offset in real time’.
– Unselect ‘Remove drift’.
– Select the checkboxes of channels 17 to 25.
– Set the 8 force-plate channels name in the order indicated in the screenshot and the 9th channel for the speed signal if available. The order shall match the one of Table 16.
– Set the ‘Compensate offset/drift’ to ‘Yes’ for these channels.
– Set the ‘Delay (ms)’ to 4 for these channels.</td><td>
</td></tr>
</table>

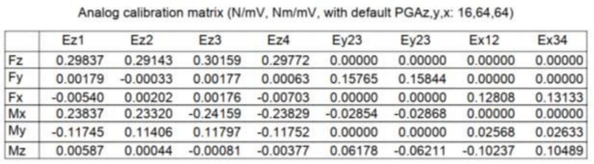
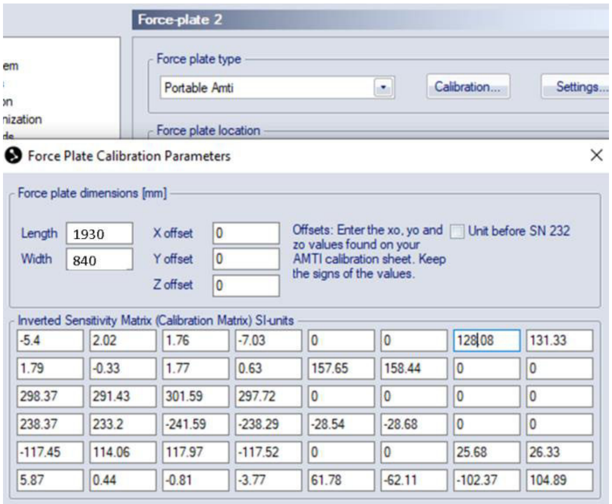
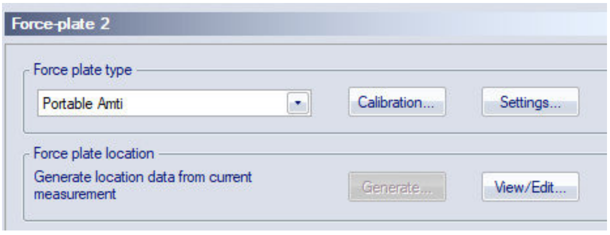
<table>
<tr><th>Step</th><th>Description</th><th>Illustration</th></tr>
<tr><td>4.</td><td>In the ‘Projects Options’, enter in the ‘Processing’ then ‘Force Data’ menu and click on ‘Add Plate’.</td><td>


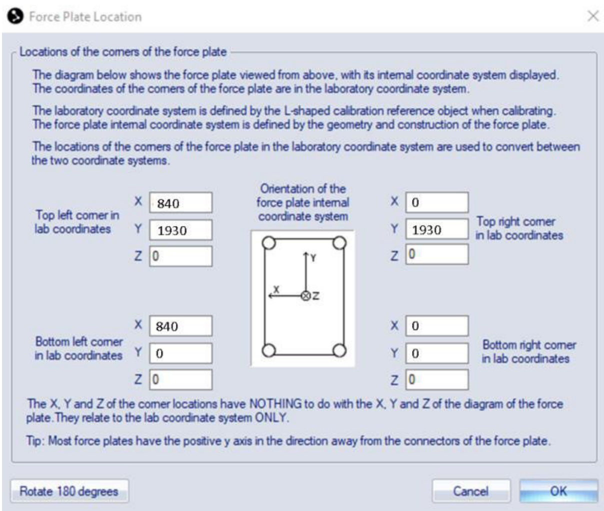
</td></tr>
<tr><td>5.</td><td>Select the newly created force plate and click on ‘Edit Plate’</td><td>


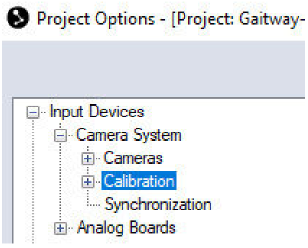
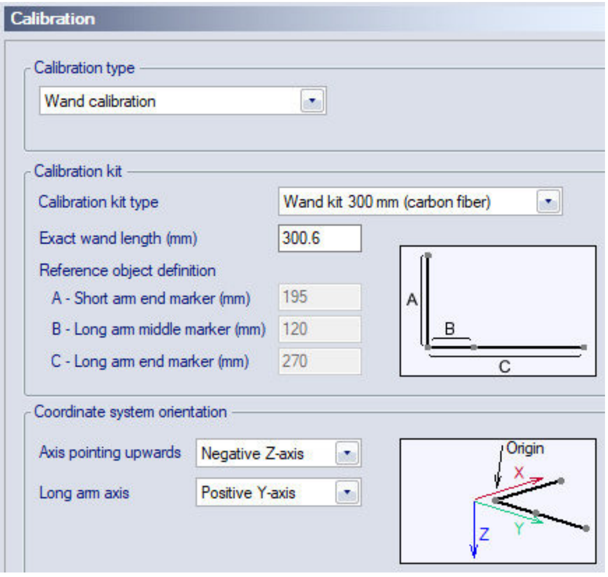
</td></tr>
<tr><td>6.</td><td>Set the ‘Force plate type’ as ‘Portable Amti’</td><td>


</td></tr>
</table>

Step	**Description**	**Illustration**
7.	Click on 'Settings' and select the 8 channels in the order indicated in the screenshot.	
8.	Click on 'Calibration' and enter the 'Length' and 'Width' of the force-plate for the treadmill size used as indicated hereunder: **<u>QTM</u>** **<u>S/N cos30000va</u>** Length 2010 Width 800 **<u>QTM</u>** **<u>S/N cos30000-02</u>** Length 1930 Width 840 **<u>QTM</u>** **<u>S/N cos30003</u>** Length 2310 Width 1050 **<u>QTM</u>** **<u>S/N cos30004</u>** Length 2610 Width 1050	

<table>
<tr><th>Step</th><th>Description</th><th>Illustration</th></tr>
<tr><td>9.</td><td>Enter the calibration factors for all analog force channels from the gaitway 3D calibration certificate under the heading ‘Analog calibration matrix (N/mV, Nm/mV, with default PGAz,y,x: 16,64,64)’:
– Multiply all values by 1000.
– Enter values in the following order for rows 1 to 6: Fx, Fy, Fz, Mx, My, Mz.</td><td>
Analog calibration matrix (N/mV, Nm/mV, with default PGAz,y,x: 16,64,64)
<table>
<tr><th></th><th>Ez1</th><th>Ez2</th><th>Ez3</th><th>Ez4</th><th>Ey23</th><th>Ey23</th><th>Ex12</th><th>Ex34</th></tr>
<tr><td>Fz</td><td>0.29837</td><td>0.29143</td><td>0.30159</td><td>0.29772</td><td>0.00000</td><td>0.00000</td><td>0.00000</td><td>0.00000</td></tr>
<tr><td>Fy</td><td>0.00179</td><td>-0.00033</td><td>0.00177</td><td>0.00063</td><td>0.15765</td><td>0.15844</td><td>0.00000</td><td>0.00000</td></tr>
<tr><td>Fx</td><td>-0.00540</td><td>0.00202</td><td>0.00176</td><td>-0.00703</td><td>0.00000</td><td>0.00000</td><td>0.12808</td><td>0.13133</td></tr>
<tr><td>Mx</td><td>0.23837</td><td>0.23320</td><td>-0.24159</td><td>-0.23829</td><td>-0.02854</td><td>-0.02868</td><td>0.00000</td><td>0.00000</td></tr>
<tr><td>My</td><td>-0.11745</td><td>0.11406</td><td>0.11797</td><td>-0.11752</td><td>0.00000</td><td>0.00000</td><td>0.02568</td><td>0.02633</td></tr>
<tr><td>Mz</td><td>0.00587</td><td>0.00044</td><td>-0.00081</td><td>-0.00377</td><td>0.06178</td><td>-0.06211</td><td>-0.10237</td><td>0.10489</td></tr>
</table>

</td></tr>
<tr><td>10.</td><td>Click on ‘View/Edit’ in the ‘Force plate location’ window and enter the coordinates of each corner for the treadmill size used as indicated hereunder:
<table>
<tr><td><u>QTM</u></td><td><u>S/N cos30000va</u></td></tr>
<tr><td>Y front</td><td>2010</td></tr>
<tr><td>X left</td><td>800</td></tr>
<tr><td><u>QTM</u></td><td><u>S/N cos30000-02</u></td></tr>
<tr><td>Y front</td><td>1930</td></tr>
<tr><td>X left</td><td>840</td></tr>
<tr><td><u>QTM</u></td><td><u>S/N cos30003</u></td></tr>
<tr><td>Y front</td><td>2310</td></tr>
<tr><td>X left</td><td>1050</td></tr>
<tr><td><u>QTM</u></td><td><u>S/N cos30004</u></td></tr>
<tr><td>Y front</td><td>2610</td></tr>
<tr><td>X left</td><td>1050</td></tr>
</table>These positions are valid for the positon of the calibration frame illustrated in Table 18 step1.
If the calibration frame is positioned somewhere else, then place a marker at rear left and rear right corners of the treadmill frame and two other at a ‘Y front’ distance in front. A QTM acquisition will be done and the positions of these markers in QTM reference frame are written in this menu.</td><td>

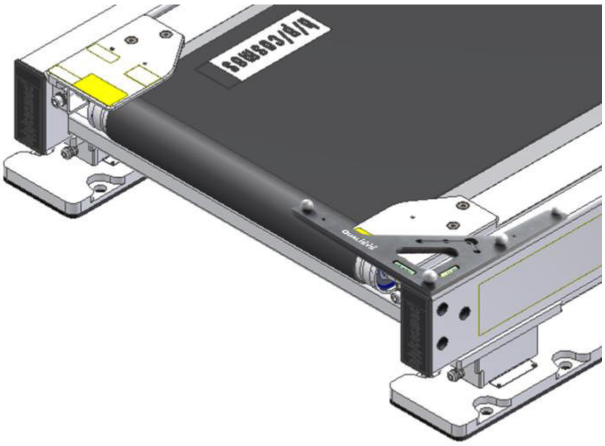
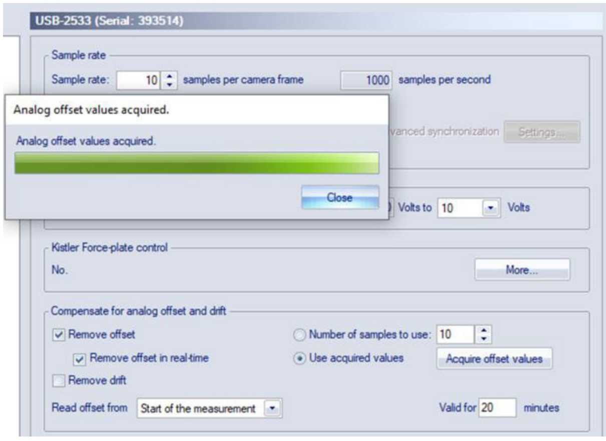

</td></tr>
</table>

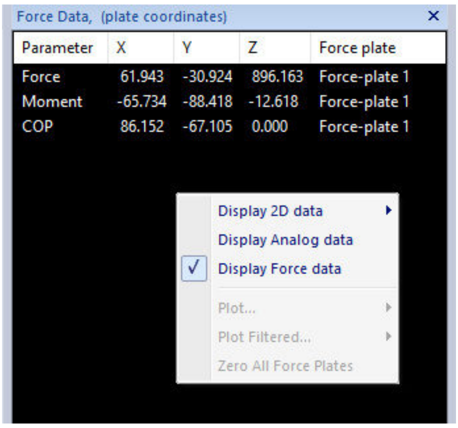
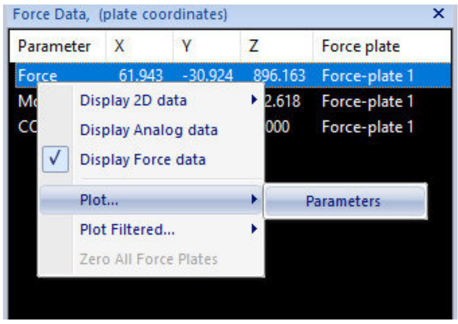
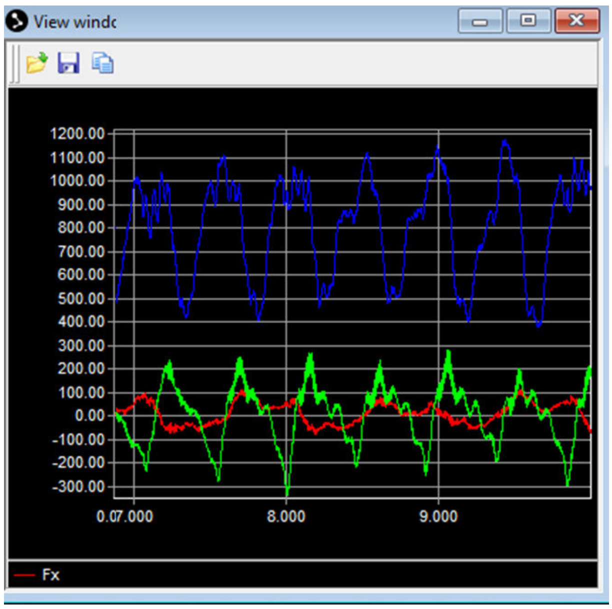
Step	Description	Illustration
11.	Return in ‘Project Options’ → ‘Input Devices’ → ‘Camera System’ → ‘Calibration’ menu. Select the ‘Negative Z-axis’ in the ‘Axis pointing upwards’ menu. Select the ‘Positive Y-axis’ in the ‘Long arm axis’ menu. These settings result in increasing Y coordinates in front direction with the long arm of the calibration L-frame pointing frontward.	

7.4. Data recording

The important operations to perform before and after recording in order to have useable data are described in Table 18.

Table 18. Data recording.

Step	Description	Illustration
1.	When performing the QTM calibration, place the QTM L-frame at the right side of the treadmill, aligned with the rear side of the treadmill frame. ⚠ The position of the wand illustrated here corresponds to the settings at step 10 of Table 17.	
2.	Before instructing the subject to go on the treadmill, ensure that nothing touches the treadmill and measure the channel offsets: – Click on 'Project Options' – Click on the Analog to digital converter in the menu under 'Input Devices' and 'Analog Boards'. – Check the box 'Use acquired values' – Click on 'Acquire offset values' – A popup indicates that some offsets are about 5.0V. Click on 'Use anyway'. ⚠ Forgetting this step will result in unusable data.	

<table>
<tr>
<td>3.</td>
<td>After the data are recorded, control immediately that the acquired data are valid:
– Click on ‘Data info windows 1’ button.
– Right-click on the data panel that appeared.
– Select ‘Display force data’</td>
<td>
</td>
</tr>
<tr>
<td>4.</td>
<td>Right-click on ‘Force’
Select ‘Plot’ → ‘Parameters’</td>
<td>
</td>
</tr>
<tr>
<td>5.</td>
<td>Check that the average fore-aft and average lateral forces are about zero with meaningful amplitudes and that the average vertical forces is about the bodyweight.</td>
<td>
</td>
</tr>
</table>