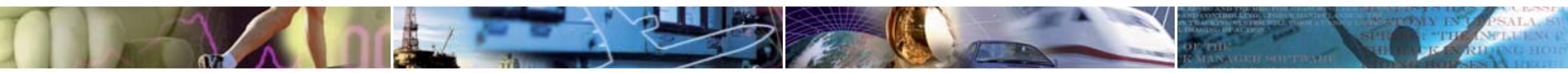
QUALISYS
Motion Capture Systems

QTM

MARINE MANUAL

QUALISYS AB
Packhusgatan 6 · 411 13 Gothenburg · SWEDEN
Tel. +46 31 336 94 00 · Fax. +46 31 336 94 20
e-mail: sales@qualisys.com · www.qualisys.com

User MANUAL



Qualisys AB, 2008-12-11

www.qualisys.com

Table of Contents

Qualisys Track Manager - Marine manual 1

Getting started 1
Introduction 1
Organization of the manual 1
Quick guides 1
Installation of a fixed camera system 2
Outline of how to calibrate a fixed camera system 2
Outline of how to define 6DOF bodies 3
Outline of how to capture 4
Outline of how to output 6DOF data in real-time 5

Euler angles in QTM 7
Introduction 7
Rotation angles in QTM 7
Rotation angles in marine application 9
QTM settings - Euler angles 11
Select Euler angle definition 11
Definition of rotation axes 12

Fixed camera calibration method 14
Introduction 14
Requirements for a Fixed camera calibration 14
Performing a Fixed camera calibration 14
Single marker calibration 15
Calibration results 16
Check tracking residuals 17
Validation 17
Performing a validation 18
Validation results 18
QTM settings - Fixed camera calibration 19
Fixed camera calibration 19
Reference marker locations 19
Camera locations and markers seen by each camera in order from left to right 20
Apply coordinate transformation 20
Transformation 21
Rotate axis to line 22

6DOF bodies 23
Introduction 23
How to design a 6DOF body 23
Definition of 6DOF bodies 24
Definition of local coordinate system 25
QTM settings - 6DOF Tracking 26
Rigid bodies 26
Coordinate system for rigid body data 27
Add body 28
Remove body 28
Save bodies 28
Load bodies 28
Reset rotation 28
Translate 28
Translate body 28
Rotate 29
Rotate body 29
Acquire body 30

Import markers 31
Add point 31
Remove point 31
Edit point 32

Capture 6DOF data 33
Introduction 33
Capturing 33
6DOF real-time output 34
Real time in QTM 34
How real time works in QTM 34
Real time processing on file 35
Real time latency 35
6DOF analog output 36
Analog output hardware 36
QTM settings - Capture 37
RT output 37
Real time server communication 37
Legacy RT server 38
6DOF analog export 39
Analog channel settings 39
Test output 40
Range calibration 41
Start capture 42
Capture period 42
Capture delay and notification 42
Real time processing while capturing 43
Automatic capture control 43
Camera systems settings 43

6DOF data in QTM 43
Introduction 43
Tracking 6DOF bodies 43
Post-processing 6DOF data 44
6DOF bodies in 3D views 44
6DOF data information 44
Export 6DOF to TSV format 46
6DOF data format 47
Export to MAT format 48
MAT file format 49
Export directly into Matlab 51
Matlab variables 51

Calculation of 6DOF data 54
6DOF tracking output 54
Calculation of rotation angles from the rotation matrix (Qualisys standard) 54
Calculation of other rotation matrixes 56

Long range active markers 57
Introduction 57
Getting started 57
Getting started long range 57
Usage 57
Power 58
Performance 58
Long range active marker package 58
Specifications 59
QTM settings - Long range active markers 59

Glossary I

Index I

Qualisys Track Manager - Marine manual

Getting started

Introduction

This is a complementary manual with information that is specific for marine systems. It is only applicable if you have a fixed camera system, which uses the Fixed camera calibration method. The functions that have nothing to do with 6DOF or Fixed camera calibration are only described on a basic level in this manual, if you need more detailed information to QTM please refer to the complete **QTM - User manual**.

Organization of the manual

The manual is organized in to six main parts:

Getting started
Quick guides to calibration and capturing with a fixed camera system.

Euler angles in QTM
Detailed description of how Euler angles is used in QTM.

Fixed camera calibration
Detailed description of how to calibrate a fixed camera system.

6DOF bodies
Guidelines to construction of a 6DOF body and the definition and settings for the body in QTM.

Capture 6DOF data
Detailed description of how to capture with a fixed camera system.

6DOF data in QTM
Information about 6DOF data in QTM.

Calculation of 6DOF data
How the 6DOF data is calculated in QTM.

Long range active markers
Getting started for the Long range active marker.

Quick guides

The following chapter contains outlines on how to perform the following tasks: Installation, Fixed camera calibration, 6DOF bodies, Capture and 6DOF real-time output.

Installation of a fixed camera system

The installation must be done correctly to ensure the quality of the measurement data. The most important issues to keep in mind when installing the system is that the consoles for the cameras and reference markers are extremely stable and rigid and to make a precise survey measurement. Since these issues are extremely important to the overall performance of the system and that no measurement site is alike the system installation must be designed for each specific site, please contact Qualisys AB for more information.

Outline of how to calibrate a fixed camera system

With a Fixed camera calibration QTM will determine the rotation of the cameras using the data of a survey measurement. The calibration will be very exact as long as none of the reference markers are moved. The cameras can on the other hand be rotated slightly to adjust the overlap of the cameras. However after the rotation you need to perform a new calibration.

Important: If the reference marker has been moved even the slightest you need to perform a new survey measurement to achieve the highest accuracy.

The first quality check that can be performed is to check the tracking residuals, see chapter “Check tracking residuals” on page 17.

Then you can check the accuracy of the current calibration with the following validation process:

1. Switch on the camera system and the reference markers.
2. Start QTM and open a new file by clicking the **New file** icon .
3. Go to the **Advanced** page (for ProReflex the **Camera settings** page) and select **Long range active markers**. Click **OK**.
4. Switch to 2D view and check that all of the cameras can see at least one reference markers. You can still run the validation process if a camera cannot see any reference marker, but that camera position will not be validated.
5. Switch to video/viewfinder mode and check for each camera that the visible reference markers are not partially obscured, i.e. that nothing is blocking them.
6. Click the **Calibration** icon and activate the option **Validate calibration for all visible reference markers (don't calibrate)**. Click **OK**.
7. Wait for the validation to finish and check the **Validation results**. Compare the average residual in the **Avg. res.** column with the average residual of the current calibration. Since the accuracy varies between different system you must evaluate what is acceptable for your system. For more information see chapter “Validation results” on page 18
8. If the average residual is OK you must also check the **Points** column. There should be the same number of points as the number of visible reference markers for that camera.
9. If the calibration passes the validation you do not need to make a new calibration. Otherwise continue with the steps below to calibrate the system.

If you need to calibrate follow the steps below. For more information see chapter “Fixed camera calibration method” on page 14.

1. Locate the data from the survey measurement.
2. Switch on the camera system and the reference markers.
3. Start QTM and open a new file by clicking the **New file** icon .

4. Open the **Workspace options** dialog and go to the **Calibration** page. Change the **Calibration type** to **Fixed camera calibration**.
5. Enter the data from the survey measurement. When you have entered the data, it can be saved with the **Save definition** option.

   Tip: It is a good idea to enter the reference markers from left to right round the basin, since they can then be entered in numerical order for the cameras.
6. Go to the **Advanced** page (for ProReflex the **Camera settings** page) and select **Long range active markers**. Click **OK**.
7. Switch to 2D view and check that all of the cameras can see their respective reference markers.
8. Click the **Calibration** icon and check that all of the cameras have **Linearization parameters** (if any is missing click **Load** to go to the **Linearization** page). Click **OK**.
9. Wait for the calibration to finish and check the **Calibration results**, see chapter "Calibration results" on page 16.

   Note: For large basins with long focal length Oqus cameras, you also need to perform a single marker calibration, see chapter "Single marker calibration" on page 15.
10. It is a good idea to make a validation directly after the calibration to find out a typical value of the average residual in the validation.

Outline of how to define 6DOF bodies

When capturing 6DOF data it is important to define the correct 6DOF bodies in QTM before starting the capture. The definition can be done in four ways: manually, with a capture, from a file or load a previously saved 6DOF body. In the steps below it is just described how to acquire the points through a capture in preview mode. For more information about the definition of 6DOF bodies see chapter "Definition of 6DOF bodies" on page 24.

Note: To get help on how to design a 6DOF body see chapter "How to design a 6DOF body" on page 23.

Follow these steps to acquire the 6DOF bodies with a 3D capture:

1. Switch on the camera system.
2. Start QTM and open a new file by clicking the **New file** icon .
3. Place the rigid body in the measurement volume so that the position of the desired local coordinate system is known in reference to the global coordinate system. One way is to place the body so that the desired local coordinate system is aligned with the global coordinate system and then the local origin can just be translated to the desired position.
4. Check that the markers on the 6DOF body do not merge in any of the cameras' 2D views.
5. The following three steps are not needed to acquire the data, but it makes it possible to preview the changes made to the body without closing the **Workspace options** dialog.

   a. Activate **Track each frame in 3D** and **Calculate 6DOF** for the **Real time actions** on the **Processing** page. Click **OK**.

   b. Change to a **3D view** window.

   c. Open the **Data info** window and change the display to **6DOF data**.
6. Open the **Workspace options** dialog in QTM and go to the **6DOF tracking** page.

7. Click **Acquire body**.
8. Click **Acquire**. When the collection is done the new 6DOF body definition will appear on the **6DOF tracking** page.
9. If you want to change the local coordinate system follow these steps:
    a. Go to the **6DOF Tracking** page and rotate and translate the local coordinate system to the correct orientation, see chapter “Rotate” on page 29 and “Translate” on page 28.
    b. Click **Apply** to see the rotation and translation in the **3D view** window.
10. If you want to change the coordinate system that the 6DOF body refer to follow these steps:
    a. Double-click on **Global origin** to open the **Coordinate system for rigid body data** dialog where you can change the origin and the rotation of the coordinate system, see chapter “Coordinate system for rigid body data” on page 27.
    b. Click **Apply** to see the changes in the **Data info** window.
11. Repeat the steps 3 – 10 for all of the 6DOF bodies that will be included in the measurement. Just one rigid body at a time can be acquired with **Acquire**.
12. You can save your 6DOF bodies with **Save bodies** and then load them another time with **Load bodies**.
    Note: **Load bodies** will overwrite any other bodies in the list.
13. Make sure that **Calculate 6DOF** is activated for the **Capture actions** on the **Processing** page, otherwise the 6DOF bodies will not be tracked in the captured file.
14. Click **OK** to exit the **Workspace options** dialog.

Outline of how to capture

When you have defined the 6DOF bodies that are included in the measurement follow these steps to do a capture:

1. Switch on the camera system and start QTM.
2. Open a new file by clicking the **New file** icon .
3. Open the **Workspace options** dialog and make sure that **Calculate 6DOF** is activated for the **Capture actions** on the **Processing** page, otherwise the 6DOF bodies will not be tracked in the captured file.
4. If you use Long range active markers, make sure that the setting **Long range active markers** is selected on the **Advanced** page (for ProReflex the **Camera settings** page). Click **OK**.
5. Click the **Capture** icon .
6. Specify the capture settings in the **Start capture** dialog, especially the **Capture period**, see chapter “Start capture” on page 42.
7. Click **Start** to start the capture. When the capture is finished the new motion capture data is shown in QTM. The capture can always be stopped with **Stop capture** on the **Capture** menu or by clicking the **Stop capture** icon .

Note: If you want to output the 6DOF data in real-time to another computer you should follow the instructions in chapter “Outline of how to output 6DOF data in real-time” on page 5 instead.

Outline of how to output 6DOF data in real-time

If you want to export the 6DOF data in real-time to another computer you can use either 6DOF real-time output or 6DOF analog output. The two alternatives can be used simultaneously but it may slow down the highest possible capture rate. For more details see chapter “6DOF real-time output” on page 34 respectively “6DOF analog output” on page 36.

For the 6DOF real-time output follow these steps:

1. Switch on the camera system and start QTM.
2. Open a new file by clicking the **New file** icon .
3. Open the **Workspace options** dialog and check the settings on the **RT output** page.
4. Make sure that **Calculate 6DOF** is activated for the **Real time actions** on the **Processing** page, otherwise the 6DOF bodies will not be tracked by QTM.
5. If you use Long range active markers, make sure that the setting **Long range active markers** is activated on the **Advanced** page (for ProReflex the **Camera settings** page). Click **OK**.
6. Go to the **Camera system** page and set the capture rate. The maximum capture rate depends a lot on the computer and the AIM model, but 100 Hz usually works with a dual-core computer.
7. Go to the **GUI** page and set the **Real time mode** screen update to 15 Hz.
8. Test the real-time with the motion that you want to capture. Look especially at how the 6DOF tracking is applied and if the RT frequency shown in the **Status** bar is close to the capture rate. If it differs to much lower the capture rate.
    a. If the real-time is slow close all windows, including the **Data info** window and the **Trajectory info** windows, except for a **3D view** window.
    b. When the real-time is working fine you can even turn off the GUI with the **Disable GUI update** button . This will reduce the processing capacity needed for QTM.
    c. 6DOF tracking can be restart with the **Apply AIM model** button .
9. When you are satisfied with the real-time in QTM, you can connect with the other program. Check that the communication cable is connected and then start the software that will receive the data on the remote computer.

For the 6DOF analog output you need a PCI-DAC6703 D/A board in your measurement computer. If that is installed follow these steps:

1. Switch on the camera system and start QTM.
2. Open a new file by clicking the **New file** icon .
3. Open the **Workspace options** dialog and check the settings on the **6DOF analog export** page.
4. Select the **Enable analog 6DOF output** option and then add the output that you want with **Add value**.
5. Make sure that **Calculate 6DOF** is activated for the **Real time actions** on the **Processing** page,, otherwise the 6DOF bodies will not be tracked by QTM.
6. If you use Long range active markers, make sure that the setting **Long range active markers** is activated on the **Advanced** page (for ProReflex the **Camera settings** page). Click **OK**.

7. The analog output will start immediately if you are in preview mode and will be sent during a 6DOF real-time output.
8. The analog output will be used as long as the **Enable analog 6DOF output** option is selected.

Euler angles in QTM

Introduction

Euler angles (rotation angles) are the way that QTM shows the rotation of a 6DOF body. It is also how you enter any rotation that should be applied to a global or a local coordinate system. It is therefore important to understand how Euler angles work to be able to use 6DOF data correctly.

Euler angles are a method to define the rotation of a body. The problem is that they are not unambiguous and therefore QTM internally uses a rotation matrix to define the rotations. This means that changing the Euler angles definition only changes the interpretation of the matrix. The rotation angles are transformed into the rotation matrix with the calculations described in chapter "Calculation of rotation angles from the rotation matrix" on page 54. The same calculations are then used to acquire the measured rotation angles, since they can be more directly interpreted and visualized by the user.

Important: When you change the Euler angles definition that change will be effective immediately everywhere in QTM. This means for example that if you open a file after you have changed the definitions it will be displayed using the new definitions and not those used when the file was saved. It also means that the angles on the **Transformation** page will change to reflect the rotation of the global coordinate system with the new definition.

In QTM you can define the Euler angles as any possible rotation of a right-hand coordinate system, see chapter "QTM settings - Euler angles" on page 11. By default QTM uses the **Qualisys standard** definition, which is described in the chapter "Rotation angles in QTM" on page 7.

Rotation angles in QTM

The rotation angles of a rigid body can be defined in any number of ways, see chapter "QTM settings - Euler angles" on page 11. The **Qualisys standard** of the rotation angles are defined as:

- Rotation around the X-axis is called roll.
- Rotation around the Y-axis is called pitch.
- Rotation around the Z-axis is called yaw.
- Positive rotation is defined as clockwise rotation when looking in the direction of the axis
- The angles are applied to the local coordinate system in the order: roll, pitch and finally yaw. Therefore to find the rotation of a rigid body with given roll, pitch and yaw angles from QTM, apply the rotations in the same order: first roll, then pitch and finally yaw.
- QTM uses the following ranges for the angles, see also the figures below:

  $-180° \leq \text{Roll} \leq 180°$

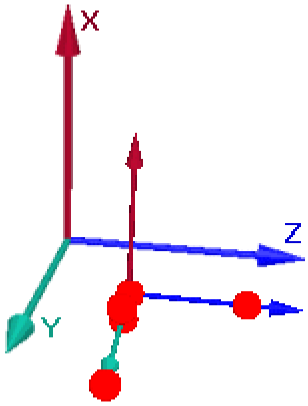
  $-90° \leq \text{Pitch} \leq 90°$

  $-180° \leq \text{Yaw} \leq 180°$

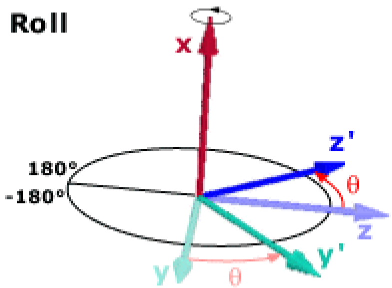
  In these ranges, roll, pitch and yaw are unambiguous and can describe any orientations of a rigid body.

Important: When the pitch (ϕ) is close to ±90°, small changes in the orientation of the measured rigid body can result in large differences in the rotations because of the singularity at ϕ=±90°, see chapter “Calculation of 6DOF data” on page 54.

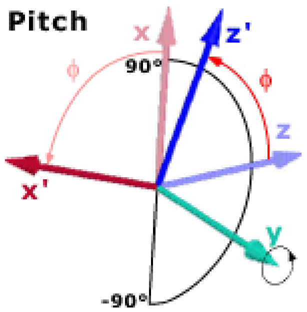
Below follows an example to show the definitions of the rotation angles. It starts with a 6DOF body, which is in alignment with the global coordinate system.



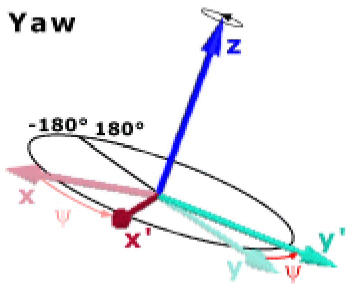
First the local coordinate system is rotated around the X-axis (roll) with an angle θ to the new positions y’ and z’ of the Y- and Z-axis.



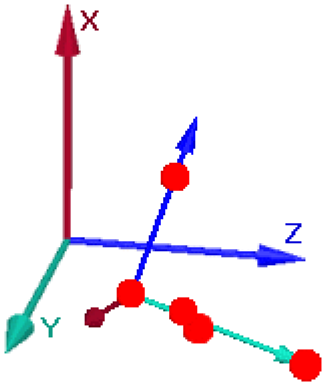
After the roll the local coordinate system rotates around the Y-axis (pitch) with the Y-axis in its new position. The X- and Z-axis is rotated with an angle ϕ to the new positions x’ and z’.



Finally the local coordinate system is rotated around the Z-axis (yaw) with the Z-axis in its final position. The X- and Y-axis is rotated with an angle ψ to the new positions x’ and y’.

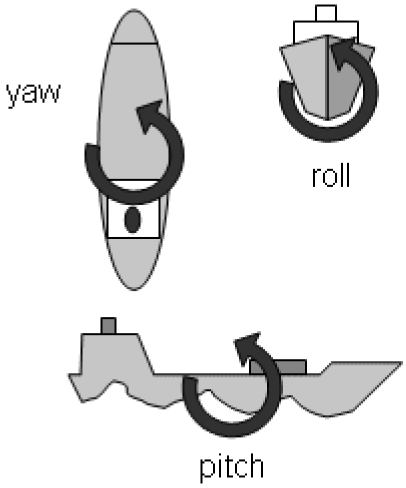


After the rotations the rigid body has a new orientation in reference to the global coordinate system, see figure below.



Another description of rotations is to use the rotation matrix, which does not have a singularity. QTM uses the rotation matrix internally to describe the rotation of rigid bodies, and when exporting 6DOF to TSV files the rotation matrix is included for all bodies in all frames, together with roll, pitch and yaw angles. For a description of the calculation of the angles from the rotation matrix see chapter “Calculation of 6DOF data” on page 54.

Rotation angles in marine application



Traditionally, when describing the motions of a craft, the terms surge, sway and heave are used for the translations of the boat in the local coordinate system, and the terms roll, pitch and yaw for the rotations of the local coordinate system. This description is based on a local coordinate system fixed in the craft, with, typically, the following conventions:

- The origin is located in the centre of gravity of the craft.
- The Roll axis points in the bow direction of the craft and horizontally at ideal trim of the craft.
- The Pitch axis points in the Starboard direction of the craft and horizontally at ideal trim of the craft.
- The Yaw axis points up in the opposite direction of gravity at ideal trim of the craft.
- The system is orthogonal, i.e. all axes are at 90 degrees angle to each other.

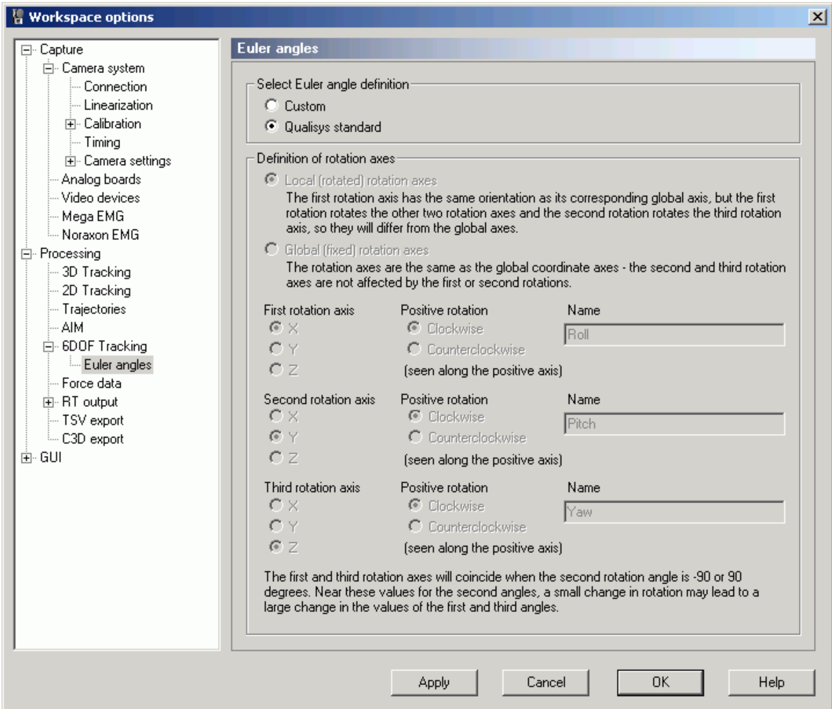
The Roll, Pitch and Yaw axis can be defined as any of the alternatives on the **Euler angles** page in the **Workspace options** dialog, see chapter “QTM settings - Euler angles” on page 11.

Note: The surge, sway and heave parameters are not shown in QTM. However they can be calculated from the velocity and rotation of the boat.

QTM settings - Euler angles

On the **Euler angles** page you can change the definition of all transformations to and from and rotation matrix in QTM. This means that it affects among other things the transformation of the global coordinate system and the definition and measurement of 6DOF bodies.

Select Euler angle definition

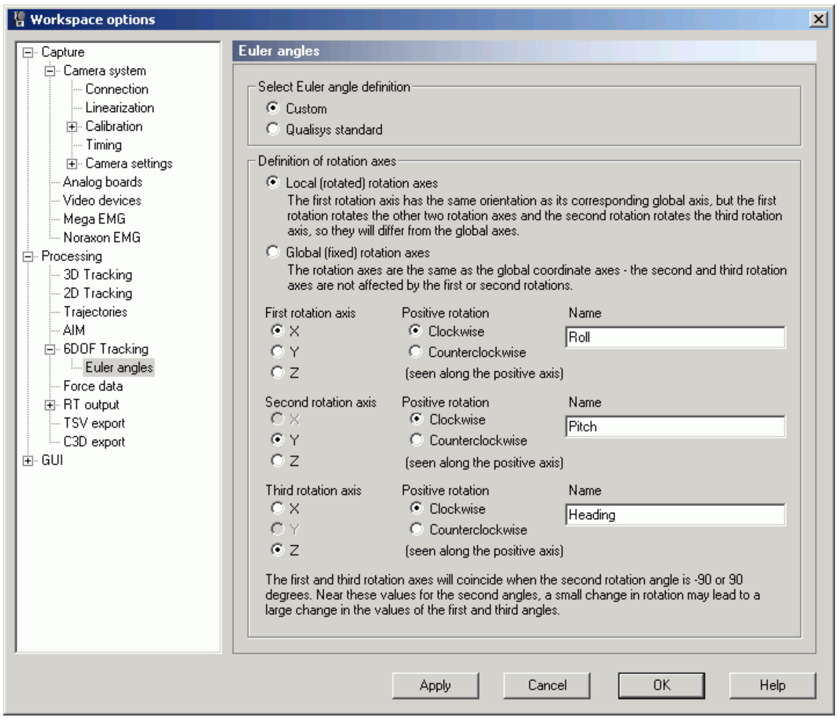


By default QTM uses the **Qualisys standard**, which is described in the chapter “Rotation angles in QTM” on page 7. The definition can also be seen when **Qualisys standard** is selected as the grayed settings under the **Definition of rotation axes** heading, see screen dump above.

Use the **Custom** setting under the **Select Euler angle definition** heading if you want another definition of the rotation angles. Change the definition under the **Definition of rotation axes** heading.

Important: If you define custom rotation angels the examples of the rotation angles in the manual does not apply. Therefore you need to have knowledge of how Euler angles work when changing this setting. However you can always go back to **Qualisys standard** angles in a file since the rotation is saved as a rotation matrix.

Definition of rotation axes



The following settings are used to define the Euler angles under the **Definition of rotation axes** heading:

Local (rotated) rotation axes
The rotations will be made round the axes of the rotated coordinate system. This means that the first rotation axis will be the same as its corresponding global axis. However this will rotate the local axes and the following rotations will be made round the rotated axes which differ from the global axes. Of course the second rotation also rotates the local coordinate system and affects the rotation axis of the third rotation.

Global (fixed) rotation axes
The rotations will be made round the axes of the global coordinate system. This means that the first or second rotations will not affect the axes of the following rotations.

First rotation axis
Define the first rotation axis. This can be any of the three axes.

Second rotation axis
Define the second rotation axis. This cannot be the same as the **First rotation** axis.

Third rotation axis
Define the third rotation axis. This cannot be the same as the **Second rotation** axis. However it can be the same as the **First rotation** axis.

Positive rotation
For each axis you can define the direction of **Positive rotation**. It can be either **Clockwise** or **Counterclockwise** when seen along the positive direction of the axis.

Name
For each axis you can set a new name. This name will then be used everywhere in QTM.

Important: To get an unambiguous definition of the rotation there have to be two additional definitions used on the rotation angles. These two definitions are set by QTM, but the second also depends on how you define the Euler angles.

1. The rotation angles are always applied with the first rotation first and so on.
2. The rotation angles have limitations to the ranges of the angles. The first and third angle is always defined between -180° and 180°. But the middle angle depends on the Euler angle definition:

   First and third rotation round different axes

   The second rotation is always defined between -90° to 90°.
   Note: There are singularities at -90° and 90°.

   First and third rotation round the same axis

   The second rotation is defined between 0° to 180° or 0° to -180°, depending on the order of the axes and the positive rotation. Check the text at bottom of the **Euler angle** page to find out which it is for the current definition.
   Note: There are singularities at 0° and 180° respectively at 0° to -180°.

Fixed camera calibration method

Introduction

The Fixed camera calibration method uses fixed locations of the cameras and the reference markers to calibrate a camera system. It can be used for systems covering large areas, where other methods are impractical. With this method a much larger measurement volume can be used, since one camera must not see the whole measurement volume. It is also easy to repeat the calibration. The disadvantage is however that the camera system must be fixed to its location.

Requirements for a Fixed camera calibration

To perform a Fixed camera calibration the camera system must be installed in a special way. The installation is described in detail in the document **Fixed camera system - Installation procedure**. Depending on the installation the cameras will see different number of reference markers, but the following conditions must always be fulfilled by the camera system:

- Each camera must be able to see at least three reference markers.
- The reference markers must be distributed as mush as possible in the horizontal FOV, which is fulfilled by the following two rules:
  - There must be at least one marker in the overlap of two cameras FOV.
  - There must be at least one marker in the area where the FOV does not overlap.
- The markers should be placed close to the middle of the cameras' vertical FOV. In most installations the reference markers will be placed above the middle, since the cameras must be placed horizontal to the water.

The locations of the markers are best decided by looking at a **2D view** window in the preview mode.

Another requirement for the calibration is that the positions of the cameras and the reference markers have been measured by a survey measurement. The survey measurement data is very important for the overall accuracy of the camera system. If the data is incorrect the error will propagate throughout the measurement data. Therefore the survey measurement must be performed with high accuracy. How to perform the survey measurement is described in detail in the manual **Fixed camera system - Installation procedure**.

Important: When the survey measurement has been performed the reference markers must be stationary. If the reference marker has been moved or rotated even the slightest you need to perform a new survey measurement to achieve the highest accuracy. The cameras can on the other hand be rotated slightly to adjust the overlap of the cameras. However after the rotation you need to perform a new calibration.

Performing a Fixed camera calibration

To perform a Fixed camera calibration you need to enter the survey measurement data on the **Calibration** page in the **Workspace options** dialog, see chapter "Fixed camera calibration" on page 14. In the **Workspace options** dialog you can also transform the global coordinate system and change the Euler angles definitions, see chapter "Transformation" on page 21 respectively "QTM settings - Euler angles" on page 11.

Before starting a calibration switch on the camera system and the reference markers. Open the **Workspace options** dialog and select **Long range active**

markers/Reference marker on the **Advanced** page (for ProReflex the **Camera settings** page). Open a new file in QTM and change to a **2D view** window. In the **2D view** window it is easy to see the markers seen by each camera.

Before you start the Fixed camera calibration you should check the following four points:

1. Do all of the cameras have the correct linearization parameters on the **Linearization** page in the **Workspace options** dialog?

   If the cameras do not have linearization parameters, load the correct linearization parameters.

2. Does the old calibration pass the validation process? See chapter “Validation” on page 17.

   If it passes the validation, you do not need to calibrate the system.

3. Do all of the cameras see the reference markers which they should see according to the installation?

   If they cannot see all of the markers, you should check the following:

   a. Is there something blocking the sight of the cameras?

      Remove the obstacles.

   b. Have any of the cameras been rotated?

      Rotate the cameras so that they can see the correct reference markers.

4. Are there any reflexes above the reference markers?

   Eliminate the reflexes, since it is the top markers in the ***2D view*** *window that is used as reference markers.*

5. Have any of the reference markers been moved or been rotated?

   If it has moved or rotated you have to perform a new survey measurement to achieve the highest accuracy.

When the correct data have been entered on the **Calibration** page and you have checked the points above, you can start the calibration with either the **Calibration** icon or with **Calibration** on the **Capture** menu. This will display the **Calibration** dialog, where you can check that you have loaded **Linearization parameters** for the cameras. However for Fixed camera calibration the **Calibration quality** settings in this dialog have no effect. The calibration will always capture 100 frames during 2 seconds. Click **OK** to start the calibration.

Note: For large basins with long focal length Oqus cameras, you also need to perform a single marker calibration, see chapter “Single marker calibration” on page 15.

After the calibration the **Calibration results** dialog is displayed, see chapter “Calibration results” on page 16.

Single marker calibration

The single marker calibration is performed in large basins to refine the calibration result.

1. Perform the initial reference marker calibration using the standard procedure. Make sure that there at this stage is no **Transformation** applied on the **Calibration** page in the Workspace options dialog.

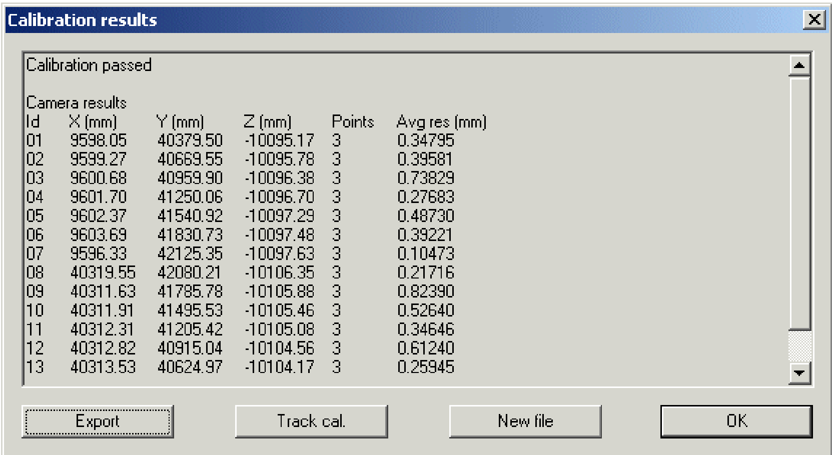
2. Make a sufficiently long measurement of a single marker. The measurement must be long enough so that movement cover the measurement volume as well as possible. Try to avoid partial occlusion of the marker.

3. Track this long measurement with the reference marker calibration and identify the marker in the whole measurement. Delete any extra markers from the **Unidentified trajectories** window.

4. Save and close the long measurement file and change the file extension to .qca.
5. Reopen the file and perform a refine calibration using it.
    a. Click on the Calibration icon and choose the **Calibration** page.
    b. Select **Fixed camera calibration** and check the **Refine** box.
    Note: If you want to apply a transformation of the coordinate system it must be applied at this point.
    c. Click OK to start the refine calibration process, which can take some minutes to perform.
6. When the process has finished, save and close the file.
7. Open the **Workspace options** dialog and go to the **Current Calibration** page. Click **Load other…** and choose the file that you just saved.

Calibration results

The **Calibration results** dialog is shown after a calibration is completed. It shows if the calibration passed and the calibration quality results.


Calibration results

Calibration passed

Camera results

Id	X (mm)	Y (mm)	Z (mm)	Points	Avg res (mm)
01	9598.05	40379.50	-10095.17	3	0.34795
02	9599.27	40669.55	-10095.78	3	0.39581
03	9600.68	40959.90	-10096.38	3	0.73829
04	9601.70	41250.06	-10096.70	3	0.27683
05	9602.37	41540.92	-10097.29	3	0.48730
06	9603.69	41830.73	-10097.48	3	0.39221
07	9596.33	42125.35	-10097.63	3	0.10473
08	40319.55	42080.21	-10106.35	3	0.21716
09	40311.63	41785.78	-10105.88	3	0.82390
10	40311.91	41495.53	-10105.46	3	0.52640
11	40312.31	41205.42	-10105.08	3	0.34646
12	40312.82	40915.04	-10104.56	3	0.61240
13	40313.53	40624.97	-10104.17	3	0.25945

Export Track cal. New file OK

The quality results under the **Camera results** heading are camera specific. For each camera ID there are the following five results:

X (mm), Y (mm) and Z (mm)
The distance (in mm) between the origin of the coordinate system of the motion capture to the optical center of the camera. The distances are respectively in the X, Y and Z direction.
Note: The optical center is not the same as the rotation center and therefore the coordinates will differ compared to the survey data.

Points
Number of 2D points used in the calculation of the distance above. In Fixed camera calibration this number is equal to the number of reference marker seen by the camera. The 2D point of the reference marker is the average of the position in the 100 captured frames.

Avg. res. (mm)
The average residual (in mm) for the points above, i.e. the distance between the 2D marker ray and the reference marker position of the survey measurement. The residual of the cameras should be similar in size. However the size depends among other things on the accuracy of the survey measurement and the measurement volume.

Important: If an average residual differs a lot from the rest of the residuals, it can either be that the survey data has not been entered correctly. If that is not the case you probably need to perform a new survey measurement.

Note: If the camera result says **Unused camera**, then the camera has been deactivated on the **Linearization** page in the **Workspace options** dialog. That camera cannot be used in measurements, unless the calibration is reprocessed, see chapter “Reprocess calibration” in the **QTM - User manual**.

There are four buttons at the bottom of the dialog, clicking them have the following effects.

OK
Close the dialog and the calibration file.

New file
Close the dialog and the calibration file and open a new capture file in preview mode.

Track cal.
Track the calibration file and close the dialog.

Export
Export the calibration results to a txt file. The default folder is the **Calibrations** folder in the **Qualisys Track Manager** folder.

Check tracking residuals

At least once a day it is a good idea to check the tracking residuals after a measurement. This can be done with the following procedure.

1. Capture and track a file where markers are moved in as much of the volume as possible so that all cameras can see markers during the measurement.
2. Click on File information in the View menu.
3. Check the residuals. If the residual is larger than 3-5 mm (depending on the size of the basin) for any camera, it is recommended to perform either a validation measurement to investigate further or the single marker calibration procedure described below.
   Note that the average values are calculated using also the outliers that are due to partially occluded markers.
4. A second condition for recalibration is if the residuals have grown by a factor 2 since the first few measurements after the last single marker calibration.

Validation

The validation process will check that the calibration of the Fixed camera system is still valid. This feature should only be used if something is blocking some of the reference markers. If all of the reference markers are visible it is best to calibrate the system, because it takes the same time as a validation.

The validation will check that the 2D positions of the reference markers in each camera are the same as in the calibration. This is done by capturing the 2D position of the visible markers. The 2D position is projected to a 2D marker ray, using the linearization and the calibration data of the camera. The rays are then matched for each camera with its reference marker positions. The residual of the positions (i.e. the distance to position in the survey data) are then weighed together.

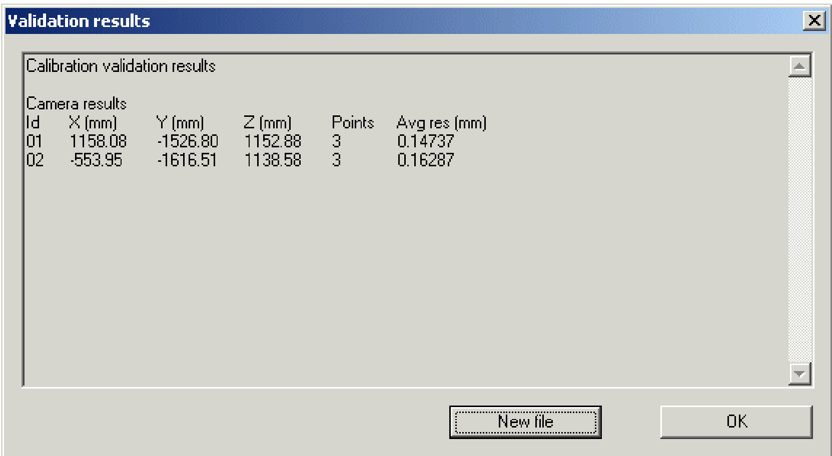
Performing a validation

Performing a validation is similar to the Fixed camera calibration, this means that the reference markers must be switched on. In the validation process some of the reference markers can be blocked. However you should check that none of the visible reference markers are partially obscured, i.e. that the whole circle with IR diodes is visible. If you are not sure use the **Video/Viewfinder** function in the **2D view** window to see the camera view.

Note: If a camera does not see any reference marker, the validation can still be performed. But that camera position will not be validated.

Start the validation process by clicking the **Calibration** icon and activate the **Validate calibration for all visible reference markers (don't calibrate)** option. Then click **OK** to start the validation. When it is finished the results are reported in the **Validation results** dialog. If the validation does not pass the camera system must be calibrated to get correct measurements.

Validation results



The result of the validation is similar to the calibration result. The cameras' positions are the same as in the calibration. It is only the **Point** and **Avg. res.** columns that are calculated by the validation. To see whether the validation has passed you must check the values in these two columns manually. Follow these instructions:

1. Check the average residual (in mm) of the measured points in the **Avg. res.** column for each camera. The average residual depends on the system and it must therefore be compared with the average residual of the current calibration. You must then evaluate how large residual you can accept in the measurement system. If the average residual is OK, you must also check that the number of points in the **Points** column is OK.
   Note: If there is no points that can be matched with a reference marker the average residual and the points is reported as "--". This means that the camera has not passed the validation.

2. The **Point** column contains the number of points that the validation identified as reference markers. You should check that the number of points is the same as the number of visible reference markers. If the number of points is larger or smaller the camera has not passed the validation.

Click **OK** to close the **Validation results** dialog and the validation file or click **New file** to close the dialog and the validation file and open a new capture file in preview mode.

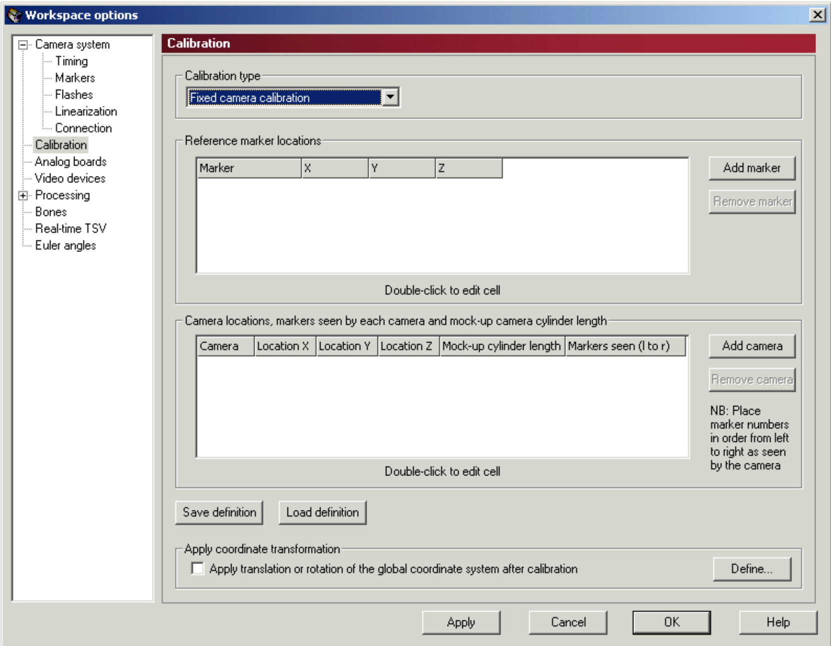
QTM settings - Fixed camera calibration

The following two pages in the **Workspace options** dialog have settings that directly affect the Fixed camera calibration: **Fixed camera calibration** and **Transformation**.

If you need to change something on the **Fixed camera calibration** page after the calibration, you have to reprocess the calibration file, see chapter “Reprocess calibration” in the **QTM User manual**. However changes on the **Transformation** page can be applied to the current calibration without reprocessing.

Fixed camera calibration

On the **Calibration** page for Fixed camera calibration you should enter the data from the survey measurement. If you cannot see this **Calibration** page change the **Calibration type** option to **Fixed camera calibration**. For more detailed information on fixed camera systems contact Qualisys AB about the **QTM - Marine manual**. They include detailed descriptions of the camera installation, survey measurement, fixed camera calibration, validation and the use of 6DOF bodies in marine applications.



Use the options **Save definition** and **Load definition** to save respectively load the data for the Fixed camera calibration. The default folder is the **Labels** folder in the **Qualisys Track Manager** folder.

Note: The first time you enter the survey data it must be entered manually.

Reference marker locations

Under the **Reference marker locations** heading you should enter the survey data of the reference marker positions. Use the **Add marker** and **Remove marker** options to add or delete reference marker locations. Add the markers in the physical order from left to right. This will make it much easier to enter the markers seen by camera. Double-click the **X**, **Y** and **Z** locations of each marker to edit it.

Note: All of the markers’ locations must be entered to make a successful Fixed camera calibration.

Camera locations and markers seen by each camera in order from left to right

Under the **Camera locations and markers seen by each camera in order from left to right** heading you should enter the survey data of the camera positions. Use the **Add camera** to add a new camera last in the list. The cameras must be entered in the same order as the camera system, i.e. the master MCU first and then on through the chain. It is not possible to rearrange the cameras after they have been added, just to remove a camera with **Remove camera**. Double-click the column to enter the following data:

Location X, **Location Y** and **Location Z**
The survey measurement data of the camera.

Mock-up cylinder length
The length of the cylinder that was used on the camera dummy when making the survey measurement.
Note: This length is the horizontal distance between the plate of the camera dummy and the front side of the cylinder. For the ProReflex MCU it is always 18 mm.

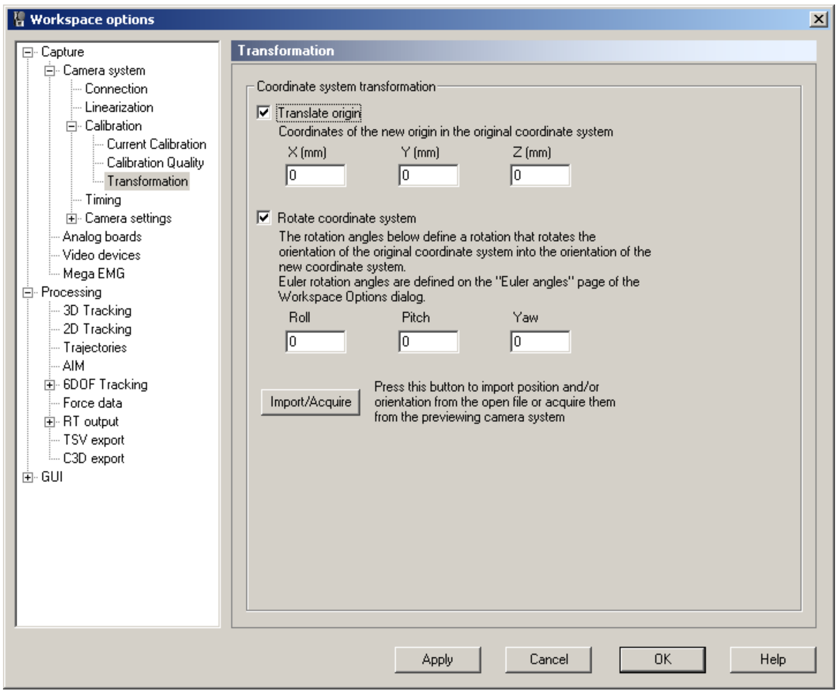
Markers seen (l to r)
The markers seen by the camera. Enter them in order from left to right as seen by the camera and separate them with commas (the numbers refer to the first column in the **Reference marker locations** list).
Note: QTM uses the top markers in the **2D view** window as reference markers.

Note: All of the cameras must be entered to make a successful Fixed camera calibration.

Apply coordinate transformation

With **Apply coordinate transformation** you can translate and rotate the global coordinate system to any desired position. Select the checkbox and then click **Define** to set the coordinate transformations on the **Transformation** page, see chapter “Transformation” on page 21.

Transformation



The **Transformation** page contains the settings for defining a new global coordinate system. The two changes that can be made to the coordinate system is **Translate origin** and **Rotate coordinate system**. By changing these parameters you can in fact move and turn the coordinate system to any position and orientation. The change is always related to the original position and orientation of the calibration coordinate system. In the case of the Fixed camera calibration this means the origin of the survey measurement.

Important: A new calibration file is saved if you apply a new transformation on the current calibration. The saved calibration only includes calibration data and no 2D data. Therefore you must always go back to the first calibration if you need to recalibrate the calibration.

To activate the change you must select the checkbox of respective setting.

Translate origin (X(mm), Y(mm), Z(mm))
Enter the new position of the origin of the coordinate system (in mm). The direction of the parameters (X, Y and Z) is always related to the original coordinate system of the calibration.

Rotate coordinate system (Roll, Pitch, Yaw)
Enter the new rotation of the coordinate system (in degrees). The rotations always refer to the original coordinate system and they are always applied from left to right. To which axes the rotations are applied depends on the Euler angles definitions on the **Euler angles** page, see chapter “QTM settings - Euler angles” on page 11.

Use **Import/Acquire** to define the rotation from a measured line, see chapter “Rotate axis to line” on page 22.

Note: If the Euler angles are changed after a transformation, the transformed coordinate system will have the same orientation as before but the rotation parameters on the **Transformation** page will change to reflect the new definition.

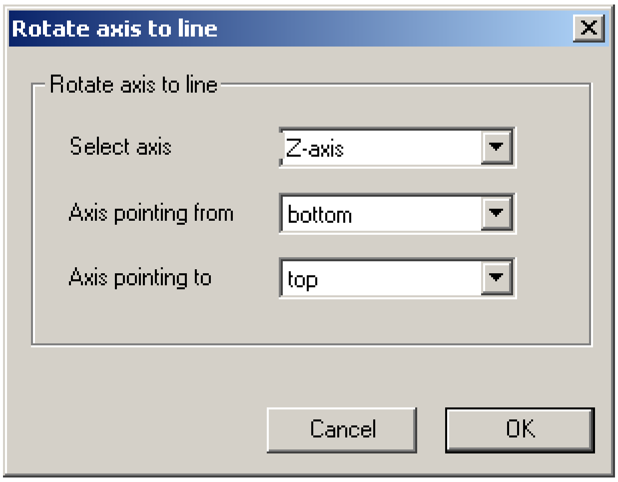
Note: The rotation angles are used to calculate a rotation matrix, which is then used to transform the coordinate system. When the resulting rotation matrix is converted back to rotation angles again it is not necessarily the same angles. This means that the angles that you have entered can change after you have applied it to the coordinate system. E.g. if you just enter a pitch of 100 degrees (using Qualisys standard) this will result in the angles roll = 180°, pitch =80°, yaw =180°.

Important: If you use a custom bounding box on the **3D Tracking** or **6DOF tracking** page or have a force plate, these will be moved with the transformation and the positions must therefore be corrected manually.

Rotate axis to line

With the **Rotate axis to line** function a line can be used to define the direction of one of the axes. This can for example be useful to define a vertical or horizontal axis if the floor is not level enough. Follow this procedure to use the function:

1. Make a measurement with two static markers that defines the line that you want. It is important that the markers are as static as possible, because an average is used to define the line. It is also important that the file uses the current calibration.
2. Keep the file open and go to the **Transform** page in the **Workspace options** dialog. If the **Transform** page is not active go to the **Calibration** page and check the **Apply coordinate transformation** box.
3. Activate the **Rotate coordinate system** option on the **Transformation** page.
4. Click on **Import/Acquire** to open the **Rotate axis to line** dialog.



5. Select the axis that you want to define the rotation for.
6. Then select the trajectory that the **Axis is pointing from** and the trajectory that the **Axis pointing to**.
   Note: The position of the coordinate system will not change only the rotation.
   Note: The rotation of the other axes can change after the rotation.
7. Click **OK** to calculate the rotation and show the result on the **Transformation** page.
8. A new calibration file will be saved in the **Calibration** folder after you click OK in the **Workspace options** dialog.

6DOF bodies

Introduction

A single point in the mathematical sense can be fully described by its three coordinates (X, Y, Z) in a Cartesian coordinate system (3D). This can also be described as having three degrees of freedom. A physical body, such as a ship or an aircraft, requires three additional degrees of freedom to fully characterize its location, i.e. three rotation angles. The characterization of an object by three positional coordinates and three rotational angles is therefore called “six degrees of freedom” (6DOF).

To measure the 6DOF data of a physical body QTM uses 6DOF bodies (rigid bodies). A 6DOF body consists of markers placed on an object so that their mutual distances are constant. The physical design of a 6DOF body is described in the next chapter.

The 6DOF bodies must then be defined on the **6DOF bodies** page in the **Workspace options** dialog, see “Definition of 6DOF bodies” on page 24. Given the information on the **6DOF bodies** page the 6DOF tracking function can calculate the rotation and position of objects in the measurement.

How to design a 6DOF body

A rigid body is a configuration of points with fixed separations. For the 6DOF tracking function to work the rigid body must be defined by at least four points, which cannot all be in the same plane. There are at least five points that must be considered when designing a 6DOF body.

Active vs. Passive markers

In marine applications it is often best to use Long range active markers in the 6DOF body. Since the measurement volume often is too large for passive markers. However, passive markers can be used at shorter distances, check the marker size according to point below.

Marker size (passive markers)

The marker size of passive markers on the 6DOF body depends on the measurement volume. An estimation that can be used for the marker size in relation to the measurement volume is that the 2D data **xSize** and **ySize** in the **Data info** window should be at least 7. However, it can be smaller but then the residual increases.

6DOF body size

Another factor to consider is the size of the 6DOF body in relation to the marker size. Very large markers in small bodies increase the risk of merging markers (two markers appearing as one in the **2D view** window). Merging should be avoided as mush as possible. Try to design the 6DOF body so that it can be viewed by the camera system in most angles that will be used in the measurement without merging.

Marker distance

Try to keep the marker distance as large as possible, provided that they fit within the measurement volume (including the model’s movements). Ideally the distances between all pairs of points that can be chosen from every rigid body definition in a motion capture should be sufficiently distinct, i.e. differ by at least twice the **Bone length tolerance**. This will increase the accuracy of the angle calculations. It also makes it easier to avoid merging markers.

Marker configuration

There are two requirements that must be fulfilled by the 6DOF body for the 6DOF tracking to work.

1. The 6DOF body must consist of at least 3 markers.

Depending on the accuracy of the system, the point configurations of the 6DOF body definition may have to be chosen with some care. There are two situations that should be avoided.

1. Symmetric configurations of the points in the 6DOF body. Because the 6DOF tracking function can only identify rigid bodies if the distances from one point to every other point are unique. This is especially important when the 6DOF body only has 3 markers.
2. Similar configurations in different 6DOF bodies. Because in a measurement each definition should correspond to just one measured 6DOF body.

It is also important to consider the placement of the 6DOF body on the model.

1. Put the markers sufficiently high so that they are not obscured by the model when it rolls away from the camera.
2. Preferably, have the markers of the rigid body on a plate or similar, that fits securely to the model in a well-defined position. The position of the Centre of Gravity (COG) in relation to one of the markers should be known if you want to place the local coordinate system in COG.

The following two points are only tips to make it easier to define a horizontal xy plane for the local coordinate system.

1. Keep at least 3 of the markers on the same vertical level. In this way you can use the **Define x y plane with 3 points in body** option in the **Rotate body** dialog to get a defined xy- plane which is horizontal, see chapter “Rotate body” on page 29.
2. The line between the two markers farthest apart should be parallel with the longitudinal (roll) axis of the model. Together with the previous point this will mean that the initial position of the local coordinate system is horizontal and that the local x-axis is parallel with the global x-axis. The y-axis is always placed in the direction of the third point used in **Define x y plane with 3 points in body**.

Definition of 6DOF bodies

When the 6DOF body has been designed according to the previous chapter you must define the points of the body in QTM. The following four ways can be used to define 6DOF body definitions in the list on the **6DOF tracking** page:

1. Load a saved file with 6DOF body definitions with the **Load bodies** option on the **6DOF bodies** page.
   Note: This will delete any other 6DOF definition in the list.
2. Import the points from a measurement of a stationary object. Use the **Define 6DOF body** function on the **Trajectory info window** menu or **Import markers** on the **6DOF bodies** page.
3. Define the points of the body directly on the **6DOF bodies** page, see chapter “QTM settings - 6DOF Tracking” on page 26.
4. Acquire the points through a capture in preview mode, see chapter “Acquire body” on page 30. This method is described in chapter “Outline of how to define 6DOF bodies” on page 3.

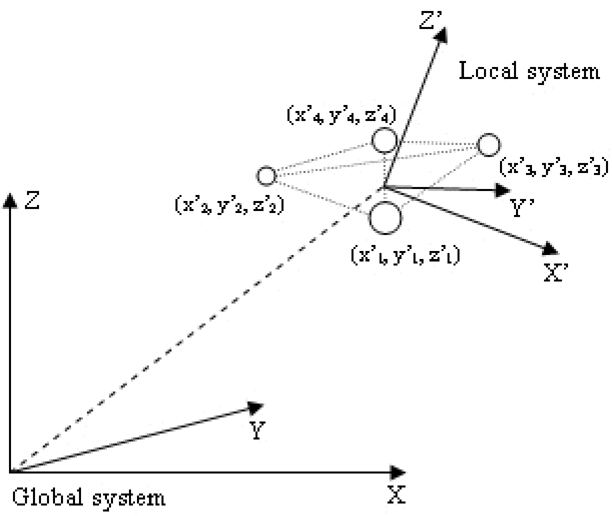
Note: Make sure that at least four points are included in the 6DOF body definition.

When you have defined a 6DOF body in QTM it is a good idea to save the definition with **Save bodies** on the **6DOF tracking** page. This way you can always retrieve the bodies if you need to restore the settings after processing the file.

The same markers can be used for several bodies. The benefit of this feature is that each body can have different local coordinate system definitions, which means different rotation and translation. When using this feature the bodies must be created with the following two prerequisites.

1. The bodies must use exactly the same markers in its respective definition.
2. The bodies must have the exact same name, which means that you must distinguish between them by the order and not the name.

Definition of local coordinate system



When you have defined the points of the 6DOF body in QTM you can change the definitions of the local coordinate system. If you have used **Acquire body** or **Import markers** the local coordinate system is by default placed where the global coordinate system were when the points were captured.

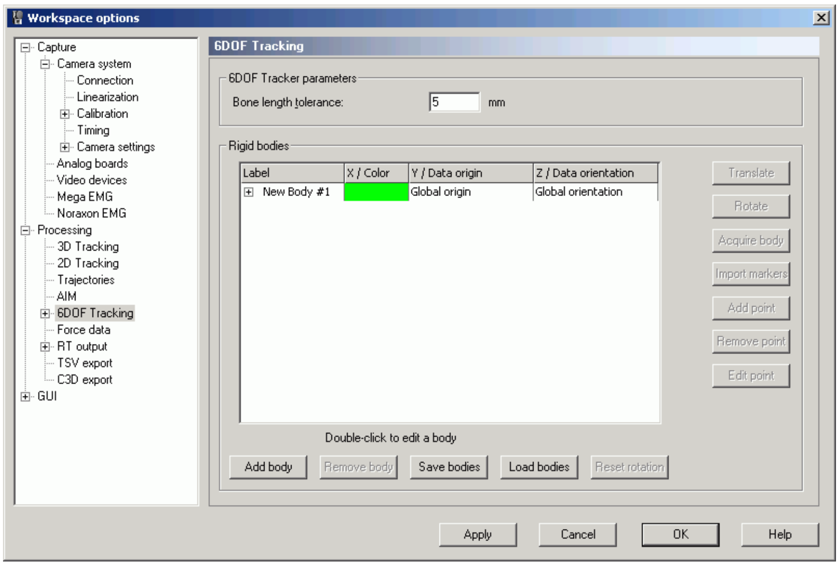
The local coordinate system is used in the calculation of rotation and position of the measured rigid body in reference to a reference coordinate system. Therefore it is important that the local coordinate system is defined according to the specifications of the measurement. The local coordinate system should have an orientation and a location in reference to the points in the 6DOF body definition, which is well-defined. Use a definition where the normal orientation of the body is the same as no rotation, i.e. aligned with the reference coordinate system.

When you have decided where the local coordinate system should be, use the **Translate** and **Rotate** functions on the **6DOF Tracking** page to specify the local coordinate system, see chapter “QTM settings - 6DOF Tracking” on page 26.

Then you should also decide which coordinate system that the 6DOF body data should refer to. This done in the **Coordinate system for rigid body data** dialog, which is opened by double-clicking on **Global origin** on the **6DOF bodies** page. See chapter “Coordinate system for rigid body data” on page 27 for the alternatives.

Note: If you want to change these setting in a capture file you must retrack the file with the new setting.

QTM settings - 6DOF Tracking



The **6DOF Tracking** page contains the **6DOF Tracker parameters** and the list of **Rigid bodies**. The 6DOF tracker uses this information to calculate the position and rotation from the 3D data, see chapter “6DOF tracking of rigid bodies”. For description of the **Rigid bodies** list see chapter “Rigid bodies” on page 26.

It is also possible to export the 6DOF tracking output to another computer and as an analog signal, see chapter “RT output” on page 37 respectively chapter “6DOF analog export” on page 39.

Under the **6DOF Tracker parameters** heading the tracking parameter for the 6DOF tracking is specified. The only parameter is the **Bone length tolerance.**

The **Bone length tolerance** (in mm) is the maximum separation between the lengths of the corresponding bones in a rigid body definition and a measured rigid body. E.g. if the **Bone length tolerance** is specified to 5.0 mm and the current bone in the rigid body definition is 100.0 mm, then the measured separation between two markers must be in the range of 95.0 - 105.0 mm for the QTM tracking to accept the possibility that the calculated markers may be the pair specified for the rigid body.

The default value of the **Bone length tolerance** is 5 mm. Increase the value of the parameter if the 6DOF tracking cannot find the body. Decrease the value of the parameter if a body is found but the orientation or something else is wrong.

For information on 6DOF tracking see chapter “6DOF tracking of rigid bodies”.

Rigid bodies

The **Rigid bodies** list contains the definition of the 6DOF bodies. The bodies are used by the 6DOF tracking to find the measured rigid bodies in a motion capture. The list consists of four columns: **Label**, **X / Color**, **Y / Data origin** and **Z / Data orientation**.

The **Label** column contains the name of the rigid body and the numbers of its points.

The color of the rigid body is displayed in the **X / Color** column on the same row as the name of the rigid body. Double-click on the color to open the **Color** dialog where any color can be selected. The color is used in the **3D view** window for the markers of the rigid body and for its name.

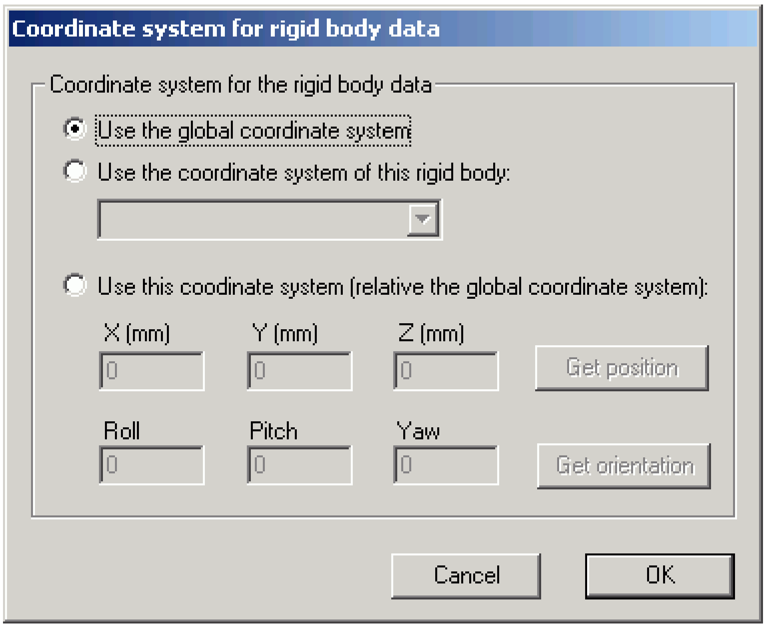
The coordinate system that the 6DOF body data refer to is displayed in the **Y / Data origin** and **Z / Data orientation** columns on the same row as the name of the rigid body. Double-click on either the origin or the orientation setting to open the **Coordinate system for rigid body data** dialog, see chapter “Coordinate system for rigid body data” on page 27.

The **X**, **Y** and **Z** columns contain the coordinates of the points in reference to the local origin.

Note: Double-click on the name or the coordinates of a point to edit them.

The options that are used to edit the list are described in the sections below.

Coordinate system for rigid body data



To describe the position and orientation of the 6DOF body its data must be referred to another coordinate system. By default the data is referred to the position and orientation of the global coordinate system. However, with the settings on the **Coordinate system for rigid body data** dialog you can refer the local coordinate system to the following alternatives of coordinate system origin and orientation.

Origin of the coordinate system for the rigid body data

Use the global coordinate system
The position is referred to the origin and orientation of the global coordinate system.

Use the coordinate system of this rigid body
The position is referred to the current position and orientation of another rigid body. This means that if the reference body moves the 6DOF body data will change even if that body is stationary. Select the body from the drop-down list.
Note: If the reference 6DOF body cannot be tracked the 6DOF body will disappear in the **Data info** window. However the 6DOF data is always saved and displayed in the **3D view** window so that if the file is retracked with another reference the 6DOF body will appear again.

Use this coordinate system (relative the global coordinate system)
The position is referred to a stationary point defined in the global coordinate system. Define the position in mm in the three directions (**X**, **Y** and **Z**) and orientation in degrees for **Roll**, **Pitch** and **Yaw**.
Note: Roll, pitch and yaw is the **Qualisys standard**, but if the Euler angles definition are changed on the **Euler angles** page the new settings will be used in this dialog.

With **Get position** and **Get orientation** the current position or orientation is acquired. Which means that the data will be zeroed for the current position of the rigid body.

Add body

Add body adds a new body to the **Rigid bodies** list. The new body will be empty and called 'New Body #1', 'New Body #2' and so on.

Remove body

Remove body removes the selected body from the **Rigid bodies** list.

Save bodies

Save bodies saves the bodies in the **Rigid bodies** list to an XML file. Name the file and click **Save**, the file is saved in the same folder as the Label list files. The file can be edited in a text editor, e.g. Notepad.

Note: Make sure that all of the bodies for the measurement are in the same file, since **Load bodies** overwrites the bodies in the list.

Load bodies

Load bodies loads bodies to the **Rigid bodies** list from an XML file or from a BOD file. The BOD file is an old format for rigid body definitions.

Note: **Load bodies** will overwrite any other bodies in the list.

Reset rotation

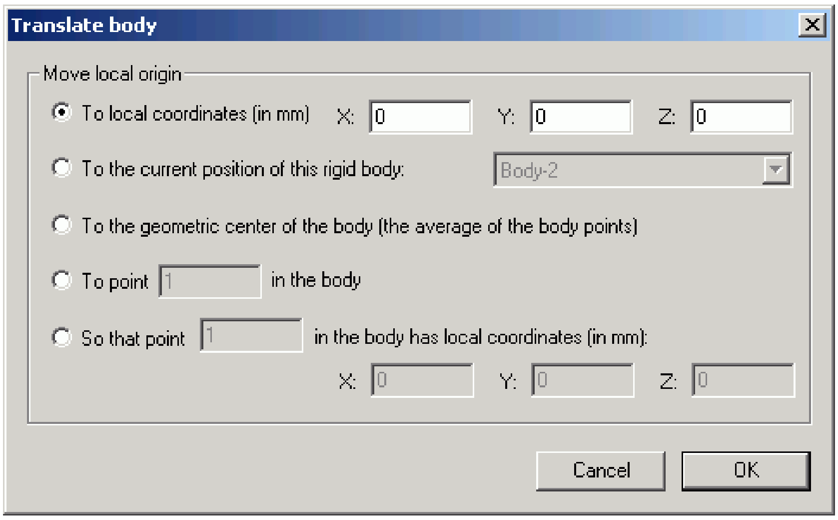
Reset rotation will reset the orientation of all the rigid bodies in the list. Reset means that the local coordinate systems will be aligned to the global coordinate system and all the angles will therefore be zeroed.

Note: This does not work if the reference has been changed in the **Coordinate system for rigid body data** dialog so that it is not the global coordinate system.

Translate

With **Translate** the local origin of the 6DOF body definition can be moved to any place in reference to the points of the body, which means that the rotation center of the body is changed. The local origin is also the origin of the coordinate system that represents the 6DOF body in the 3D view. Click **Translate** to open the **Translate body** dialog.

Translate body



The **Translate body** dialog contains the following five ways to translate the local origin:

To local coordinates (in mm)
Specify the translation of the local origin in the X, Y and Z direction of the local coordinate system. E.g. if the local origin is translated 1 mm in the X direction all of the points' X coordinates will be 1 mm less than before.

To the current position of this rigid body
Move the local origin to current position of the selected rigid body in the list. This will zero the position of the body in the list if its position is referred to the current rigid body.

To the geometric center of the body (the average of the body points)
Move the local origin to the geometric center of all the points in the rigid body definition. The geometric center can be seen as the center of mass of a body with the same weight at all of the points.

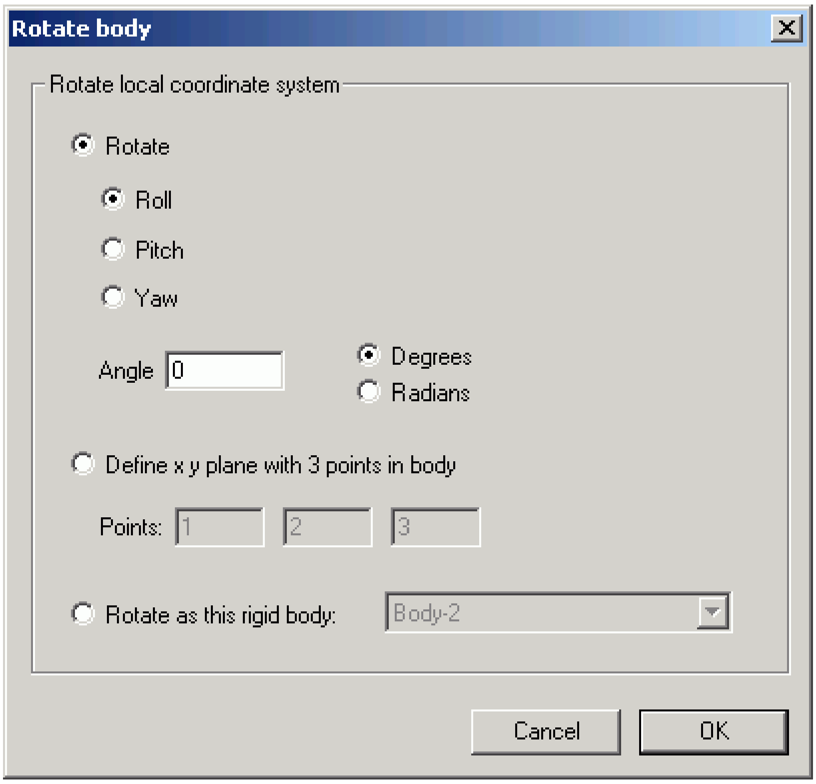
To point in the body
Move the local origin to one of the points in the rigid body definition. Enter the number of the point that is used as local origin.

So that point ... in the body has local coordinates (in mm)
Move the local origin so that one of the points in the rigid body definition has a desired position. Enter the number of the point and the position in X, Y and Z direction (local coordinate system).

Rotate

With **Rotate** the pitch, roll and yaw of the local coordinate system is changed. This will change the orientation of the local coordinate system in reference to the global coordinate system. I.e. it changes the rotation of the rigid body where its roll, pitch and yaw are zero in reference to the global coordinate system. Click **Rotate** to open the **Rotate body** dialog.

Rotate body



The **Rotate body** dialog contains the following two ways to rotate the local coordinate system:

Rotate
Rotate the local coordinate system clockwise around one of the axes, when looking in the positive direction.

Roll
The axis of rotation is the X-axis.

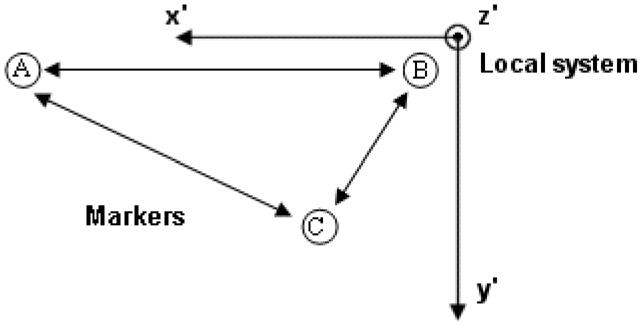
Pitch
The axis of rotation is the Y-axis.

Yaw
The axis of rotation is the Z-axis.

Angle
Choose the angle of rotation either in **Degrees** or in **Radians**.

Note: The description above is for the **Qualisys standard** for the Euler angles. If you have changed the definition on the **Euler angles** page the new settings will be used in this dialog.

Define x y plane with 3 points in body
Define the position of the xy plane with three points from the rigid body definition. The x axis will be parallel with the largest distance between the three markers. The y axis will then be directed in the same direction as the third point, see image below.

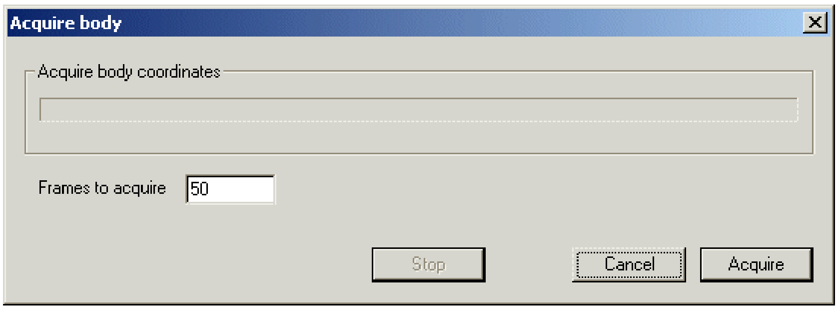


Points
Choose the number of the three points for the xy plane.

Rotate as this rigid body
Rotate the local coordinate system to current orientation of the selected rigid body in the list. This will zero the orientation of the body in the list if its orientation is referred to the current rigid body.

Acquire body

With **Acquire body** a rigid body definition can be acquired from preview mode. Place the rigid body with the markers in the measurement volume and open a new file with **New** on the **File** menu. Open the **6DOF tracking** page in the **Workspace options** dialog and click **Acquire body** to open the **Acquire body** dialog.



Specify the number of frames to collect with the **Frames to acquire** setting. Click **Acquire** to start the acquisition. The points of the rigid body definition are then calculated from the average of each marker's position in these frames. The **Stop** option can be used to cancel the collection before all frames have been captured.

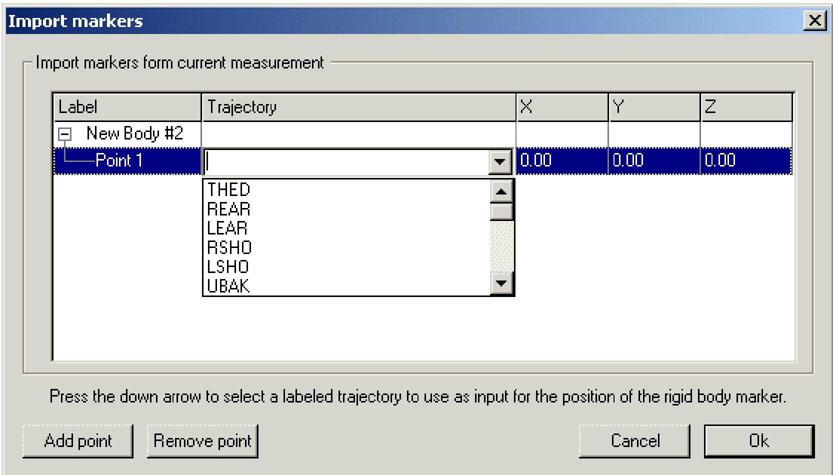
To see that the 6DOF tracking can find the body, change to 6DOF tracking on the **Processing** page and click **Apply**. The body should appear in the 3D view.

Note: The measurement must be done on a stationary rigid body with at least four markers and the body cannot be flat.

Note: It is a good idea to place the body so that the orientation of the desired local coordinate system is aligned with the global coordinate system. It is also a good idea to place the desired origin of the local coordinate system in the origin of the global coordinate system. Another way to easily define the local origin of the body is to use an extra marker placed at the desired location of the local origin. After acquiring the body coordinates, use the **Translate body** dialog to translate the local origin to the location of the extra marker. Then delete the extra marker from the body definition with **Remove point**.

Import markers

With **Import markers** the average position of a trajectory from the current measurement can be imported to a point in the rigid body definition. Since it is the average of all the frames in the measurement it is important that the trajectory is stationary. Click **Import markers** to open the **Import markers** dialog.



In the **Import markers** dialog labeled trajectories from the current measurement can be chosen for the points of the rigid body definition. The trajectory for each point is specified in the **Trajectory** column. Click on the arrow on the right in the column to open a list of trajectories to choose from.

If an extra point is needed, click on **Add point**. To remove a point, select it and click on **Remove point**.

Add point

Add point adds a point to the selected rigid body.

Remove point

Remove point removes the selected point.

Edit point

Edit point edits the selected point. Use Tab and Shift+Tab to go to the next respectively the previous coordinate.

Capture 6DOF data

Introduction

In a motion capture where 6DOF tracking is activated, QTM identifies rigid bodies from the 3D data of a measurement and calculates their translation and rotation with respects to the global coordinate system. It is done by comparing the distances between points in the 6DOF body definitions to all distances between the computed markers' locations. Then it computes the location and orientation of each measured rigid body in the coordinate system of the motion capture. Each 6DOF body definition can just have one solution in the measurement.

The 6DOF tracking is activated with **Calculate 6DOF** on the **Processing** page in the **Workspace options** dialog and is controlled by the 6DOF tracking parameters, see chapter "QTM settings - 6DOF Tracking" on page 26. An important characteristic of the 6DOF calculation is that at least three markers from the 6DOF body must be tracked in a frame for the 6DOF data to be calculated.

6DOF data can either be captured to a QTM-file or exported in real-time to another application. The first method is a regular capture in QTM, see chapter "Capturing" on page 33. In marine application it is often the latter which is used. You can then choose between two methods to export the data in real-time: 6DOF real-time output, see chapter "6DOF real-time output" on page 34 or 6DOF analog output, see chapter "6DOF analog output" on page 36. The two real-time methods can be used simultaneously.

Capturing

Before you can start a measurement you must open a new empty capture file with **New** on the **File** menu. The file will be opened in preview mode where you can check measurement volume and settings before starting the capture.

Note: With ProReflex when you track a 6DOF body during a capture the tracking can be poorer than it will be in the finished capture. This is because the preview frame rate is lower than the actual frame rate during capture. Therefore you should look at the finished measurement to evaluate the tracking.

The capture is then started by clicking either the **Capture** icon or clicking **Capture** on the **Capture** menu. The settings needed to start the capture are set in the **Start capture** dialog, see chapter "Start capture" on page 42. Before you start the capture, you should also check the other settings for the camera system and that the camera system is calibrated, see chapter "QTM configuration" in the **QTM - User manual** respectively the following chapters in this manual which refer to the **Workspace options** dialog:

"QTM settings - Euler angles" on page 11

"QTM settings - Fixed camera calibration" on page 19

"QTM settings - 6DOF Tracking" on page 26

"QTM settings - Capture" on page 37

"QTM settings - Long range active markers" on page 59

Examples of how to capture 6DOF data can be found in the chapters "Outline of how to capture" on page 4 and "Outline of how to output 6DOF data in real-time" on page 5.

How 6DOF data is displayed in QTM is described in the chapter "6DOF data in QTM" on page 43.

6DOF real-time output

With 6DOF real-time output you can export the 6DOF data to another computer. The data that is exported is position, rotation angles and rotation matrix. The 6DOF data will use the same definitions as you have specified in QTM and the 6DOF real-time output is accessed the same way as the 3D real-time, see chapter “Real time in QTM” on page 34.

Note: If you are using the old real-time called the Legacy RT server it must be activated on the **Legacy RT server** page in the **Workspace options** dialog. The Legacy RT server is accessed with a DLL file. The file is supplied by Qualisys AB on demand.

Real time in QTM

The QTM real time process enables QTM to send data to any program that can receive data on TCP/IP or UDP/IP. If you want real time to other programs please contact Qualisys AB for the real time protocol. Then you can write your own interface for the program.

The real time performance depends on the computer, the number of cameras and the number of markers. To get the best performance use a stationary dual-core computer with at least 2 gigabyte RAM and a good graphic board.

How real time works in QTM

QTM will process the 2D in real time as soon as a measurement file is open in preview, i.e. when you click on **New** in the **File** menu. The following processing steps can be done in real-time, depending on the settings on the **Processing** page in the **Workspace options** dialog.

3D tracking

Apply the current AIM models

Calculate 6DOF

Calculate force data

This data can then be viewed in QTM and also send to another computer via TCP/IP. The TCP/IP server is always active and waits for a connection from another program. The following data that can be sent via TCP/IP.

3D data (Identified and/or Unidentified)

2D data (unlinearized)

Analog data (Analog boards and EMG)

Force data (Force, Moment and COP)

6DOF data (Rotation matrix and/or Euler angles)

Parameters (e.g. Label names, Force plate settings)

These are the different steps in the real-time process.

1. The cameras captures data at a fixed frequency.
2. RT processing of data in QTM which is performed as fast as possible.
3. Data is sent on the TCP/IP output. If QTM has not finished the processing in time a blank frame is sent. This is shown in the main status bar as decreased RT frequency.

The real-time marker frequency is set on the **Camera system** page in the **Workspace options** dialog. The analog and EMG sample rates depend on their respective setting. The analog and EMG is started in synchronization with the markers. The analog boards are always started in synchronization with the sync out signal.

All of the analog, EMG and force samples are sent with each camera frame, e.g. if the analog capture rate is three times the camera capture rate there will be in average three analog samples sent with each frame. However because of the buffering in the analog board the number of samples sent with each marker frame can differ, but the total number of samples will be correct.

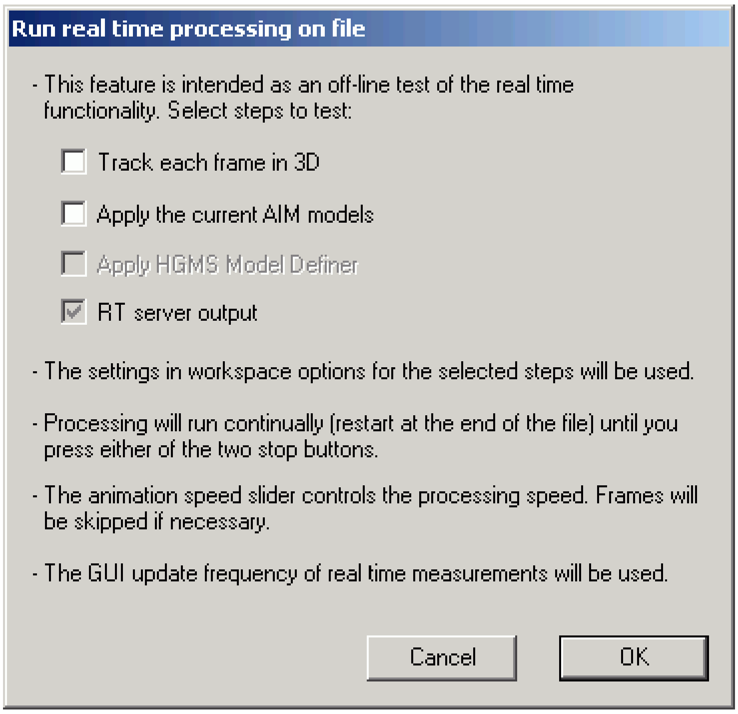
Check that the processing can be done fast enough in QTM by looking at the status bar, the RT frequency should be close to the capture frequency. For more information see chapter “Main status bar” in the **QTM - User manual**.

Use the following guidelines to get as fast real-time as possible:

- Activate only the necessary processing steps on the **Processing** page.
- Set the GUI update to 15 Hz on the **GUI** page, or shut it off completely to get the maximum performance.
- Check that the RT frequency is stable during the RT measurement. Lower the rate if it changes to much from the specified capture rate.

Real time processing on file

The real time can be tested from a tracked file with **Run real time processing on file**, this option is especially useful when testing the other program as it gives full control of what is sent.

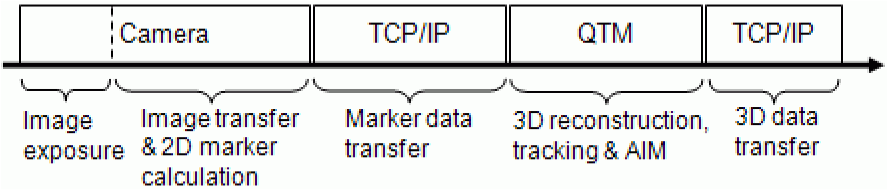


When testing the RT output it is best to have an identified file and then uncheck all of the options in the **Run real time processing on file** dialog. Otherwise the data will be processed for each frame, which will change the data in the file. The options **Track each frame in 3D** and **Apply the current AIM models** should only be used if you specifically want to test these functions in real-time.

The speed of the real time process can be controlled with the **Playback speed** bar. Stop the real time with the **Stop** button on the **Playback** toolbar.

Real time latency

Real time latency is the time it takes from the marker exposure to the when the TCP/IP signal can be received on another computer. The latency can be divided into the parts in the image below. The size of the different parts shows approximately how long time the different steps will take.



This delay will depend on the following factors:

Number of cameras
Increasing the number of cameras can increase the delay. Both because of the extra data and extra complexity in tracking

Computer
The computer performance will influence the latency and because QTM runs on Windows the latency may also differ depending on which other programs that are running.

Because the latency is system and computer dependent it is not possible to give a latency for any system. The best is therefore to measure the latency for your setup. Contact Qualisys AB for help on how to measure the latency.

6DOF analog output

With the analog output option the information about 6DOF bodies' positions and rotations can be used in feedback to an analog control system. The analog output is activated on the **6DOF Analog export** page in the **Workspace options** dialog and it is only used during measurements of 6DOF bodies. To be able to output the analog data the 6DOF body must be tracked, i.e. **Calculate 6DOF** must be activated and a **3D View** window must be open. The analog signal is sent whenever the 6DOF body is tracked, which means that the output will only be in sync with every captured frame in preview and in 6DOF real-time output.

Note: In regular capture it will only work when **Display the last fetched frame** is selected and then it will only be used on the frames that are tracked and displayed.

The data values that will be used are selected on the **6DOF Analog export** page, see chapter "6DOF analog export" on page 39. Since the required board, see chapter "Analog output hardware" on page 36, has 16 channels the output is limited to 16 data values of 6DOF bodies. In order to maximize the use of the 16 bit resolution, the data on each channel can be scaled so that the resulting value is then converted to a voltage which represents the value's proportional position within the range.

Note: The output of a channel will be 0 V if the body is not found. If the input value is outside of the input range the output will be either the **Output min** or the **Output max** value depending on the input value.

Analog output hardware

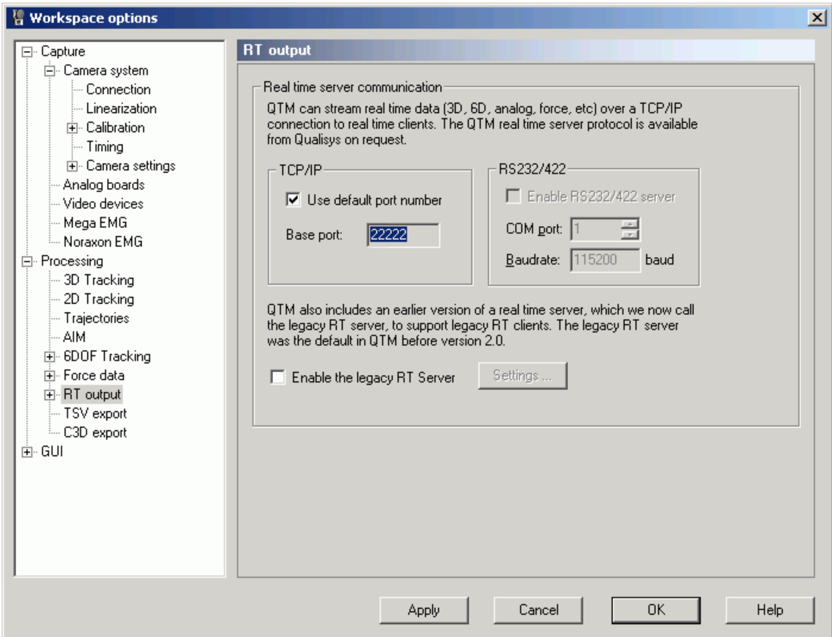
To enable analog output a D/A board must be installed in the measurement computer. Analog output is only available with the Measurement Computing board PCI-DAC6703. This is a 16 channel board with 16 bit resolution. To install the card insert it in any available PCI slot and then start the program Instacal from Measurement computing.

QTM settings - Capture

The following four chapters contain settings for the capture of 6DOF data. The settings in QTM which are not specific for 6DOF capture can be found in the **QTM - User manual**.

RT output

With the real-time output function any tracked data (3D or 6DOF) and also analog and force data can be sent to another computer via TCP/IP. The RT server is always running so that a program can acquire the RT data. The settings for the real time server is found under the **Real time server communication** heading.

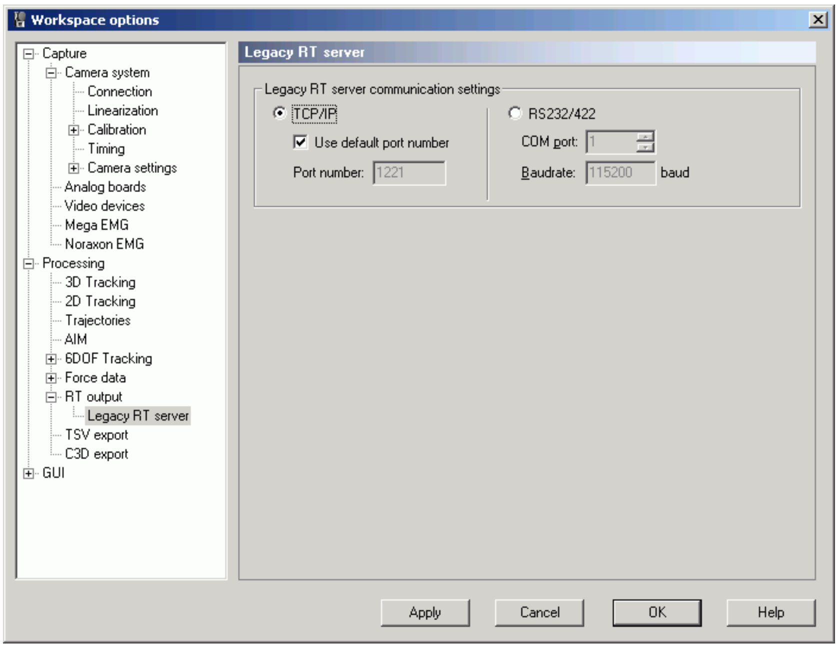


Real time server communication

The only setting that can be changed for the RT output is the TCP/IP port. Uncheck the option **Use default port number** to set another port number. The default **Base port** number is 22222. You only specify one port even though there are several ports used in the RT protocol, for a description of the different ports see the SDK for the RT output.

Enable the old RT server that could only output 6DOF data with **Enable the legacy RT server**. Click on **Settings** to go to the **Legacy RT server** page, see chapter “Legacy RT server” on page 38.

Legacy RT server

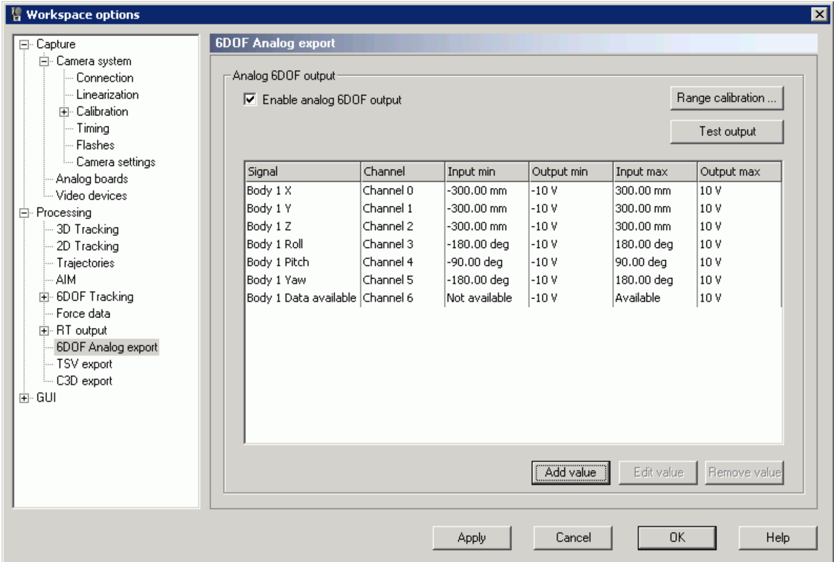


Under the **Legacy RT server communication settings** heading there are settings for the communication of the old RT server that can only handle 6DOF data. For this RT server the data is accessed in the remote computer with a DLL file, which is supplied by Qualisys AB.

The communication can be done either via **TCP/IP** or **RS232/422**, where the **TCP/IP** is the much faster option. For **TCP/IP** the port number is always set to 1221. While the number (**COM port**) and **Baudrate** can be changed for the **RS232/422** setting.

6DOF analog export

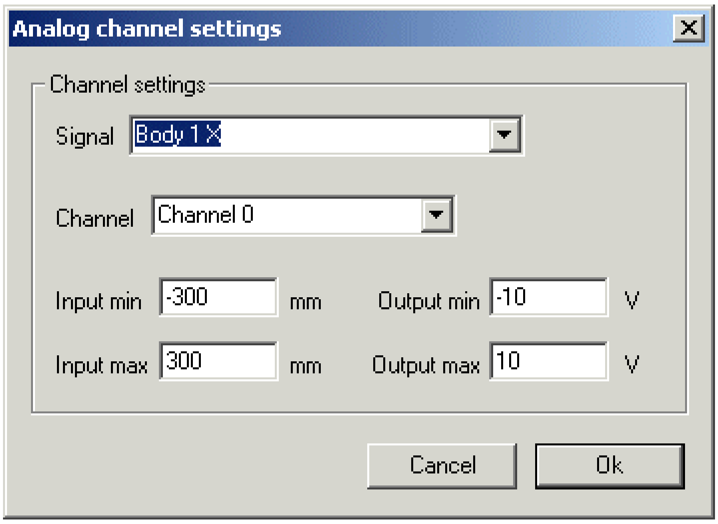
The **6DOF analog export** page is only available if an analog output board (PCI-DAC6703) is installed in the measurement computer. With the analog export the information about 6DOF bodies' positions can be used in feedback to an analog control system. Select the **Enable analog 6DOF output** option to enable the output of the board. The output will continue as long as the option is selected and the 6DOF body is being tracked.



The list on the **6DOF Analog export** page contains the wanted signals and their respective settings. Use **Add value** or double-click in the empty area to add a new signal, see chapter "Analog channel settings" on page 39. Use **Edit value** or double-click on the signal to change the settings of the selected signal. With **Remove value** the selected signals are removed from the list.

Before using the analog export you should set the **Range calibration**. Use the **Test output** option to test the output of the analog board.

Analog channel settings



When clicking on **Add value** or **Edit value** the **Analog channels settings** dialog is displayed. In the dialog the following settings can be set:

Signal
The data in QTM that is used for the output signal. For each 6DOF body on the

6DOF bodies page there are seven available outputs: **X**, **Y**, **Z**, **Roll**, **Pitch**, **Yaw** and **Data available**. **Data available** shows whether the 6DOF body is visible or not.

Note: The rotation angles will change if you change the Euler angles definitions.

Channel
The channel on the analog output board that will be used for the signal. Each channel can only have one signal assigned to it.

Input min/Input max
The minimum respectively the maximum value (mm or degrees) of the input data. If the input data is equal or smaller than the **Input min** the output of the channel is equal to the **Output min**. If the input data is equal or larger than the **Input max** the output of the channel is equal to the **Output max**.

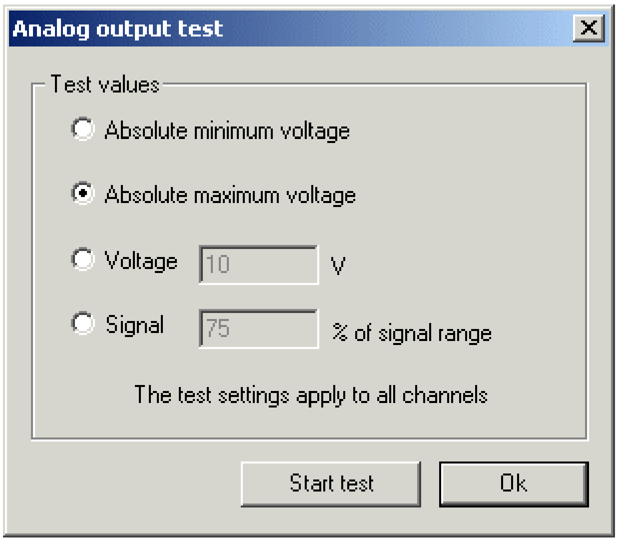
Note: For the three rotation angles the maximum input ranges depend on the ranges of the respective angle.

Output min/Output max
The minimum respectively the maximum value (V) of the output on the channel.

Note: **Data available** has two positions **Available** and **Not available** instead of the input and output settings. Set the value in V which will be on the channel depending on whether the 6DOF body as seen or not.

Test output

When clicking on **Test output** the dialog below is opened.



In the dialog four tests can be performed to test the output of the channels:

Absolute minimum voltage
The output of all channels are set to the minimum value of the analog board. This value should be entered on the **Analog output range calibration** dialog.

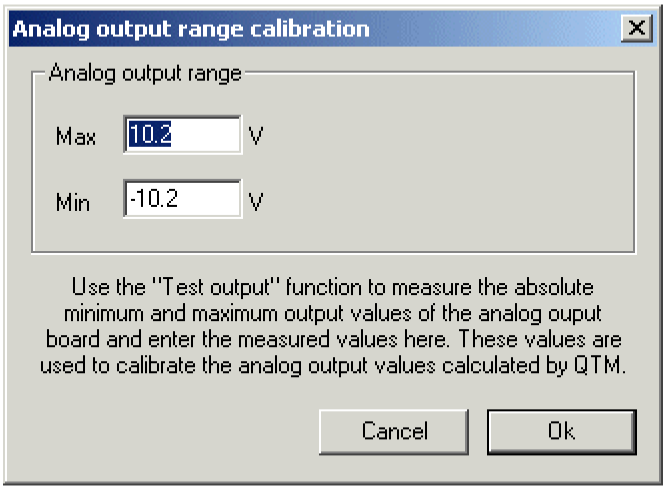
Absolute maximum voltage
The output of all channels are set to the maximum value of the analog board. This value should be entered on the **Analog output range calibration** dialog.

Voltage
The output of all channels are set to the specified voltage.

Signal % of signal range
The output of all channels is set to the specified percentage of the channel's specified output range. If the channel is not used the output will be 0 V.

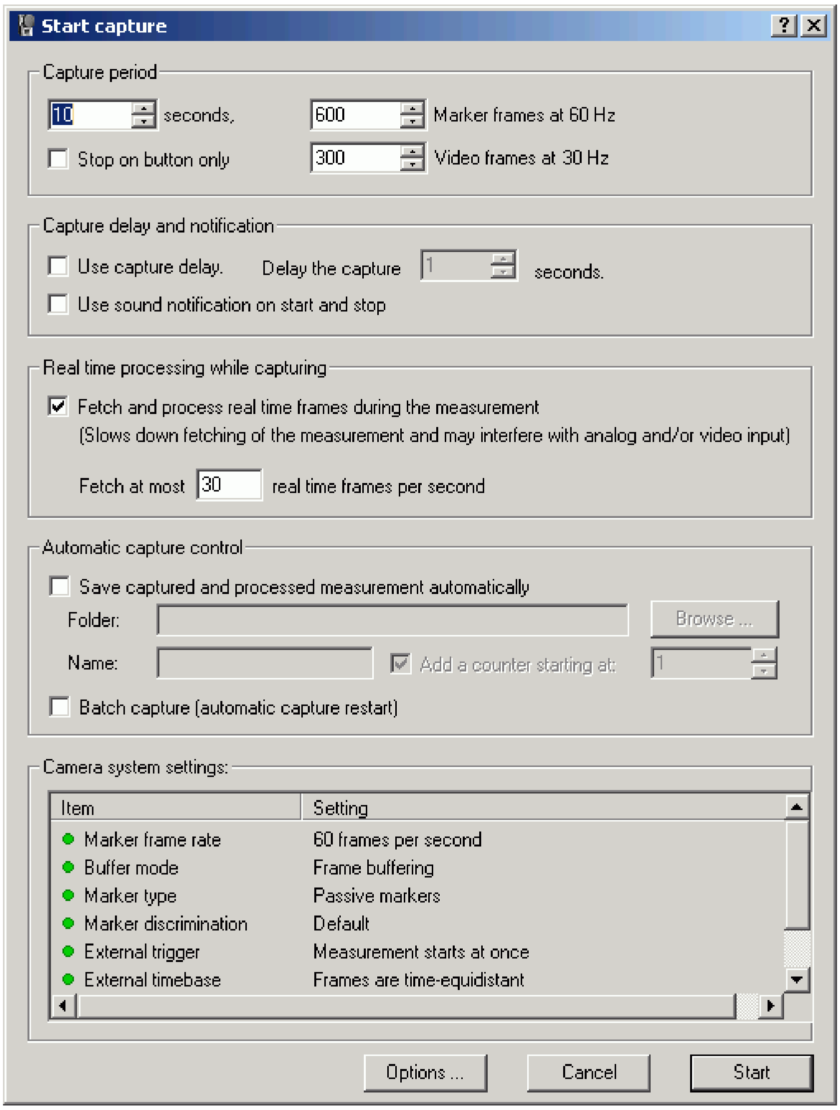
Range calibration

In the **Analog output range calibration** dialog the range of the specific board is entered to calibrate the output of the channels. The maximum and minimum values can be measured with the **Test output** option.



Start capture

The **Start capture** dialog appears before the start of every capture or batch capture.



Click **Start** to start a capture or click **Options** to change the settings in the **Workspace options** dialog.

Capture period

Under the **Capture period** heading, the capture period is specified in seconds or in number of frames. Fractions of a second can be specified, which will be rounded off to the nearest number of frames. If an Oqus camera is in Video mode the number of **Video frames** and the corresponding video capture rate are also shown.

With the **Stop on button only** option the capture does not stop until the **Stop capture** ■ button is pressed.

Capture delay and notification

Under the **Capture delay and notification** heading there are options for delaying the start of the capture (**Use capture delay**) and for sound notification on start and stop of the capture (**Use sound notification on start and stop**). When the **Use capture delay** option is used the delay is specified in seconds in the text box next to the option.

Real time processing while capturing

The process while capturing of the motion capture data can be turned on under the **Real time processing while capturing** heading. When the preview is used the last frame fetched from the cameras (during the measurement) is displayed and QTM also applies the processing steps under **Real time actions** on the **Processing** page in the **Workspace options** dialog. This means that the data can be retrieved on TCP/IP during the capture.

Note: If **Real time processing while capturing** is not used, the frames are only fetched and not displayed. This can make the fetching process faster for ProReflex if your graphics display is slow.

Automatic capture control

Under the **Automatic capture control** heading there are options for automatic saving of measurement files and whether to use batch capture.

Select the **Save captured and processed measurement automatically** option to automatically save the measurement file. Enter the folder in which the files will be saved (**Folder**) and the name of the files (**Name**). An automatic counter can also be assigned to the filename.

When **Batch capture** is selected, QTM will make several consecutive measurements. When batch capturing **Save captured and processed measurement automatically** and the automatic counter must be selected. For information on batch capture see chapter “Batch capture”.

Camera systems settings

Under the **Camera system settings** heading the measurement settings are displayed. The settings can be changed by right-clicking on the entry and then click **Change** or **Reset to default value**. The **Workspace options** dialog can also be reached by clicking **Options**.

6DOF data in QTM

Introduction

QTM can display the 6DOF data in a **3D view** window and plot the position, angles and velocities of the data. In this way you can check the 6DOF data before exporting it to another program for more analysis. The following chapters will describe how the 6DOF data is displayed in QTM and how it can be exported to other formats.

Tracking 6DOF bodies

To track the 6DOF data you must 3D track a file and then activate **Calculate 6DOF** on the **Processing** page in the **Workspace options** dialog. The 6DOF tracking function can either be applied in the processing directly after a motion capture or by retracking a 3D tracked file. You can also use retracking to edit the 6DOF data, see chapter “Post-processing 6DOF data” on page 44.

QTM will identify the trajectories of the 6DOF bodies and place them in the **Labeled trajectories** window. For each 6DOF body the trajectories are named the same as the body with a number at the end, see image below.

Note: If several bodies share the same marker definition, the trajectories will only be shown once in the **Labeled trajectories** window.

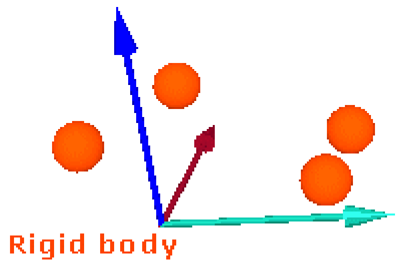
Labeled trajectories (4)

Trajectory	Fill Level	Range	Type
Body - 1	100.0%	1 - 180	Measured
Body - 2	100.0%	1 - 180	Measured
Body - 3	100.0%	1 - 180	Measured
Body - 4	100.0%	1 - 180	Measured

Post-processing 6DOF data

The 6DOF data can be edited in a capture file. This is because each 6DOF body consists of labeled trajectories, from which the 6DOF data is calculated. This means that if the 6DOF data is wrong you can look at the 3D data to find the problem. To edit the 6DOF data just change the 3D data of the labeled trajectories and then reprocess the file with only the **6DOF tracking** option activated. Then QTM will recalculate the 6DOF data from the available 3D data. Which means that any trajectories that are labeled will be unchanged, while unidentified trajectories might be identified if they fit the definition.

6DOF bodies in 3D views



Measured 6DOF bodies are displayed as separate local coordinate systems in a **3D view** window, where the origin is placed at the position of the local origin of the 6DOF body. The axes of the local coordinate system have the same color codes as the coordinate system of the motion capture.

For each 6DOF body the measured markers, which correspond to the points of the 6DOF body definition, are displayed in the local coordinate system. The colors of the markers and the body name are set for each 6DOF body definition on the **6DOF tracking** page in the **Workspace option** dialog.

Note: In a capture file, definition, name and color of a 6DOF body can only be changed by retracking the file, see chapter “Retracking a file” in the **QTM - User manual**.

The 6DOF data can be viewed in the **Data info** window or exported to a TSV file and Matlab, see chapter “6DOF data information” on page 44 respectively chapters “Export to TSV format” on page 1 and “Export directly into Matlab” on page 51.

6DOF data information

6DOF Data

x	y	z	Roll	Pitch	Yaw	Residual
-0.065	-3.006	0.809	-0.049	0.037	-0.049	0.629
1644.997	-536.373	10070.459	-0.505	0.462	105.800	7.227

The data of the 6DOF bodies in the current frame can be viewed in the **Data info** window. The bodies will be shown in the same order as on the **6DOF bodies** page and the data will use the definitions for angles and local coordinate system on the **Euler angles** page respectively the **6DOF bodies** page.

Click **Display 6DOF data** in the **Data info window** menu to show the 6DOF data in the following seven columns:

x, y and z
The position (in mm) of the origin of the measured rigid body's local coordinate system. The distance is to the origin of the coordinate system for rigid body data, see chapter "Coordinate system for rigid body data" on page 27.

Roll, Pitch and Yaw
The rotation (in degrees) of respectively the X-axis, Y-axis and Z-axis in the local coordinate system compared with the orientation of the coordinate system of the motion capture.

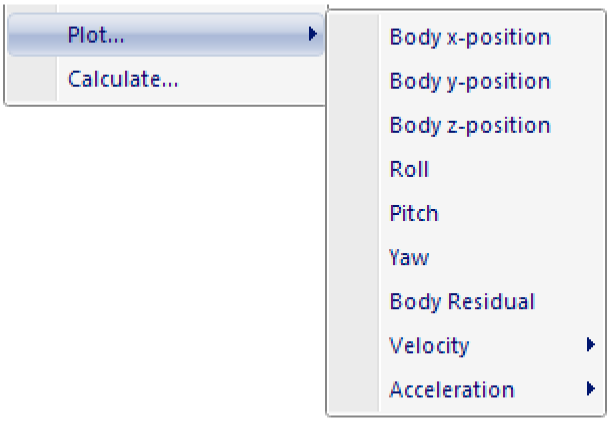
Note: The rotation is positive when the axis rotates clockwise when looking in the positive direction of the axis and it is applied in the order: roll, pitch and yaw. E.g. to mimic the rotation of a certain rigid body in a certain frame follow these steps:

1. Align the local coordinate system with the global.
2. Rotate roll to the correct angle.
3. Rotate pitch to the correct angle. Remember that the Y-axis has moved because of the roll.
4. Rotate yaw to the correct angle. Remember that the Z-axis has moved because of roll and pitch.

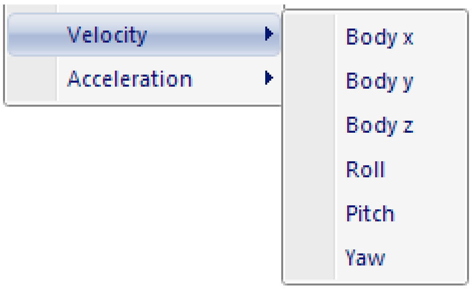
Note: If you change the Euler angle definition the example above will not be correct and the name of the angles can be changed.

Residual
The average of the errors (in mm) of each measured marker compared to the 6DOF body definition. This error is probably larger than the 3D residual.

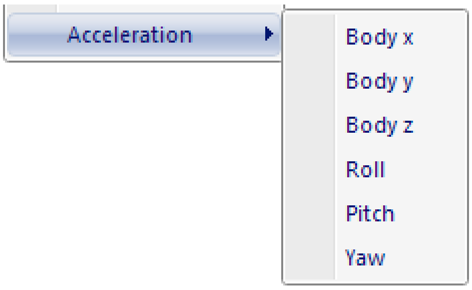
To plot the data select the data for one or more 6DOF bodies and click **Plot** on the **Data info window** menu and then the type of data. The 6DOF bodies will have the same color in the **Plot** window as in the **3D view** window.



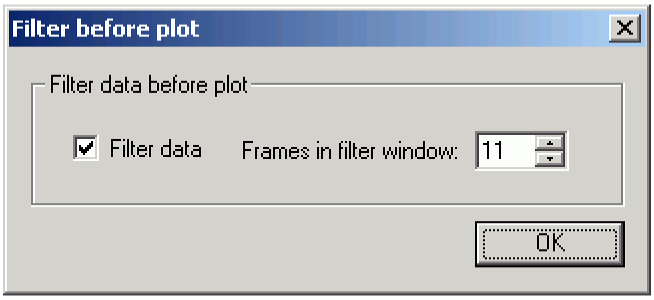
You can also plot the velocity in the three directions of the coordinate system for rigid body data and the angular velocity for the three rotation angles.



Finally the acceleration can also be plotted for the three directions of the coordinate system for rigid body data and the three rotation angles



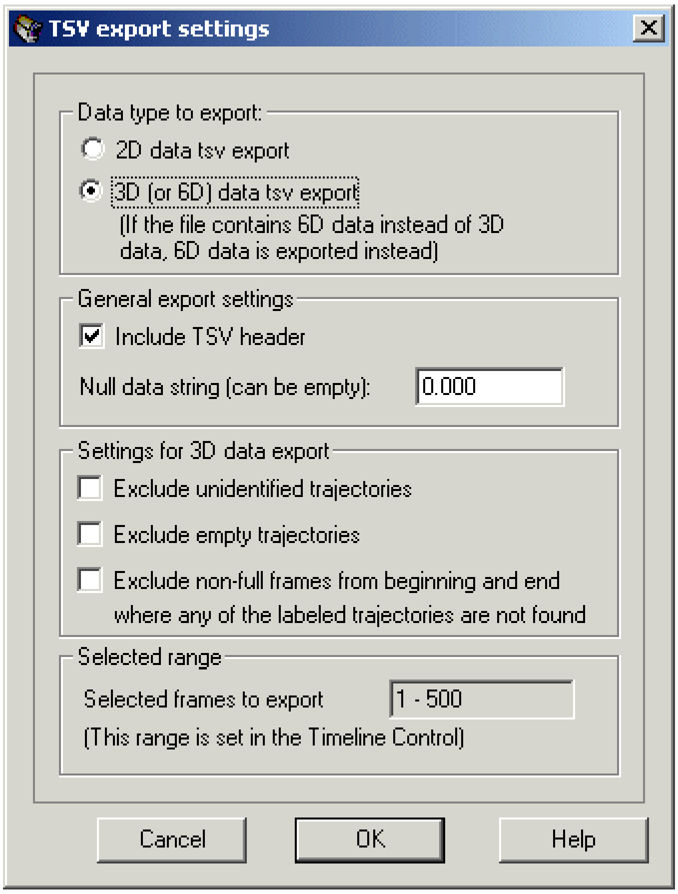
It is possible to filter the data when plotting the velocity or acceleration from a file. Select **Filter data** in the dialog below to apply the filter. The velocity or acceleration calculated and then fitted to a 2nd degree curve from the frames in the **Frames in filter window** option.



For information about the **Plot** window see chapter "Plot window" in the **QTM -User manual**.

Export 6DOF to TSV format

By exporting the data to TSV format you can analyze the data in any other program reads text files, e.g. Excel. Click **Export** on the **File** menu and then **To TSV** to export to the TSV format (Tab Separated Values).



For information about the settings see chapter “TSV export” in the **QTM - User manual**. The frames that are included in the export are shown under the **Selected range** heading. The range is set by the measurement range on the **Timeline control** bar.

6DOF data format

The TSV export of files with 6DOF data creates a TSV file (.tsv) with a file header and a data part. The variable names in the file header are followed by a tab character and then the value. Each variable is on a new line.

NO_OF_FRAMES
Total number of frames in the exported file.

NO_OF_CAMERAS
Number of cameras used in the motion capture.

NO_OF_BODIES
Total number of rigid bodies in the exported file.

FREQUENCY
Measurement frequency used in the motion capture.

NO_OF_ANALOG
Not in use by QTM.

ANALOG_FREQUENCY
Not in use by QTM.

DESCRIPTION
At present not in use by QTM.

TIME_STAMP
Date and time when the motion capture was made. The date and time is followed

by a tab character and then the timestamp in seconds from when the computer was started.

DATA_INCLUDED
Type of data included in the file, i.e. 6D.

BODY_NAMES
Tab-separated list with the names of the rigid bodies in the exported file.

On a new line after the last rigid body name follows a tab-separated list of the data headings for the rigid bodies. The headings are:

X, Y and Z
The position of the origin of the local coordinate system of the rigid body. Where X, Y and Z are the distance in mm to the origin of the coordinate system for rigid body data, see chapter "Coordinate system for rigid body data" on page 27.

Roll, Pitch and Yaw
Roll, pitch and yaw of the rigid body in degrees.
Note: The names and their definition will change if the definition is changed on the **Euler angles** page in the **Workspace options** menu.

Residual
The average of the errors (in mm) of each measured marker compared to the 6DOF body definition. This error is probably larger than the 3D residual.

Rot[0] - Rot[8]
The elements of the rotation matrix for the rigid body. Where the elements are placed in the matrix according to the following table:

Rot[0]	Rot[3]	Rot[6]
Rot[1]	Rot[4]	Rot[7]
Rot[2]	Rot[5]	Rot[8]

Note: For information about the rotation matrix see chapter "Calculation of 6DOF data" on page 54.

The data part follows on a new line after **Rot[8]**. The data is stored in tab-separated columns, where each row represents a frame. The columns are in the same order as the heading list described above. If there is more than one rigid body, their frames are stored on the same rows as the first body. They are just separated by two tab characters after the **Rot[8]** data of the previous body.

Note: If the TSV file is opened in Excel the headings can be copied to all of the rigid bodies.

Export to MAT format

Click **Export** on the **File** menu and then **To MAT** to export to the MAT format. The MAT file can then be opened in Matlab. You can select the data that is exported on the **Matlab file export** page in the **Workspace options** dialog, see chapter "Matlab file export". For further information about the file format see chapter "MAT file format" on page 49.

Note: Because of Matlab limitations it is important that the file does not start with a number or a none English letter.

Note: The names of trajectories and analog channels must be longer than 3 letters. Shorter names will be extended with underscore so that they are 3 letters.

MAT file format

When the data from QTM is exported to a MAT file a struct array is saved in the file. The struct array is named the same as the file. Therefore it is important that the file does not start with a number or a none English letter.

The struct array contains four to seven fields depending on if the file includes analog, EMG and 6DOF data. The fields are **File**, **Frames**, **FrameRate**, **Trajectories**, **Analog**, **EMG**, **Force** and **RigidBodies**, that have the following contents:

File
File name and directory path.

Frames
Number of frames.

FrameRate
Frame rate in frames per second.

Trajectories
Struct array with fields for the three **Trajectory info** windows: **Labeled**, **Unidentified** and **Discarded**. These fields are struct arrays with three fields:

Count
Number of trajectories in the window.

Labels
A list of the trajectory labels.
Note: This field is only included in the **Labeled** struct array.

Data
The location of the 3D points (in mm) of the trajectories in the window. The data is given in a matrix with the dimensions: Trajectories * X, Y and Z direction * Frames. The trajectories are in the same order as in the **Trajectory info** window.

Analog/EMG
Struct array with data from the analog capture. The analog and EMG data from integrated wireless EMGs are stored in separate struct arrays, but the data that is included is the same.
Note: This struct array is only included if the capture file has analog data.

BoardName
The name of the board that was used in the capture.

NrOfChannels
The number of channels that were used in the capture.

ChannelNumbers
The channel numbers that were used in the capture.

Labels
An array with the names of the channels that were used on the analog board.

Range
The range of the channels on the analog board.

NrOfFrames
The number of frames of the analog capture.

SamplingFactor
The multiplication factor compared with the motion capture frame rate.

NrOfSamples
The number of samples in the analog capture.

Frequency
The frequency of the analog capture.

Data
The data (in V) of the analog capture. The data is given in a matrix with the dimensions: Analog channels * Frames of the analog capture.

Force
Struct array with data from the force plates.
Note: This struct array is only included if the capture file has force data.

ForcePlateName
The name of the force plate that was used in the capture.

NrOfFrames
The number of channels that were used in the capture.

SamplingFactor
The multiplication factor compared with the motion capture frame rate.

NrOfSamples
The number of samples in the analog capture.

Frequency
The frequency of the analog capture.

Force
The force data in newton (N), the data is given for X, Y and Z direction.

Moment
The moment data in newton metre (Nm), the data is given for X, Y and Z direction.

COP
The centre of pressure on the force plate (in mm), the data is given X, Y and Z direction. The position is given in the internal coordinate system of the force plate

RigidBodies
Struct array with data for the 6DOF bodies.
Note: This struct array is only included if the capture file has 6DOF bodies.

Bodies
The number of 6DOF bodies.

Name
The names of the 6DOF bodies.

Positions
The position of the origin of the measured rigid body's local coordinate system. It is given as a matrix with the dimensions: Bodies * Distances (X, Y and Z) * Frames. The distances are in mm to the origin of the coordinate system of the motion capture.

Rotations
The rotation matrixes of the rigid bodies. It is given as a matrix with the dimensions: Bodies * Rotation matrixes (elements 0-8) * Frames. The elements are placed in the matrix according to the following table:

[0]	[3]	[6]
[1]	[4]	[7]
[2]	[5]	[8]

Note: For information about the rotation matrix see chapter "Calculation of 6DOF data" on page 54.

RPYs
The roll, pitch and yaw of each rigid body. It is given as a matrix with the dimensions: Bodies * Rotation angles (roll, pitch and yaw) * Frames. The rotation angles are in degrees.
Note: The matrix will always be called **RPYs** even if the definitions

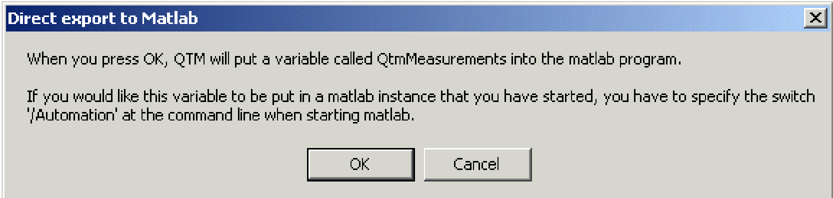
are changed on the **Euler angles** page in the **Workspace options** menu.

Residual
The residual of the rigid bodies.

Note: To use the struct array, write the name of the struct array and the fields with a period between them. If several files have been exported to Matlab, write the variable as **QTMmeasurements(1)**, **QTMmeasurements(2)** and so on to get the data of the file.

Export directly into Matlab

The export directly into Matlab requires that Matlab is installed, since it is exported into a struct array in a Matlab command window. Click **Export** on the **File** menu and then **Directly into Matlab** to export to Matlab. The frames that are included in the export are set by the measurement range on the **Timeline control** bar.



The export creates a struct array called **QTMmeasurements** in the Matlab workspace, see chapter “Matlab variables” on page 51. Both motion data and analog data are exported to the struct array. Data from several capture files can be exported to the same Matlab window, the data will just be added to the struct array. Use the Matlab command 'save' so that you can then open the struct array in a Matlab window with the regular GUI.

Matlab variables

When the data from QTM is exported directly to Matlab, two variables are created in the Matlab workspace: **QTMfileNum** and **QTMmeasurements**.

QTMfileNum is an array which contains the number of capture files that has been exported to Matlab.

QTMmeasurements is a struct array with the data from the exported capture files. The struct array contains four or five fields depending on if the file includes analog and 6DOF data. The fields are **File**, **Frames**, **FrameRate**, **Trajectories**, **Analog** and **RigidBodies**, that have the following contents:

File
File name and directory path.

Frames
Number of frames.

FrameRate
Frame rate in frames per second.

Trajectories
Struct array with fields for the three **Trajectory info** windows: **Labeled**, **Unidentified** and **Discarded**. These fields are struct arrays with three fields:

Count
Number of trajectories in the window.

Labels
A list of the trajectory labels.
Note: This field is only included in the **Labeled** struct array.

Data
The location of the 3D points (in mm) of the trajectories in the window. The data is given in a matrix with the dimensions: Trajectories * X, Y and Z direction * Frames. The trajectories are in the same order as in the **Trajectory info** window.

Analog
Struct array with data from the analog capture.
Note: This struct array is only included if the capture file has analog data.

BoardName
The name of the board that was used in the capture.

NrOfChannels
The number of channels that were used in the capture.

ChannelNumbers
The channel numbers that were used in the capture.

Labels
An array with the names of the channels that were used on the analog board.

Range
The range of the channels on the analog board.

NrOfFrames
The number of frames of the analog capture.

SamplingFactor
The multiplication factor compared with the motion capture frame rate.

NrOfSamples
The number of samples in the analog capture.

Frequency
The frequency of the analog capture.

Data
The data (in V) of the analog capture. The data is given in a matrix with the dimensions: Analog channels * Frames of the analog capture.

RigidBodies
Struct array with data for the 6DOF bodies.
Note: This struct array is only included if the capture file has 6DOF bodies.

Bodies
The number of 6DOF bodies.

Name
The names of the 6DOF bodies.

Positions
The position of the origin of the measured rigid body's local coordinate system. It is given as a matrix with the dimensions: Bodies * Distances (X, Y and Z) * Frames. The distances are in mm to the origin of the coordinate system of the motion capture.

Rotations
The rotation matrixes of the rigid bodies. It is given as a matrix with the dimensions: Bodies * Rotation matrixes (elements 0-8) * Frames. The elements are placed in the matrix according to the following table:

[0]	[3]	[6]
[1]	[4]	[7]
[2]	[5]	[8]

Note: For information about the rotation matrix see chapter "Calculation of 6DOF data" on page 54.

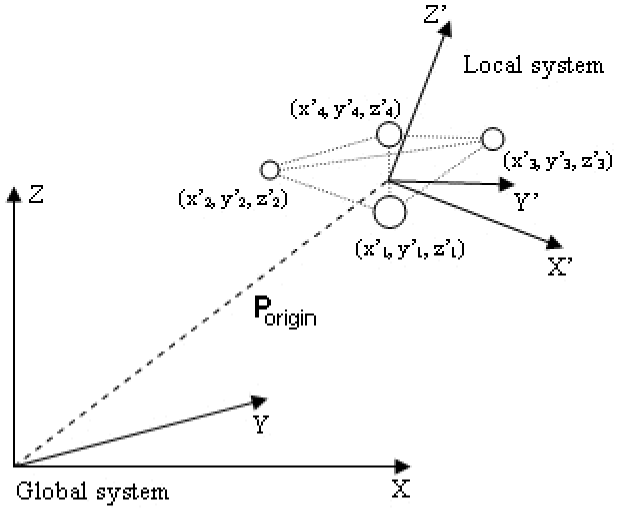
RPYs
The roll, pitch and yaw of each rigid body. It is given as a matrix with the dimensions: Bodies * Rotation angles (roll, pitch and yaw) * Frames. The rotation angles are in degrees.
Note: The matrix will always be called **RPYs** even if the definitions are changed on the **Euler angles** page in the **Workspace options** menu.

Residual
The residual of the rigid bodies.

Note: To use the struct array, write the name of the struct array and the fields with a period between them. If several files have been exported to Matlab, write the variable as **QTMmeasurements(1)**, **QTMmeasurements(2)** and so on to get the data of the file.

Calculation of 6DOF data

6DOF tracking output



The 6DOF tracking function uses the rigid body definition to compute $\mathbf{P}_{origin}$, the positional vector of the origin of the local coordinate system in the global coordinate system, and **R**, the rotation matrix which describes the rotation of the rigid body.

The rotation matrix (**R**) can then be used to transform a position $\mathbf{P}_{local}$ (e.g. x'_1, y'_1, z'_1) in the local coordinate system , which is translated and rotated, to a position $\mathbf{P}_{global}$ (e.g. x_1, y_1, z_1) in the global coordinate system. The following equation is used to transform a position:

$$\mathbf{P}_{global} = \mathbf{R} \cdot \mathbf{P}_{local} + \mathbf{P}_{origin}$$

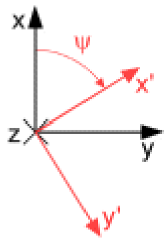
If the 6DOF data refer to another coordinate system than the global coordinate the position and rotation is calculated in reference to that coordinate system instead. The coordinate system for rigid body data is then referred to the global coordinate system.

Calculation of rotation angles from the rotation matrix (Qualisys standard)

The rotation angles are calculated from the rotation matrix (**R**), by expressing it in the three rotation angles: roll (θ), pitch (ϕ) and yaw (ψ).

To begin with the rotations are described with individual rotation matrixes: $\mathbf{R}_x$, $\mathbf{R}_y$ and $\mathbf{R}_z$. The rotations are around the X-, Y- respectively Z-axis and positive rotation is clockwise when looking in the direction of the axis.

The individual rotation matrix can be derived by drawing a figure, see example below. To get an individual rotation matrix express for example the new orientation x' and y' in the coordinates x, y and ψ and then make a matrix of the equations. The example below is of rotation around the Z-axis, where positive rotation of yaw (ψ) is clockwise when the Z-axis points inward.



The resulting three rotation matrixes are then:

$$\mathbf{R}_x = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\theta & -\sin\theta \\ 0 & \sin\theta & \cos\theta \end{bmatrix}$$

$$\mathbf{R}_y = \begin{bmatrix} \cos\phi & 0 & \sin\phi \\ 0 & 1 & 0 \\ -\sin\phi & 0 & \cos\phi \end{bmatrix}$$

$$\mathbf{R}_z = \begin{bmatrix} \cos\psi & -\sin\psi & 0 \\ \sin\psi & \cos\psi & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

The rotation matrix (**R**) is then calculated by multiplying the three rotation matrixes. The orders of the multiplications below means that roll is applied first, then pitch and finally yaw.

$$\mathbf{R} = \mathbf{R}_x \cdot \mathbf{R}_y \cdot \mathbf{R}_z = \begin{bmatrix} r_{11} & r_{12} & r_{13} \\ r_{21} & r_{22} & r_{23} \\ r_{31} & r_{32} & r_{33} \end{bmatrix} =$$

$$= \begin{bmatrix} \cos\phi \cdot \cos\psi & -\cos\phi \cdot \sin\psi & \sin\phi \\ \cos\theta \cdot \sin\psi + \cos\psi \cdot \sin\theta \cdot \sin\phi & \cos\theta \cdot \cos\psi - \sin\theta \cdot \sin\phi \cdot \sin\psi & -\cos\phi \cdot \sin\theta \\ \sin\theta \cdot \sin\psi - \cos\theta \cdot \cos\psi \cdot \sin\phi & \cos\psi \cdot \sin\theta + \cos\theta \cdot \sin\phi \cdot \sin\psi & \cos\theta \cdot \cos\phi \end{bmatrix}$$

The following equations are then used to calculate the rotation angels from the rotation matrix:

$$\text{Pitch}: \phi = \arcsin(r_{13})$$

$$\text{Roll}: \theta = \arccos\left(\frac{r_{33}}{\cos\phi}\right)$$

$$\text{Yaw}: \psi = \arccos\left(\frac{r_{11}}{\cos\phi}\right)$$

The range of the pitch angle is -90° to 90°, because of the nature of the arcsin function. The range of the arcos function is 0° and 180°, but the range of roll and yaw can be expanded by looking respectively on the r_{23} and r_{12} elements in the rotation matrix (**R**). The roll and yaw will have the opposite sign compared to these elements, since $\cos(\phi)$ is always positive when ϕ is within ±90°. This means that the range of roll and yaw are -180° to 180°.

A problem with the equations above is that when pitch is exactly ±90° then the other angles are undefined, because of the division by zero, i.e. singularity. The result of a pitch of exactly ±90° is that the Z-axis will be positioned at the position that the X-axis had before the rotation. Therefore yaw can be set to 0°, because every rotation of the Z-axis could have been made on the X-axis before pitching 90°. When yaw is 0° and pitch is ±90°, the rotation matrix can be simplified to:

$$\begin{matrix} 0 & 0 & \pm 1 \\ \pm\sin(\theta) & \cos(\theta) & 0 \\ \pm\cos(\theta) & \sin(\theta) & 0 \end{matrix}$$

From the matrix above the roll can be calculated in the range ±180°.

Important: With the definitions above, roll, pitch and yaw are unambiguous and can describe any orientations of the rigid body. However, when the pitch (ϕ) is close to ±90°, small changes in the orientation of the measured rigid body can result in large differences in the rotations because of the singularity at ϕ=±90°.

Calculation of other rotation matrixes

This chapter describes how other rotation matrixes are calculated. The calculations are not described in the same detail for each matrix as with the Qualisys standard, but you should be able to calculate the exact rotation matrix from these descriptions.

Note: If you use rotations around global axes the order of multiplication of the individual rotation matrixes are reversed and if you use a left-hand system change the positive direction to counterclockwise, which means that the sign of the angle is swapped.

First there are two types of rotation matrixes: those with three different rotation axes and those with the same rotation axis for the first and third rotation.

The first type is of the same type as the one used as Qualisys standard. This means that for this type the same individual rotation matrixes ($\mathbf{R}_x$, $\mathbf{R}_y$ and $\mathbf{R}_z$) are used as for the Qualisys standard. The individual rotation matrixes are then multiplied in different orders to get the different rotation matrix. When you have the rotation matrix the same kind of formulas but with other indexes and signs are used to get the rotational angles as for the Qualisys standard:

$$\text{Pitch}: \phi = \arcsin(r_{13})$$

$$\text{Roll}: \theta = \arccos\left(\frac{r_{33}}{\cos\phi}\right)$$

$$\text{Yaw}: \psi = \arccos\left(\frac{r_{11}}{\cos\phi}\right)$$

You have to look at the rotation matrix to see what indexes and signs that should be used. The singularity will always be at ±90° for the second rotation and at the singularity the third rotation is always set to 0°.

In the second type the third rotation is round the same axis as the first rotation. This means that one of the individual rotation matrixes below is used as the last rotation, depending on which axis that is repeated.

$$\mathbf{R}_{x2} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\theta_2 & -\sin\theta_2 \\ 0 & \sin\theta_2 & \cos\theta_2 \end{bmatrix}$$

$$\mathbf{R}_{y2} = \begin{bmatrix} \cos\phi_2 & 0 & \sin\phi_2 \\ 0 & 1 & 0 \\ -\sin\phi_2 & 0 & \cos\phi_2 \end{bmatrix}$$

$$\mathbf{R}_{z2} = \begin{bmatrix} \cos\psi_2 & -\sin\psi_2 & 0 \\ \sin\psi_2 & \cos\psi_2 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

The rotation matrix ($\mathbf{R}$) is then calculated by multiplying two of the individual rotation matrixes from the first type and then one of matrixes above. In the example below the rotations are round the x, y and then x axis again.

$$\mathbf{R} = \mathbf{R}_x \cdot \mathbf{R}_y \cdot \mathbf{R}_{x2} = \begin{bmatrix} r_{11} & r_{12} & r_{13} \\ r_{21} & r_{22} & r_{23} \\ r_{31} & r_{32} & r_{33} \end{bmatrix} =$$

$$= \begin{bmatrix} \cos\phi & \sin\theta_2 \cdot \sin\phi & \cos\theta_2 \cdot \sin\phi \\ \sin\theta \cdot \sin\phi & \cos\theta \cdot \cos\theta_2 - \cos\phi \cdot \sin\theta \cdot \sin\theta_2 & -\cos\theta_2 \cdot \cos\phi \cdot \sin\theta - \cos\theta \cdot \sin\theta_2 \\ -\cos\theta \cdot \sin\phi & \cos\theta_2 \cdot \sin\theta + \cos\theta \cdot \cos\phi \cdot \sin\theta_2 & \cos\theta \cdot \cos\theta_2 \cdot \cos\phi - \sin\theta \cdot \sin\theta_2 \end{bmatrix}$$

The rotation angles can then be calculated according to the equations below. These equations are similar for other rotation matrixes of this type, just the indexes and types are changed.

$$\text{Pitch} : \phi = \arccos\left(\sqrt{1 - r_{11}^2}\right)$$

$$\text{Roll} : \theta = \arctan\left(\frac{r_{21}}{-r_{31}}\right)$$

$$\text{Yaw} : \psi = \arctan\left(\frac{r_{12}}{r_{13}}\right)$$

As for the first type of rotation matrixes there will be a singularity for the second rotation angel, but now it is at 0° and 180°. The third rotation angle is then set to 0° and the following rotation matrix can be used to calculate the rotation. It will of course change for other matrixes but the principle is the same.

$$\begin{matrix} 1 & 0 & 0 \\ 0 & \cos(\Theta) & -\sin(\Theta) \\ 0 & \sin(\Theta) & \cos(\Theta) \end{matrix}$$

Long range active markers

Introduction

Active markers use infrared LEDs to send an IR flash to the cameras. The advantage compared to passive markers is that it sends a more powerful signal thus increasing the measurement range of the system. The active marker uses an infrared detector to detect the flash from the camera, and a micro-controller to trigger the marker flash. Since there is a delay between the camera flash and the marker flash, direct reflections of the camera flash will not be seen by the camera.

For marine applications Qualisys has developed a Long range active marker, which is splash proof and can be seen on a large distance. This marker can be used with both Oqus and ProReflex cameras.

Getting started

Getting started long range

The following chapters describe how to get started with the Long range active marker. It also points out some important features and instructions for the marker. For a complete description of the Long range active marker please refer to the technical reference.

Usage

1. Connect the spherical markers to the connections MARKER 1 – MARKER 4 on the control box. (Note that part of the thread is still visible when it is connected correctly.)

IMPORTANT: The markers must be connected before the control box is turned on to operate with full intensity.
IMPORTANT: The spherical markers are delivered with the cable attached. Do not remove it because it is difficult to connect again.

2. Connect the battery pack or power supply to the BATTERY/12 VDC connection.

3. Connect the IR eye to the IR IN/SYNC IN connection.
   Note: The control box is usually triggered by the IR eye. It can also be triggered by a TTL pulse and there is a sync output which can trigger other control boxes.

4. Attach a protective cover to any unused connection to keep the box splash proof.

5. Start the control box with the ON/OFF button.
   IMPORTANT: The button must be pressed and held until the POWER/BATT LOW LED is lit green. When switching off the control box press and hold the button until the POWER/BATT LOW LED is turned off.

6. The Long range active marker is now ready for use.

7. Activate it in QTM by selecting **Long range active marker** as **Marker type** on the **Camera settings**/**Advanced** page in the **Workspace options** dialog.

Power

The Long range active marker is delivered with a battery pack, which contains a rechargeable LI-ION battery. When the POWER/BATT LOW LED flashes red it is time to charge the battery. The charging time for an empty battery is about 3 h 30 min. The control box can also be powered by any 12VDC power supply.

Performance

- The Long range active marker can be used with frequencies from 1 to 200 Hz. The marker will not work correctly above 200 Hz.
- The maximum triggering distance for the IR eye is at least 100 m.
- When the control box is operated on battery it will enter standby mode after 30 seconds (power LED flashes green) and shut down itself automatically after 6 hours to save battery.
- The continuous operation with 4 markers at 100 Hz is 9 h with the supplied battery pack. Other operation times can be calculated from frequency and the number of markers connected to the control box.

Long range active marker package

One package of Long Range Active Marker consist of:

- Driver for 4 markers

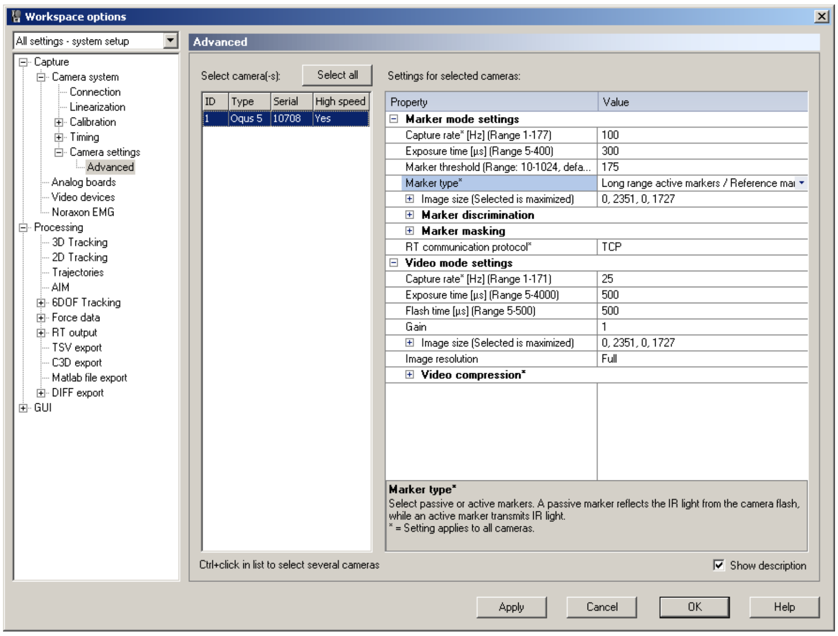
- 4pc 50mm markers with 5 meter cable
- Battery pack 14,8V 2200 mAh, Li-lon charger and battery cable
- Sync cabel, 2 meter
- IR Reciver with 5 meter cable

Specifications

Control box	114x107x34 mm, 330 g
Battery pack	114x107x34 mm, 1 m cable, 450 g
Spherical marker	50 mm in diameter, 5 m cable, 250 g
IR eye	30x40x15 mm, 5 m cable, 220 g
Total weight of a long range marker	2 kg
Frequency range	1-200 fps
Flash time	325 µm
Maximum trigger distance	at least 100 m
Battery time, 50 fps, 4 markers	18 h
Battery time, 100 fps, 4 markers	9 h
Time to charge battery	3 h 30 min
Nominal battery capacity	2200 mAh, 14.8 V
Input power range	10-18 VDC

QTM settings - Long range active markers

The only setting needed to use Long range active markers is found on the **Advanced** page (for ProReflex the **Camera settings** page) in the **Workspace options** dialog. Select **Long rang active markers** to activate the capture of Long range active markers.


Workspace options
All settings - system setup
Capture
Camera system
Connection
Linearization
Calibration
Timing
Camera settings
Advanced
Analog boards
Video devices
Noraxon EMG
Processing
3D Tracking
2D Tracking
Trajectories
AIM
6DOF Tracking
Force data
RT output
TSV export
C3D export
Matlab file export
DIFF export
GUI
Advanced
Select camera(-s):
Select all
ID Type Serial High speed
1 Oqus 5 10708 Yes
Settings for selected cameras:
Property
Value
Marker mode settings
Capture rate* [Hz] (Range 1-177) 100
Exposure time [µs] (Range 5-400) 300
Marker threshold (Range: 10-1024, defa... 175
Marker type* Long range active markers / Reference mar
Image size (Selected is maximized) 0, 2351, 0, 1727
Marker discrimination
Marker masking
RT communication protocol* TCP
Video mode settings
Capture rate* [Hz] (Range 1-171) 25
Exposure time [µs] (Range 5-4000) 500
Flash time [µs] (Range 5-500) 500
Gain 1
Image size (Selected is maximized) 0, 2351, 0, 1727
Image resolution Full
Video compression*
Marker type*
Select passive or active markers. A passive marker reflects the IR light from the camera flash, while an active marker transmits IR light.
* = Setting applies to all cameras.
Ctrl+click in list to select several cameras
Show description
Apply
Cancel
OK
Help

Glossary

2

2D marker ray: The 2D position of a marker projected into the 3D space by using the position of the camera.

2D view window: Window with the 2D views of the cameras.

3

3D view window: Window with a 3D view calculated from the 2D data.

6

6DOF: Six degrees of freedom

6DOF body (rigid body): Body that is defined by fixed points on the body and a local coordinate system, i.e. location and rotation.

A

A/D board (analog board): Analog/Digital board, which converts an analog signal to a digital.

Analog capture: QTM can capture analog voltage data in synchronization with the motion capture data. If you have an analog board.

Analog output: With analog output 6DOF data can be used as feedback to an analog control system. If you have an analog output board.

Analog output board: Board which converts a digital value to an analog signal.

Analog synchronization cable: Cable that connects the camera system with the analog board for synchronization of the start.

B

Bone length tolerance: The maximum differance between the lengths of corresponding bones in a rigidbody definition and a measured rigid body.

C

Calibration: Process that defines the position of the cameras in the 3D space. The calibration is used for the 3D reconstruction.

Capture: Measurement which collects several frames at a fixed frame rate.

Capture file: A qtm-file with motion capture data (.qtm).

Capture rate: Frame rate in Hz that is used for the motion capture.

Capture view: View that is used during motion capture.

Coordinate system: A system of axes which describes the position of a point. In QTM all of the 3D coordinate systems are orthogonal, right hand systems.

Coordinate system for rigid body data: The coordinate system which is used as reference for the 6DOF body data.

Coordinate system of the motion capture: The coordinate system which is defined with the calibration process.

D

D/A board: Digital/analog board, which converts a digital value to an analog signal.

Data info window: Window with data for the current frame.

E

Euler angles (rotation angles): A method to display the orientation of a 6DOF body in three angles.

F

Field of view (FOV): The MCU's view, vertical and horizontal on a specific distance from the camera.

File view (File mode): View that is used when a motion capture is finished and for saved files.

Fixed camera calibration: Calibration method which is used for large systems with fixed cameras.

Frame: Single exposure of the camera system.

Frame rate: Frequency of the motion capture.

G

Global coordinate system: In QTM it is the same as the coordinate system of the motion capture, which is defined by the calibration.

I

IR: Infrared

IR marker: A marker which reflects or transmits IR light.

L

LED: Light Emitting Diodes

Linearization: Correction data which is needed for each camera to make the capture as good as possible.

Local coordinate system: Coordinate system of a 6DOF body.

Long range active markers: A spherical active marker which can be used in large measurement volumes.

M

Marker: Item that is attached to the moving object to measure its position.

Marker – Active: Marker with an infrared LED that is activated by the camera's flash in each frame.

Marker – Passive: Marker with reflective material.

Marker (3D view): Sphere that represents a trajectory in 3D views.

Marker discrimination: Option that reduces non-wanted reflections or marker sizes during capture.

Master MCU: The MCU that is directly connected to the measurement computer.

Max residual: Maximum distance for a 2D ray to be included in a 3D point during tracking.

MCU: Motion Capture Unit (camera)

Measurement computer: Computer which is connected to a camera system, which must have the QTM application installed.

Measurement range: The range that is set with the boxes on the Timeline control bar. It defines the frames which is included in the analysis.

Motion capture: Measurement which records a motion.

P

Pitch: Rotation around the Y-axis (Qualysis standard).

Plot window: Window with data plots.

Preview mode: Mode when QTM is showing the measured data before the start of a capture.

R

Real-time output (RT output): Function which exports 6DOF data in real-time to a remote computer.

Reference marker: Special kind of active marker which is used in fixed camera systems and is visible at long distances.

Remote computer: Computer which receives 6DOF data from the RT output.

Residual: In most cases in QTM this is the minimum distance between a 2D marker ray and its corresponding 3D point or an average of this measure.

Residual (3D): The average of the different residuals of the 2D marker rays that belongs to the same 3D point.

Residual (6DOF): The average of the errors of each measured marker compared to the 6DOF body definition.

Residual (calibration): The Average residual in the Calibration results dialog is the average of the 3D residuals of all the points measured by the camera during the calibration.

Rigid body (6DOF body): Body that is defined by points and a local coordinate system, i.e. location and rotation.

Roll: Rotation around the X-axis (Qualisys standard).

Rotation angles (Euler angles): A method to display the orientation of a 6DOF body in three angles.

Rotation matrix: A method to describe the orientation of the 6DOF body. With this method the orientation is uniquely determined and it is therefore the format that QTM uses internally.

T

TCP/IP: Protocol for communication between computers.

Tracking: Process that calculates 3D data or 6DOF data.

Trajectory: 3D data of a marker in a series of frames.

Trajectory info windows: Windows with trajectories and 3D data.

Transformation: Move the position and orientation of the global coordinate system.

Translate: Move the center of rotation and zoom in the current 2D plane of the 3D view.

TSV (Tab Separated Values): File format where the data is separated with the TAB character.

V

View window: Window in QTM which shows 2D, 3D or Video views.

Volume: The defined measurement's height, length, depth.

Y

Yaw: Rotation around the Z-axis (Qualisys standard).

Index

6
6DOF analog output
  description 36
  hardware 36
  outline 5
  settings 39
6DOF bodies (Rigid bodies)
  creating 23
  definition..................................... 24
  description 23
  graphic display........................... 44
  local coordinate system............... 25
  referring coordinate system.......... 27
  settings 26
6DOF capture
  analog output 36
  description 33
  outline 4
  real-time output........................... 34
6DOF data
  description 43
  Euler angles (rotation angles) 7
  graphic display........................... 44
  MAT export 48
  Matlab export.............................. 51
  Matlab file format 51
  tracking 43
  TSV export.................................. 46
  TSV file format........................... 47
  viewing data................................ 44
6DOF real-time output
  description 34
  outline 5
  settings 37
6DOF tracking
  output... 34
  parameters................................... 26
  settings 26
A
Active marker (Long range)
  hardware 58
  settings 59
  usage 57
Analog output
  description 36
  hardware 36
  outline 5
  settings 39
C
Calibration (Fixed camera)
  description................................... 14
  outline 2
  perform 14
  requirements 14
  results.. 16
  settings 19
  transformation............................. 21
  validation 17
Capture
  6DOF capture.............................. 33
  outline 4
  real-time output........................... 34
  start capture dialog....................... 42
Coordinate system
  for rigid body data........................ 27
  global (defined by calibration)..... 14
  local 25
  transformation............................. 21
D
D/A board 36
Data export
  MAT export 48
  MAT file format 49
  Matlab export.............................. 51
  Matlab variables.......................... 51
  TSV export.................................. 46
  TSV file format........................... 47
E
Euler angles (Rotation angles)
  calculation from the rotation matrix
    54
  custom definition 12
  description..................................... 7
  example.. 7
  marine application.......................... 9
  setting.. 11
F
Fixed camera calibration
  description................................... 14
  outline 2
  perform 14
  requirements 14

results 16
settings 19
single marker calibration 15
test tracking residual 17
transformation 21
validation 17
I
Installation of a fixed camera system . 2
IR marker
in 6DOF bodies 23
long range active marker 57
L
Long range active marker
hardware 58
settings 59
usage 57
P
Pitch
definition 54
example 7
view 44
R
Real-time output
description 34
outline 5
settings 37
Reference marker location 19
Rigid body (6DOF body)
creating 23
definition 24
description 23
graphic display 44
local coordinate system 25
referring coordinate system 27
settings 26
Roll
definition 54
example 7
view 44
Rotation angles (Euler angles)
calculation from the rotation matrix 54
custom definition 12
description 7
example 7
marine application 9
setting 11
Rotation matrix 54
S
Single marker calibration 15
T
Tracking (6DOF)
output 54
parameters 26
settings 26
V
Validation
description 17
performing 18
results 18
Y
Yaw
definition 54
example 7
view 44