Rigid Track

Generated by Doxygen 1.8.13

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Chapter 1

File Index

1.1 File List

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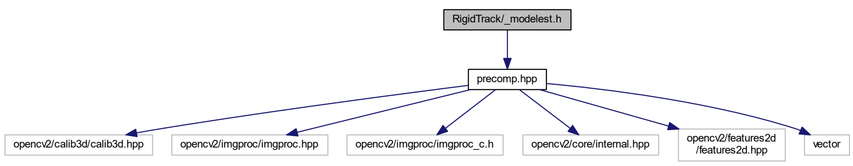
Chapter 2

File Documentation

2.1 RigidTrack/_modelest.h File Reference

```
#include "precomp.hpp"
```

Include dependency graph for _modelest.h:



Classes

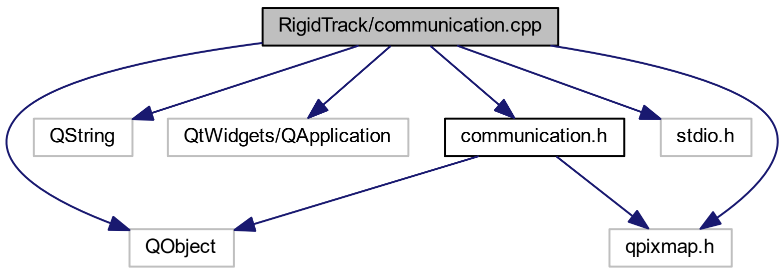
- class CvModelEstimator2

2.2 RigidTrack/communication.cpp File Reference

```
#include <QObject>
#include <QString>
#include <QtWidgets/QApplication>
#include <qpixmap.h>
#include <stdio.h>
```

```
#include "communication.h"
```

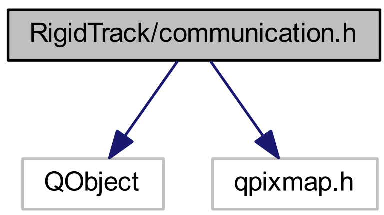
Include dependency graph for communication.cpp:



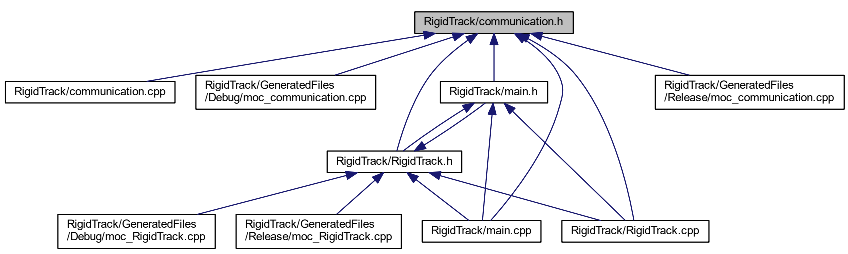
2.3 RigidTrack/communication.h File Reference

```
#include <QObject>
#include <qpixmap.h>
```

Include dependency graph for communication.h:



This graph shows which files directly or indirectly include this file:



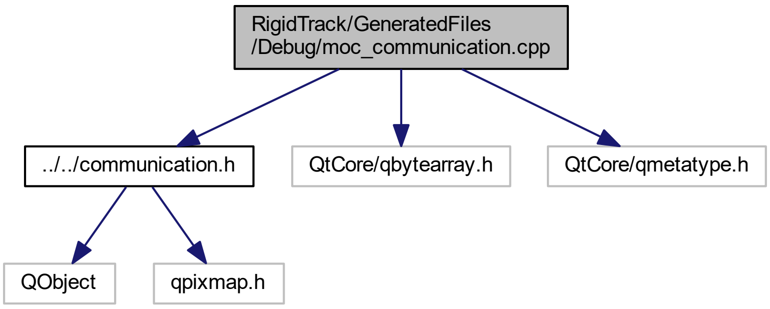
Classes

- class commObject

2.4 RigidTrack/GeneratedFiles/Debug/moc_communication.cpp File Reference

```
#include "../../communication.h"
#include <QtCore/qbytearray.h>
#include <QtCore/qmetatype.h>
```

Include dependency graph for moc_communication.cpp:



Classes

- struct qt_meta_stringdata_commObject_t

Macros

- #define QT_MOC_LITERAL(idx, ofs, len)

2.4.1 Macro Definition Documentation

2.4.1.1 QT_MOC_LITERAL

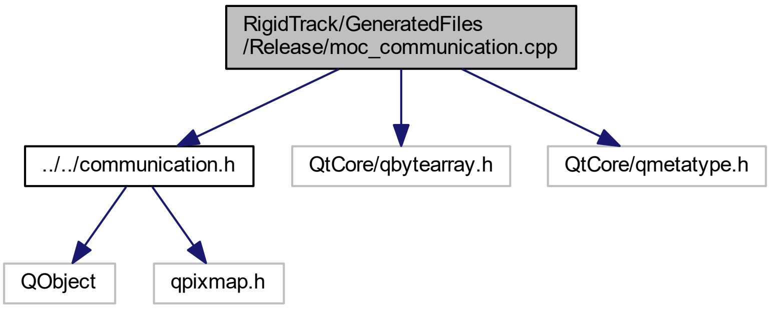
```
#define QT_MOC_LITERAL(
                idx,
                ofs,
                len )
```

Value:

```
Q_STATIC_BYTE_ARRAY_DATA_HEADER_INITIALIZER_WITH_OFFSET(len, \
    qptrdiff(offsetof(qt_meta_stringdata_commObject_t, stringdata0) + ofs \
        - idx * sizeof(QByteArrayData)) \
    )
```

2.5 RigidTrack/GeneratedFiles/Release/moc_communication.cpp File Reference

```
#include "../../communication.h"
#include <QtCore/qbytearray.h>
#include <QtCore/qmetatype.h>
```
Include dependency graph for moc_communication.cpp:



Classes

- struct qt_meta_stringdata_commObject_t

Macros

- #define QT_MOC_LITERAL(idx, ofs, len)

2.5.1 Macro Definition Documentation

2.5.1.1 QT_MOC_LITERAL

```
#define QT_MOC_LITERAL(
               idx,
               ofs,
               len )
```

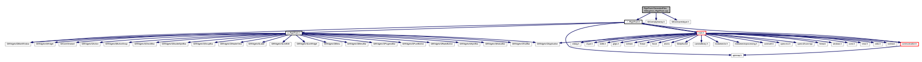
Value:

```
Q_STATIC_BYTE_ARRAY_DATA_HEADER_INITIALIZER_WITH_OFFSET(len, \
    qptrdiff(offsetof(qt_meta_stringdata_commObject_t, stringdata0) + ofs \
        - idx * sizeof(QByteArrayData)) \
    )
```

2.6 RigidTrack/GeneratedFiles/Debug/moc_RigidTrack.cpp File Reference

```
#include "../../RigidTrack.h"
#include <QtCore/qbytearray.h>
#include <QtCore/qmetatype.h>
```

Include dependency graph for moc_RigidTrack.cpp:



Classes

- struct qt_meta_stringdata_RigidTrack_t

Macros

- #define QT_MOC_LITERAL(idx, ofs, len)

2.6.1 Macro Definition Documentation

2.6.1.1 QT_MOC_LITERAL

```
#define QT_MOC_LITERAL(
                idx,
                ofs,
                len )
```

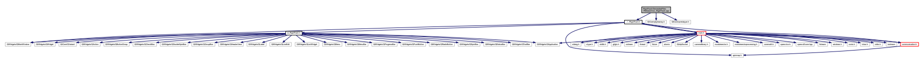
Value:

```
Q_STATIC_BYTE_ARRAY_DATA_HEADER_INITIALIZER_WITH_OFFSET(len, \
    qptrdiff(offsetof(qt_meta_stringdata_RigidTrack_t, stringdata0) + ofs \
        - idx * sizeof(QByteArrayData)) \
    )
```

2.7 RigidTrack/GeneratedFiles/Release/moc_RigidTrack.cpp File Reference

```
#include "../../RigidTrack.h"
#include <QtCore/qbytearray.h>
#include <QtCore/qmetatype.h>
```

Include dependency graph for moc_RigidTrack.cpp:



Classes

- struct qt_meta_stringdata_RigidTrack_t

Macros

- #define QT_MOC_LITERAL(idx, ofs, len)

2.7.1 Macro Definition Documentation

2.7.1.1 QT_MOC_LITERAL

```
#define QT_MOC_LITERAL(
                idx,
                ofs,
                len )
```

Value:

```
Q_STATIC_BYTE_ARRAY_DATA_HEADER_INITIALIZER_WITH_OFFSET(len, \
    qptrdiff(offsetof(qt_meta_stringdata_RigidTrack_t, stringdata0) + ofs \
        - idx * sizeof(QByteArrayData)) \
    )
```

2.8 RigidTrack/GeneratedFiles/qrc_RigidTrack.cpp File Reference

Macros

- #define QT_RCC_PREPEND_NAMESPACE(name) name
- #define QT_RCC_MANGLE_NAMESPACE(name) name

Functions

- int QT_RCC_MANGLE_NAMESPACE() qInitResources_RigidTrack ()
- int QT_RCC_MANGLE_NAMESPACE() qCleanupResources_RigidTrack ()

2.8.1 Macro Definition Documentation

2.8.1.1 QT_RCC_MANGLE_NAMESPACE

```
#define QT_RCC_MANGLE_NAMESPACE(
                name ) name
```

2.8.1.2 QT_RCC_PREPEND_NAMESPACE

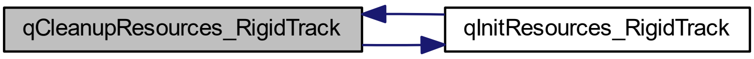
```
#define QT_RCC_PREPEND_NAMESPACE(
              name ) name
```

2.8.2 Function Documentation

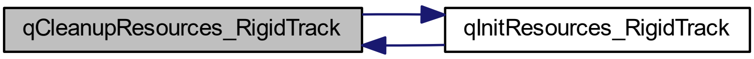
2.8.2.1 qCleanupResources_RigidTrack()

```
int QT_RCC_MANGLE_NAMESPACE() qCleanupResources_RigidTrack ( )
```

Here is the call graph for this function:



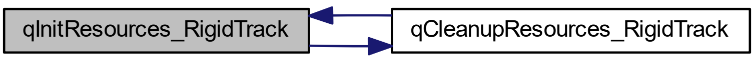
Here is the caller graph for this function:



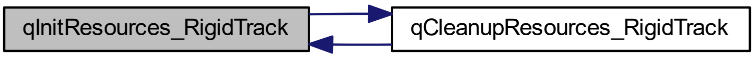
2.8.2.2 qInitResources_RigidTrack()

```
int QT_RCC_MANGLE_NAMESPACE() qInitResources_RigidTrack ( )
```

Here is the call graph for this function:



Here is the caller graph for this function:

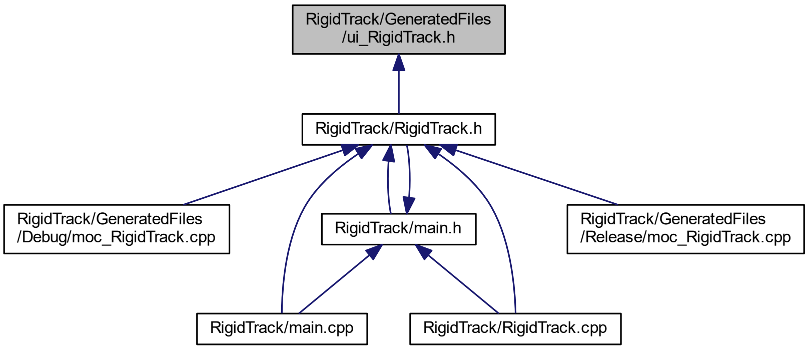


2.9 RigidTrack/GeneratedFiles/ui_RigidTrack.h File Reference

```
#include <QtCore/QVariant>
#include <QtWidgets/QAction>
#include <QtWidgets/QApplication>
#include <QtWidgets/QButtonGroup>
#include <QtWidgets/QCheckBox>
#include <QtWidgets/QDoubleSpinBox>
#include <QtWidgets/QGroupBox>
#include <QtWidgets/QHeaderView>
#include <QtWidgets/QLabel>
#include <QtWidgets/QLineEdit>
#include <QtWidgets/QListWidget>
#include <QtWidgets/QMainWindow>
#include <QtWidgets/QMenu>
#include <QtWidgets/QMenuBar>
#include <QtWidgets/QProgressBar>
#include <QtWidgets/QPushButton>
#include <QtWidgets/QRadioButton>
#include <QtWidgets/QSpinBox>
#include <QtWidgets/QStatusBar>
#include <QtWidgets/QToolBar>
#include <QtWidgets/QWidget>
```

Include dependency graph for ui_RigidTrack.h:

This graph shows which files directly or indirectly include this file:



Classes

- class Ui_RigidTrackClass
- class Ui::RigidTrackClass

Namespaces

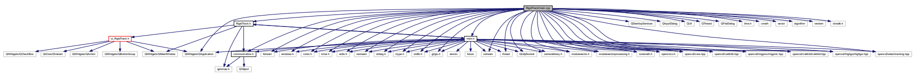
- Ui

2.10 RigidTrack/main.cpp File Reference

```
#include "RigidTrack.h"
#include "main.h"
#include "communication.h"
#include "cameralibrary.h"
#include "modulevector.h"
#include "modulevectorprocessing.h"
#include "coremath.h"
#include <QtWidgets/QApplication>
#include <QDesktopServices>
#include <QInputDialog>
#include <QUrl>
#include <QThread>
#include <QUdpSocket>
#include <QFileDialog>
#include <opencv\cv.h>
#include "opencv2\core.hpp"
#include "opencv2\calib3d.hpp"
#include <opencv2/imgproc/imgproc.hpp>
#include <opencv2/calib3d/calib3d.hpp>
#include <opencv2/highgui/highgui.hpp>
#include <opencv2\video\tracking.hpp>
#include <fstream>
#include <windows.h>
```

```
#include <conio.h>
#include <tchar.h>
#include <stdio.h>
#include <iostream>
#include <stdarg.h>
#include <ctype.h>
#include <stdlib.h>
#include <gl/glu.h>
#include <sstream>
#include <time.h>
#include <cmath>
#include <vector>
#include <algorithm>
#include <random>
#include <thread>
#include <strsafe.h>
```

Include dependency graph for main.cpp:



Functions

- int main (int argc, char ∗argv[ ])

    main initialises the GUI and values for the marker position etc

- QPixmap Mat2QPixmap (cv::Mat src)
- void calcBoardCornerPositions (Size boardSize, float squareSize, std::vector< Point3f > &corners)
- void getEulerAngles (Mat &rotCamerMatrix, Vec3d &eulerAngles)
- int startTracking ()
- void startStopCamera ()

    Start or stop the tracking depending on if the camera is currently running or not.

- int setReference ()
- int calibrateCamera ()

    Start the camera calibration routine that computes the camera matrix and distortion coefficients.

- void loadCalibration (int method)
- void testAlgorithms ()
- void projectCoordinateFrame (Mat pictureFrame)
- void setUpUDP ()

    Open the UDP ports for communication.

- void setHeadingOffset (double d)
- void sendDataUDP (cv::Vec3d &Position, cv::Vec3d &Euler)
- void closeUDP ()
- void loadMarkerConfig (int method)
- void drawPositionText (cv::Mat &Picture, cv::Vec3d &Position, cv::Vec3d &Euler, double error)
- void loadCameraPosition ()
- int determineExposure ()
- void determineOrder ()
- int calibrateGround ()

Variables

- commObject commObj

  class that handles the communication from main.cpp to the GUI
- bool safetyEnable = false

  is the safety feature enabled
- bool safety2Enable = false

  is the second receiver enabled
- double safetyBoxLength = 1.5

  length of the safety area cube in meters
- int safetyAngle = 30

  bank and pitch angle protection in degrees
- bool exitRequested = true

  variable if tracking loop should be exited
- int invertZ = 1

  dummy variable to invert Z direction on request
- double frameTime = 0.01

  100 Hz CoSy rate, is later on replaced with the hardware timestamp delivered by the camera
- double timeOld = 0.0

  old time for finite differences velocity calculation. Is later on replaced with the hardware timestamp delivered by the camera
- double timeFirstFrame = 0

  Time stamp of the first frame. This value is then subtracted for every other frame so the time in the log start at zero.
- Vec3d position = Vec3d()

  position vector x,y,z for object position in O-CoSy, unit is meter
- Vec3d eulerAngles = Vec3d()

  Roll Pitch Heading in this order, units in degrees.
- Vec3d positionOld = Vec3d()

  old position in O-CoSy for finite differences velocity calculation
- Vec3d velocity = Vec3d()

  velocity vector of object in o-CoSy in respect to o-CoSy
- Vec3d posRef = Vec3d()

  initial position of object in camera CoSy
- Vec3d eulerRef = Vec3d()

  initial euler angle of object respectivley to camera CoSy
- double headingOffset = 0

  heading offset variable for aligning INS heading with tracking heading
- int intIntensity = 15

  max infrared spot light intensity is 15 1-6 is strobe 7-15 is continuous 13 and 14 are meaningless
- int intExposure = 1

  max is 480 increase if markers are badly visible but should be determined automatically during setReference()
- int intFrameRate = 100

  CoSy rate of camera, maximum is 100 fps.
- int intThreshold = 200

  threshold value for marker detection. If markers are badly visible lower this value but should not be necessary
- Mat Rmat = (cv::Mat_<double>(3, 1) << 0.0, 0.0, 0.0)

  Rotation, translation etc. matrix for PnP results.
- Mat RmatRef = (cv::Mat_<double>(3, 3) << 1., 0., 0., 0., 1., 0., 0., 0., 1.)

  reference rotation matrix from camera CoSy to marker CoSy
- Mat M_CN = cv::Mat_<double>(3, 3)

  rotation matrix from camera to ground, fixed for given camera position

- Mat M_HeadingOffset = cv::Mat_<double>(3, 3)

  rotation matrix that turns the ground system to the INS magnetic heading for alignment
- Mat Rvec = (cv::Mat_<double>(3, 1) << 0.0, 0.0, 0.0)

  rotation vector (axis-angle notation) from camera CoSy to marker CoSy
- Mat Tvec = (cv::Mat_<double>(3, 1) << 0.0, 0.0, 0.0)

  translation vector from camera CoSy to marker CoSy in camera CoSy
- Mat RvecOriginal

  initial values as start values for algorithms and algorithm tests
- Mat TvecOriginal

  initial values as start values for algorithms and algorithm tests
- bool useGuess = true

  set to true and the algorithm uses the last result as starting value
- int methodPNP = 0

  solvePNP algorithm 0 = iterative 1 = EPNP 2 = P3P 4 = UPNP //!< 4 and 1 are the same and not implemented correctly by OpenCV
- int numberMarkers = 4

  number of markers. Is loaded during start up from the marker configuration file
- std::vector< Point3d > list_points3d

  marker positions in marker CoSy
- std::vector< Point2d > list_points2d

  marker positions projected in 2D in camera image CoSy
- std::vector< Point2d > list_points2dOld

  marker positions in previous picture in 2D in camera image CoSy
- std::vector< double > list_points2dDifference

  difference of the old and new 2D marker position to determine the order of the points
- std::vector< Point2d > list_points2dProjected

  3D marker points projected to 2D in camera image CoSy with the algorithm projectPoints
- std::vector< Point2d > list_points2dUnsorted

  marker points in 2D camera image CoSy, sorted with increasing x (camera image CoSy) but not sorted to correspond with list_points3d
- std::vector< Point3d > coordinateFrame

  coordinate visualisazion of marker CoSy
- std::vector< Point2d > coordinateFrameProjected

  marker CoSy projected from 3D to 2D camera image CoSy
- int pointOrderIndices [ ] = { 0, 1, 2, 3 }

  old correspondence from list_points3d and list_points_2d
- int pointOrderIndicesNew [ ] = { 0, 1, 2, 3 }

  new correspondence from list_points3d and list_points_2d
- double currentPointDistance = 5000

  distance from the projected 3D points (hence in 2d) to the real 2d marker positions in camera image CoSy
- double minPointDistance = 5000

  minimum distance from the projected 3D points (hence in 2d) to the real 2d marker positions in camera image CoSy
- int currentMinIndex = 0

  helper variable set to the point order that holds the current minimum point distance
- bool gotOrder = false

  order of the list_points3d and list_points3d already tetermined or not, has to be done once
- bool camera_started = false

  variable thats needed to exit the main while loop
- Mat cameraMatrix

  camera matrix of the camera
- Mat distCoeffs

distortion coefficients of the camera
- Core::DistortionModel distModel

  distortion model of the camera
- QUdpSocket * udpSocketObject

  socket for the communication with receiver 1
- QUdpSocket * udpSocketSafety

  socket for the communication with safety receiver
- QUdpSocket * udpSocketSafety2

  socket for the communication with receiver 3
- QHostAddress IPAdressObject = QHostAddress("127.0.0.1")

  IPv4 adress of receiver 1.
- QHostAddress IPAdressSafety = QHostAddress("192.168.4.1")

  IPv4 adress of safety receiver.
- QHostAddress IPAdressSafety2 = QHostAddress("192.168.4.4")

  IPv4 adress of receiver 2.
- int portObject = 9155

  Port of receiver 1.
- int portSafety = 9155

  Port of the safety receiver.
- int portSafety2 = 9155

  Port of receiver 2.
- QByteArray datagram

  data package that is sent to receiver 1 and 2
- QByteArray data

  data package that's sent to the safety receiver
- const int BACKBUFFER_BITSPERPIXEL = 8

  8 bit per pixel and greyscale image from camera
- std::string strBuf

  buffer that holds the strings that are sent to the Qt GUI
- std::stringstream ss

  stream that sends the strBuf buffer to the Qt GUI
- QString logFileName

  Filename for the logfiles.
- std::string logName

  Filename for the logfiles as standard string.
- SYSTEMTIME logDate

  Systemtime struct that saves the current date and time thats needed for the log file name creation.
- std::ofstream logfile

  file handler for writing the log file

2.10.1 Function Documentation

2.10.1.1 calcBoardCornerPositions()

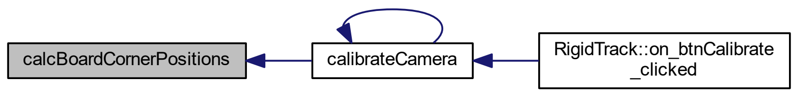
```
void calcBoardCornerPositions (
            Size boardSize,
            float squareSize,
            std::vector< Point3f > & corners )
```

Calculate the chess board corner positions, used for the camera calibration.

Parameters

`in`	*boardSize*	denotes how many squares are in each direction.
`in`	*squareSize*	is the square length in millimeters.
`out`	*corners*	returns the square corners in millimeters.

Here is the caller graph for this function:



2.10.1.2 calibrateCamera()

```
int calibrateCamera ( )
```

Start the camera calibration routine that computes the camera matrix and distortion coefficients.

Initialize Camera SDK ==–

At this point the Camera SDK is actively looking for all connected cameras and will initialize them on it's own.

Get a connected camera ================-—

Determine camera resolution

Set Video Mode ==–

We set the camera to Segment Mode here. This mode is support by all of our products. Depending on what device you have connected you might want to consider a different video mode to achieve the best possible tracking quality. All devices that support a mode that will achieve a better quality output with a mode other than Segment Mode are listed here along with what mode you should use if you're looking for the best head tracking:

```
V100:R1/R2    Precision Mode
TrackIR 5     Bit-Packed Precision Mode
V120          Precision Mode
TBar          Precision Mode
S250e         Precision Mode
```

If you have questions about a new device that might be conspicuously missing here or have any questions about head tracking, email support or participate in our forums.

Start camera output ==–

Camera Matrix creation ==–

Ok, start main loop. This loop fetches and displays ===— camera frames. ===— But first set some camera parameters the user has to provide the size of one square in mm

Fetch a new frame from the camera ===—

which is why we also set this constant to 8

later on, when we get the frame as usual:

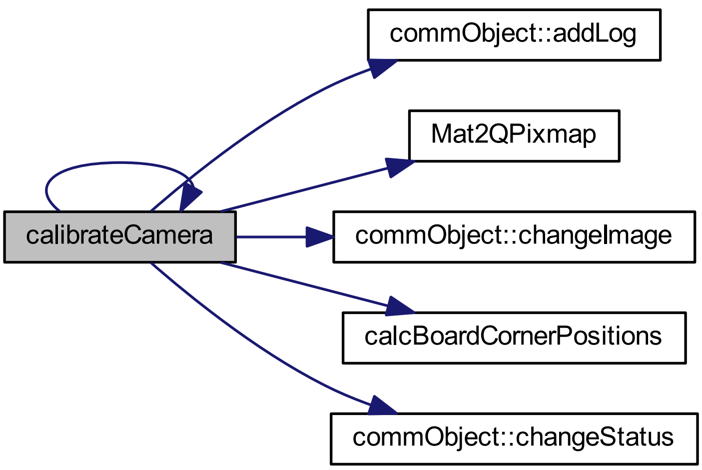
Lets have the Camera Library raster the camera's image into our texture.

< If done with success,

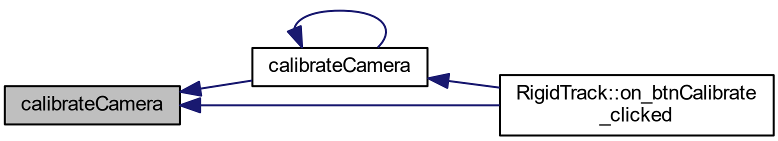
improve the found corners' coordinate accuracy for chessboard

Release camera ==–

Save the obtained calibration coefficients in a file for later use Here is the call graph for this function:



Here is the caller graph for this function:



2.10.1.3 calibrateGround()

```
int calibrateGround ( )
```

Get the pose of the camera w.r.t the ground calibration frame. This frame sets the navigation frame for later results. The pose is averaged over 200 samples and then saved in the file referenceData.xml. This routine is basically the same as setReference. initialize the variables with starting values

Initialize Camera SDK ==–

At this point the Camera SDK is actively looking for all connected cameras and will initialize them on it's own.

Get a connected camera ================-—

If no device connected, pop a message box and exit ==–

Determine camera resolution to size application window ==-—

Set camera mode to precision mode, it directly provides marker coordinates

Start camera output ==–

Turn on some overlay text so it's clear things are ===— working even if there is nothing in the camera's view. ===— Set some other parameters as well of the camera

sample some frames and calculate the position and attitude. then average those values and use that as zero position

Fetch a new frame from the camera ===—

Ok, we've received a new frame, lets do something with it.

for(int i=0; i<frame->ObjectCount(); i++)

sort the 2d points with the correct indices as found in the preceeding order determination algorithm

Compute the pose from the 3D-2D corresponses

project the marker 3d points with the solution into the camera image CoSy and calculate difference to true camera image

<Iterative Method needs time to converge to solution

< That are not the values of yaw, roll and pitch yet! Rodriguez has to be called first.

<– one sample more :D

Release camera ==–

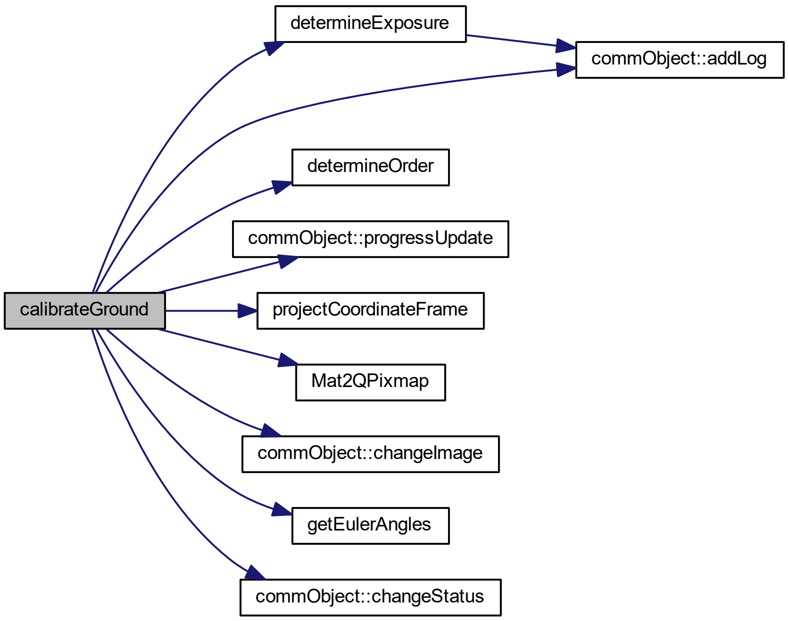
Divide by the number of samples to get the mean of the reference position

< eulerRef is here in Axis Angle notation

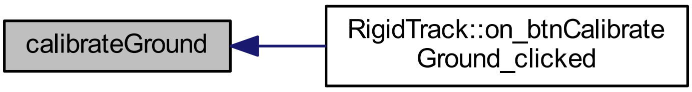
< axis angle to rotation matrix

< rotation matrix to euler

Save the obtained calibration coefficients in a file for later use Here is the call graph for this function:



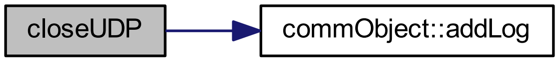
Here is the caller graph for this function:



2.10.1.4 closeUDP()

```
void closeUDP ( )
```

Close the UDP ports again to release network interfaces etc. If this is not done the network resources are still occupied and the program can't exit properly. check if the socket is open and if yes close it Here is the call graph for this function:



Here is the caller graph for this function:

2.10.1.5 determineExposure()

```
int determineExposure ( )
```

Get the optimal exposure for the camera. For that find the minimum and maximum exposure were the right number of markers are detected. Then the mean of those two values is used as exposure. For OptiTrack Ethernet cameras, it's important to enable development mode if you want to stop execution for an extended time while debugging without disconnecting the Ethernet devices. Lets do that now:

Initialize Camera SDK ==–

At this point the Camera SDK is actively looking for all connected cameras and will initialize them on it's own.

Get a connected camera ================-—

If no device connected, pop a message box and exit ==–

Determine camera resolution to size application window ==-—

set the camera mode to precision mode, it used greyscale imformation for marker property calculations

Start camera output ==–

Turn on some overlay text so it's clear things are ===— working even if there is nothing in the camera's view. ===—

set the camera exposure

set the camera infrared LED intensity

set the camera framerate to 100 Hz

enable the filter that blocks visible light and only passes infrared light

enable high power mode of the leds

enable continuous LED light

set threshold for marker detection

set exposure such that num markers are visible

Number of objects (markers) found in the current picture with the given exposure

exposure when objects detected the first time is numberMarkers

exposure when objects detected is first time numberMarkers+1

set the exposure to the smallest value possible

if the markers arent found after numberTries then there might be no markers at all in the real world

Determine minimum exposure, hence when are numberMarkers objects detected

get a new camera frame

frame received

how many objects are detected in the image

if the right amount if markers is found, exit while loop

not the right amount of markers was found so increase the exposure and try again

Now determine maximum exposure, hence when are numberMarkers+1 objects detected

if the markers arent found after numberTries then there might be no markers at all in the real world

how many objects are detected in the image

if the right amount if markers is found, exit while loop

not the right amount of markers was found so decrease the exposure and try again

set the exposure to the mean of min and max exposure determined

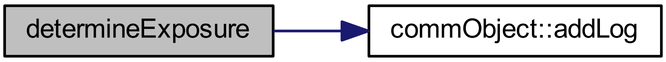
and now check if the correct amount of markers is detected with that new value

how many objects are detected in the image

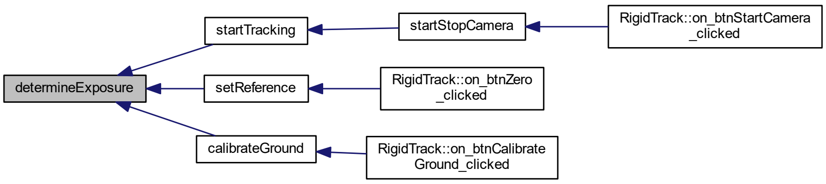
are all markers and not more or less detected in the image

Release camera ==–

all markers and not more or less are found Here is the call graph for this function:



Here is the caller graph for this function:



2.10.1.6 determineOrder()

```
void determineOrder ( )
```

Compute the order of the marker points in 2D so they are the same as in the 3D array. Hence marker 1 must be in first place for both, list_points2d and list_points3d. determine the 3D-2D correspondences that are crucial for the PnP algorithm Try every possible correspondence and solve PnP Then project the 3D marker points into the 2D camera image and check the difference between projected points and points as seen by the camera the corresponce with the smallest difference is probably the correct one

the difference between true 2D points and projected points is super big

now try every possible permutation of correspondence

reset the starting values for solvePnP

sort the 2d points with the current permutation

Call solve PNP with P3P since its more robust and sufficient for start value determination

set the current difference of all point correspondences to zero

project the 3D points with the solvePnP solution onto 2D

now compute the absolute difference (error)

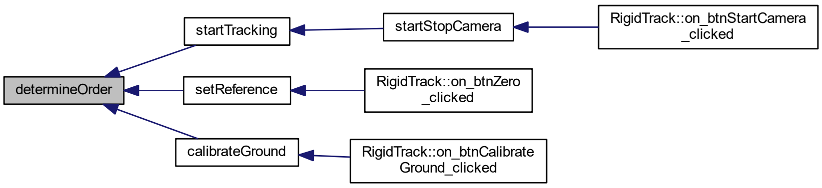
if the difference with the current permutation is smaller than the smallest value till now it is probably the more correct permutation

< set the smallest value of difference to the current one

< now safe the better permutation

try every permutation

now that the correct order is found assign it to the indices array Here is the caller graph for this function:



2.10.1.7 drawPositionText()

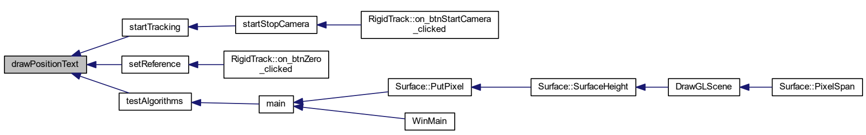
```
void drawPositionText (
            cv::Mat & Picture,
            cv::Vec3d & Position,
            cv::Vec3d & Euler,
            double error )
```

Draw the position, attitude and reprojection error in the picture.

Parameters

in	*Picture*	is the camera image in OpenCV matrix format.
in	*Position*	is the position of the tracked object in navigation CoSy.
in	*Euler*	are the Euler angles with respect to the navigation frame.
in	*error*	is the reprojection error of the pose estimation.

Here is the caller graph for this function:



2.10.1.8 getEulerAngles()

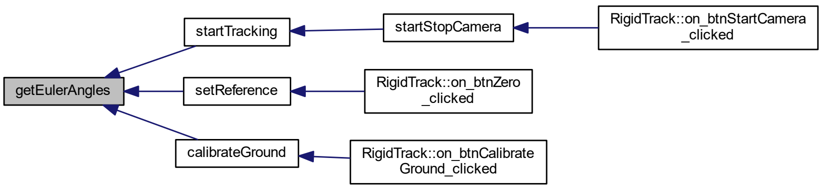
```
void getEulerAngles (
            Mat & rotCamerMatrix,
            Vec3d & eulerAngles )
```

Get the euler angles from a rotation matrix

Parameters

in	*rotCamerMatrix*	is a projection matrix, here normally only the extrinsic values.
out	*eulerAngles*	contains the Euler angles that result in the same rotation matrix as rotCamerMatrix.

Here is the caller graph for this function:



2.10.1.9 loadCalibration()

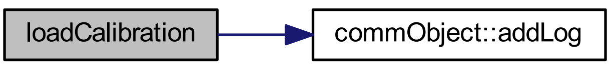
```
void loadCalibration (
            int method )
```

Load a previously saved camera calibration from a file.

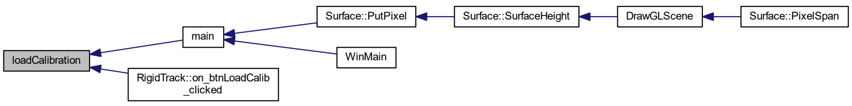
Parameters

in	*method*	whether or not load the camera calibration from calibration.xml. If ==0 then yes, if != 0 then let the user select a different file.

Here is the call graph for this function:



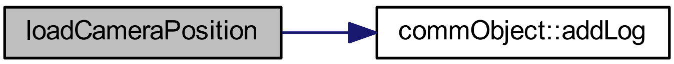
Here is the caller graph for this function:



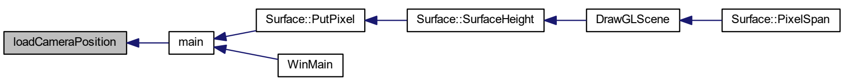
2.10.1.10 loadCameraPosition()

```
void loadCameraPosition ( )
```

Load the rotation matrix from camera CoSy to ground CoSy It is determined during calibrateGround() and stays the same once the camera is mounted and fixed. Open the referenceData.xml that contains the rotation from camera CoSy to ground CoSy Here is the call graph for this function:



Here is the caller graph for this function:



2.10.1.11 loadMarkerConfig()

```
void loadMarkerConfig (
            int method )
```

Load a marker configuration from file. This file has to be created by hand, use the standard marker configuration file as template.

Parameters

in	*method*	whether or not load the configuration from the markerStandard.xml. If ==0 load it, if != 0 let the user select a different file.

during start up of the programm load the standard marker configuration

open the standard marker configuration file

copy the values to the respective variables

inizialise vectors with correct length depending on the number of markers

save the marker locations in the points3d vector

if the load marker configuration button was clicked show a open file dialog

was cancel or abort clicked

if yes load the standard marker configuration

open the selected marker configuration file

copy the values to the respective variables

inizialise vectors with correct length depending on the number of markers

save the marker locations in the points3d vector

Print out the number of markers and their position to the GUI

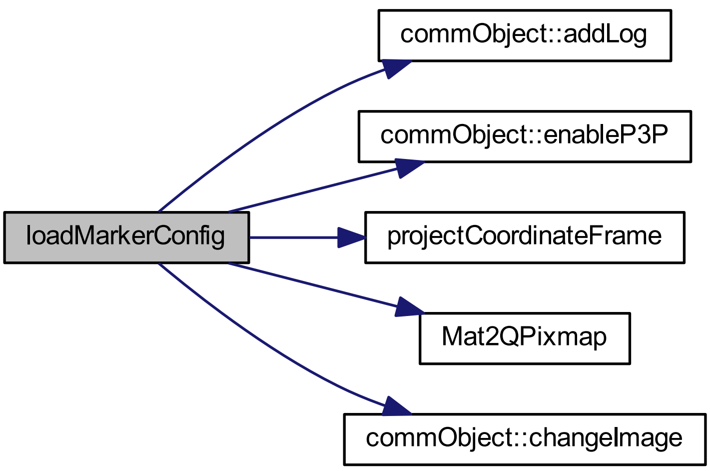
check if P3P algorithm can be enabled, it needs exactly 4 marker points to work

if P3P is possible, let the user choose which algorithm he wants but keep iterative active

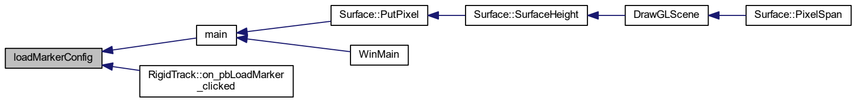
More (or less) marker than 4 loaded, P3P is not possible, hence user cant select P3P in GUI

now display the marker configuration in the camera view

Set the camera pose parallel to the marker coordinate system Here is the call graph for this function:



Here is the caller graph for this function:



2.10.1.12 main()

```
int main (
        int argc,
        char * argv[ ] )
```

main initialises the GUI and values for the marker position etc

First the GUI is set up with Signals and Slots, see Qt docu for how that works. Then some variables are initialized with arbitrary values. At last calibration and marker configuration etc. are loaded from xml files.

Parameters

in	*argc*	is not used.
in	*argv*	is also not used.

< show the GUI

connect the Qt slots and signals for event handling

initial guesses for position and rotation, important for Iterative Method!

Points that make up the marker CoSy axis system, hence one line in each axis direction

< set position initial values

< set position initial values

< set position initial values

< set velocity initial values

< set velocity initial values

< set velocity initial values

< set initial euler angles to arbitrary values for testing

< set initial euler angles to arbitrary values for testing

< set initial euler angles to arbitrary values for testing

< set the heading offset to 0

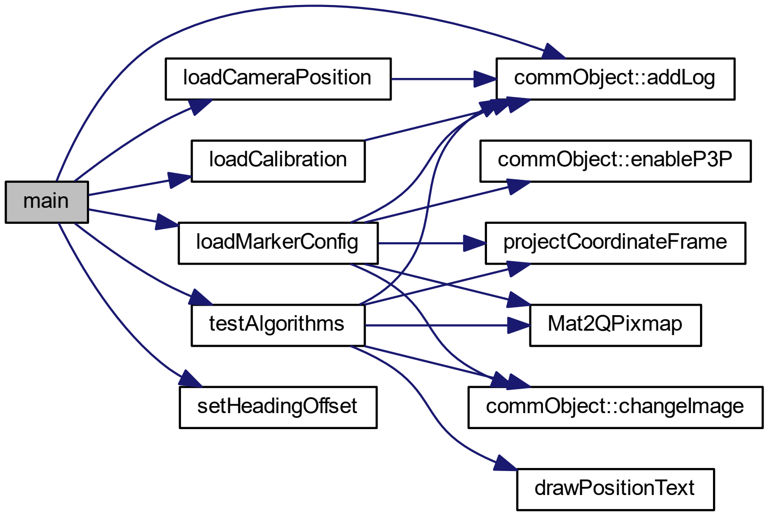
< outputs in the log etc are limited to 3 decimal values

< load the rotation matrix from camera CoSy to ground CoSy

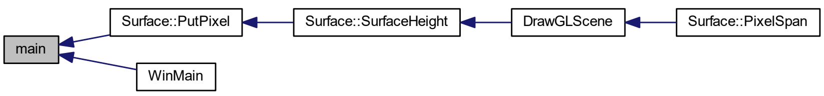
< load the calibration file with the camera intrinsics

< load the standard marker configuration

< test the algorithms and their accuracy Here is the call graph for this function:



Here is the caller graph for this function:



2.10.1.13 Mat2QPixmap()

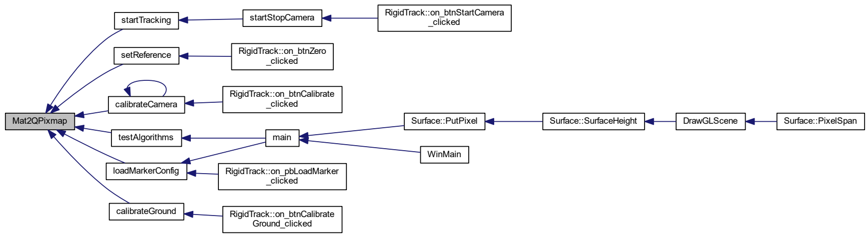
```
QPixmap Mat2QPixmap (
            cv::Mat src )
```

Convert an opencv matrix that represents a picture to a Qt Pixmap object for the GUI.

Parameters

in	*src*	is the camera image represented as OpenCV matrix.

enforce deep copy, see documentation of QImage::QImage (const uchar ∗ data, int width, int height, Format format) Here is the caller graph for this function:



2.10.1.14 projectCoordinateFrame()

```
void projectCoordinateFrame (
            Mat pictureFrame )
```

Project the coordinate CoSy origin and axis direction of the marker CoSy with the rotation and translation of the object for visualization.

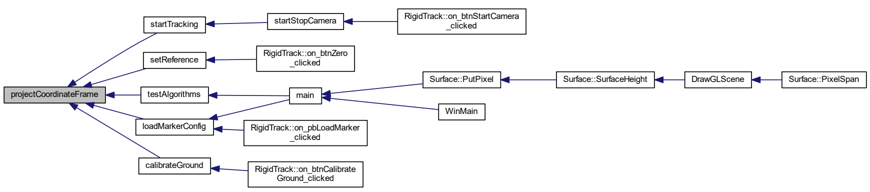
Parameters

in	*pictureFrame*	the image in which the CoSy frame should be pasted.

<z-axis

<x-axis

<y-axis Here is the caller graph for this function:



2.10.1.15 sendDataUDP()

```
void sendDataUDP (
            cv::Vec3d & Position,
            cv::Vec3d & Euler )
```

Send the position and attitude over UDP to every receiver, the safety receiver is handled on its own in the start←- Tracking function because its send rate is less than 100 Hz. Roll Pitch Heading

if second receiver is activated send it also the tracking data Here is the caller graph for this function:

2.10.1.16 setHeadingOffset()

```
void setHeadingOffset (
            double d )
```

Add a heading offset to the attitude for the case it is wanted by the user.

Parameters

in	*d*	denotes heading offset in degrees.

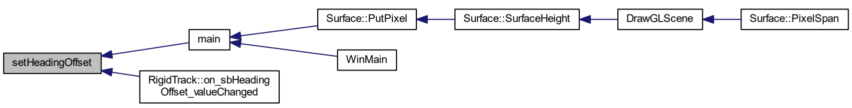
Convert heading offset from degrees to rad

Calculate rotation about x axis

Calculate rotation about y axis

Calculate rotation about z axis

Combined rotation matrix Here is the caller graph for this function:



2.10.1.17 setReference()

```
int setReference ( )
```

Determine the initial position of the object that serves as reference point or as ground frame origin. Computes the pose 200 times and then averages it. The position and attitude are from now on used as navigation CoSy. initialize the variables with starting values

Initialize Camera SDK ==–

At this point the Camera SDK is actively looking for all connected cameras and will initialize them on it's own.

Get a connected camera ================-—

If no device connected, pop a message box and exit ==–

Determine camera resolution to size application window ==-—

Set camera mode to precision mode, it directly provides marker coordinates

Start camera output ==–

Turn on some overlay text so it's clear things are ===— working even if there is nothing in the camera's view. ===— Set some other parameters as well of the camera

sample some frames and calculate the position and attitude. then average those values and use that as zero position

< difference between the marker points as seen by the camera and the projected marker points with Rvec and Tvec

Fetch a new frame from the camera ===—

Ok, we've received a new frame, lets do something with it.

for(int i=0; i<frame->ObjectCount(); i++)

sort the 2d points with the correct indices as found in the preceeding order determination algorithm

Compute the pose from the 3D-2D corresponses

project the marker 3d points with the solution into the camera image CoSy and calculate difference to true camera image

<Iterative Method needs time to converge to solution

< That are not the values of yaw, roll and pitch yet! Rodriguez has to be called first.

< one sample more :D

Release camera ==–

Divide by the number of samples to get the mean of the reference position

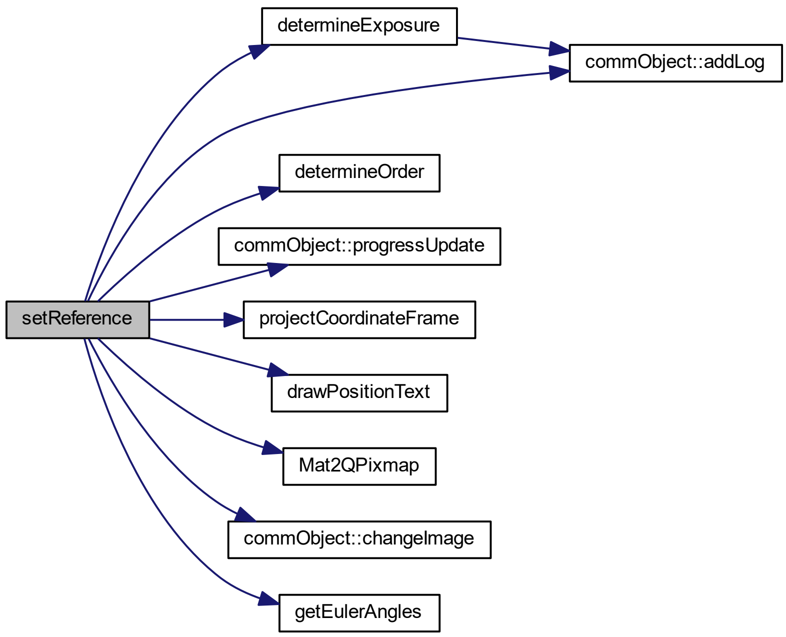
< eulerRef is here in Axis Angle notation

< axis angle to rotation matrix

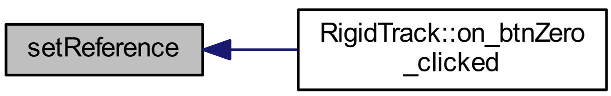
– Euler Angles, finally

< rotation matrix to euler

compute the difference between last obtained TVec and the average Value When it is large the iterative method has not converged properly so it is advised to start the setReference() function once again Here is the call graph for this function:



Here is the caller graph for this function:



2.10.1.18 setUpUDP()

```
void setUpUDP ( )
```

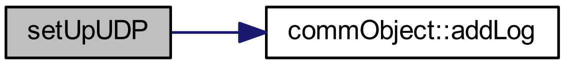
Open the UDP ports for communication.

Initialise the QDataStream that stores the data to be send

Create UDP slots

if the safety feature is activated open the udp port

if the second receiver feature is activated open the udp port Here is the call graph for this function:



Here is the caller graph for this function:

2.10.1.19 startStopCamera()

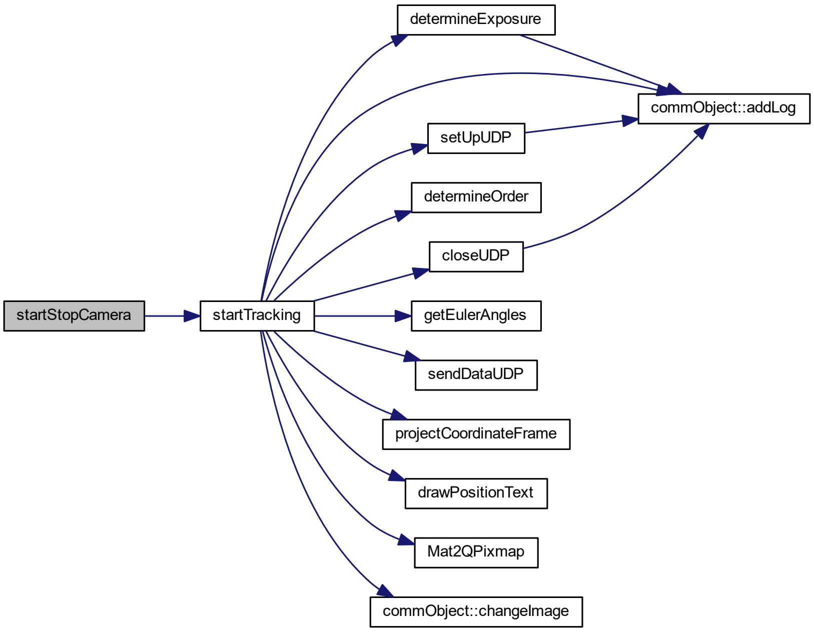
```
void startStopCamera ( )
```

Start or stop the tracking depending on if the camera is currently running or not.

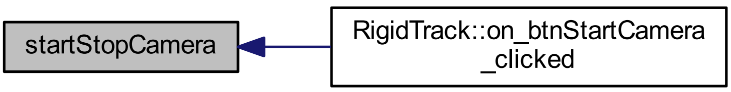
tracking is not running so start it

< tracking is currently running, set exitRequest to true so the while loop in startTracking() exits Here is the call graph

for this function:



Here is the caller graph for this function:



2.10.1.20 startTracking()

```
int startTracking ( )
```

Start the loop that fetches frames, computes the position etc and sends it to other computers. This function is the core of this program, hence the pose estimation is done here. The order of points, hence which entry in list_points3d corresponds to which in list_points2d is not calculated yet

Use the value of Rvec that was set in main() as starting value for the solvePnP algorithm

Use the value of Tvec that was set in main() as starting value for the solvePnP algorithm

Get the current date and time to name the log file

Concat the log file name as followed. The file is saved in the folder /logs in the Rigid Track installation folder

Convert the QString to a standard string

Get the exposure where the right amount of markers is detected

For OptiTrack Ethernet cameras, it's important to enable development mode if you want to stop execution for an extended time while debugging without disconnecting the Ethernet devices. Lets do that now:

Initialize Camera SDK

At this point the Camera SDK is actively looking for all connected cameras and will initialize them on it's own

Get a connected camera

If no camera can be found, inform user in message log and exit function

Determine camera resolution to size application window

Set the camera mode to precision mode, it used greyscale imformation for marker property calculations

Start camera output

Turn on some overlay text so it's clear things are working even if there is nothing in the camera's view

Set the camera exposure

Set the camera infrared LED intensity

Set the camera framerate to 100 Hz

Enable the filter that blocks visible light and only passes infrared light

Enable high power mode of the LEDs

Disable continuous LED light

Set threshold for marker detection

Create a new matrix that stores the grayscale picture from the camera

QPixmap is the corresponding Qt class that saves images

Matrix that stores the colored picture, hence marker points, coordinate frame and reprojected points

Helper variable used to kick safety switch

Variables for the min and max values that are needed for sanity checks

Ff a marker is not visible or accuracy is bad increase this counter

Equals the quality of the tracking

Open sockets and ports for UDP communication

If the safety feature is enabled send the starting message

Send enable message, hence send a 9 and then a 1

Fetch a new frame from the camera

Get the timestamp of the first frame. This time is subtracted from every subseeding frame so the time starts at 0 in the logs

While no new frame is received loop

Get a new camera frame

There is actually a new frame

Get the time stamp for the first frame. It is subtracted for the following frames

Release the frame so the camera can continue

Exit the while loop

Now enter the main loop that processes each frame and computes the pose, sends it and logs stuff

Check if the user has not pressed "Stop Tracking" yet

Fetch a new frame from the camera

Did we got a new frame or does the camera still need more time

Increase by one, if everything is okay it is decreased at the end of the loop again

Only use this frame it the right number of markers is found in the picture

Get the marker points in 2D in the camera image frame and store them in the list_points2dUnsorted vector The order of points that come from the camera corresponds to the Y coordinate

Was the order already determined? This is false for the first frame and from then on true

Now compute the order

Sort the 2d points with the correct indices as found in the preceeding order determination algorithm

pointOrderIndices was calculated in determineOrder()

The first time the 2D-3D corresspondence was determined with gotOrder was okay. But this order can change as the object moves and the marker objects appear in a different order in the frame->Object() array. The solution is that: When a marker point (in the camera image, hence in 2D) was at a position then it wont move that much from one frame to the other. So for the new frame we take a marker object and check which marker was closest this point in the old image frame? This is probably the same (true) marker. And we do that for every other marker as well. When tracking is good and no frames are dropped because of missing markers this should work every frame.

The sum of point distances is set to something unrealistic large

Calculate N_2 norm of unsorted points minus old points

If the norm is smaller than minPointDistance the correspondence is more likely to be correct

Update the array that saves the new point order

Now the new order is found, set the point order to the new value

Save the unsorted position of the marker points for the next loop

Compute the object pose from the 3D-2D corresponses

Project the marker 3d points with the solution into the camera image CoSy and calculate difference to true camera image

Difference of true pose and found pose

Increase the framesDropped variable if accuracy of tracking is too bad

Set number of subsequent frames dropped to zero because error is small enough and no marker was missing

Get the min and max values from TVec for sanity check

Sanity check of values. negative z means the marker CoSy is behind the camera, that's not possible.

Release the frame so the camera can move on

Release the camera

Close all UDP connections so the programm can be closed later on and no resources are locked

Exit the function

Next step is the transformation from camera CoSy to navigation CoSy Compute the relative object position from the reference position to the current one given in the camera CoSy: $T_C^{NM} = Tvec - Tvec_{Ref}$

Transform the position from the camera CoSy to the navigation CoSy with INS alligned heading and convert from [mm] to [m] $T_N^{NM} = M_{NC} \times T_C^{NM}$

Position is the result of the preceeding calculation

Invert Z if check box in GUI is activated, hence height above ground is considered

Realtive angle between reference orientation and current orientation

Convert axis angle respresentation to ordinary rotation matrix

The difference of the reference rotation and the current rotation $R_{NM} = M_{NC} \times R_{CM}$

Euler Angles, finally

Get the euler angles from the rotation matrix

Add the heading offset to the heading angle

Compute the velocity with finite differences. Only use is the log file. It is done here because the more precise time stamp can be used

Time between the old frame and the current frame

Set the old frame time to the current one

Calculate the x velocity with finite differences

Calculate the y velocity with finite differences

Calculate the z velocity with finite differences

Set the old position to the current one for next frame velocity calcuation

Send position and Euler angles over WiFi with 100 Hz

Save the values in a log file, values are: Time sinc tracking started Position Euler Angles Velocity

Open the log file, the folder is RigidTrackInstallationFolder/logs

Close the file to save values

Check if the position and euler angles are below the allowed value, if yes send OKAY signal (1), if not send shutdown signal (0) Absolute x, y and z position in navigation CoSy must be smaller than the allowed distance

Absolute Euler angles must be smaller than allowed value. Heading is not considered

Send the OKAY signal to the desired computer every 5th time

Send the 1

reset the counter that is needed for decimation to every 5th time step

The euler angles of the object exceeded the allowed euler angles, send the shutdown signal (0)

Send the shutdown signal, a 0

Inform the user

The position of the object exceeded the allowed position, shut the object down

Send the shutdown signal, a 0

Inform the user

Inform the user if tracking system is disturbed (marker lost or so) or error was too big

Also send the shutdown signal

Send the shutdown signal, a 0

Inform the user

Rasterize the frame so it can be shown in the GUI

Convert the frame from greyscale as it comes from the camera to rgb color

Project (draw) the marker CoSy origin into 2D and save it in the cFrame image

Project the marker points from 3D to the camera image frame (2d) with the computed pose

Draw a circle around the projected points so the result can be better compared to the real marker position In the resulting picture those are the red dots

Write the current position, attitude and error values as text in the frame

Send the new camera picture to the GUI and call the GUI processing routine

Update the picture in the GUI

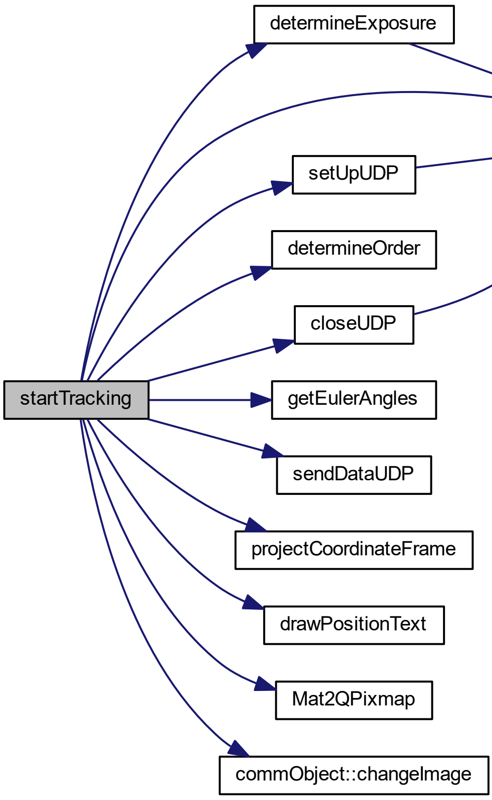
Give Qt time to handle everything

Release the camera frame to fetch the new one

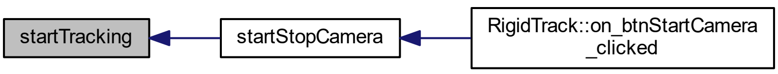
User choose to stop the tracking, clean things up

Close the UDP connections so resources are deallocated

Release camera Here is the call graph for this function:



Here is the caller graph for this function:



2.10.1.21 testAlgorithms()

```
void testAlgorithms ( )
```

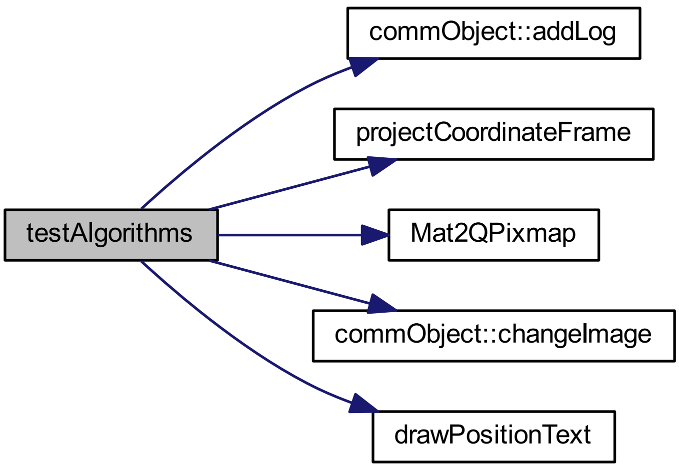
Project some points from 3D to 2D and then check the accuracy of the algorithms. Mainly to generate something that can be shown in the camera view so the user knows everything loaded correctly. $<$ in mm

$<$ 0 = iterative 1 = EPNP 2 = P3P 4 = UPNP //!$<$ not used

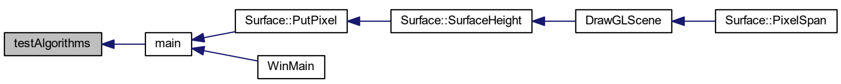
$<$ 0 = iterative 1 = EPNP 2 = P3P 4 = UPNP UPnP not used

$<$ 0 = iterative 1 = EPNP 2 = P3P 4 = UPNP //!$<$ not used

$<$ 0 = iterative 1 = EPNP 2 = P3P 4 = UPNP //!$<$ not used Here is the call graph for this function:



Here is the caller graph for this function:



2.10.2 Variable Documentation

2.10.2.1 BACKBUFFER_BITSPERPIXEL

```
const int BACKBUFFER_BITSPERPIXEL = 8
```

8 bit per pixel and greyscale image from camera

2.10.2.2 camera_started

```
bool camera_started = false
```

variable thats needed to exit the main while loop

2.10.2.3 cameraMatrix

```
Mat cameraMatrix
```

camera matrix of the camera

2.10.2.4 commObj

```
commObject commObj
```

class that handles the communication from main.cpp to the GUI

Now declare variables that are used across the main.cpp file. Basically almost every variable used is declared here.

2.10.2.5 coordinateFrame

```
std::vector<Point3d> coordinateFrame
```

coordinate visualisazion of marker CoSy

2.10.2.6 coordinateFrameProjected

```
std::vector<Point2d> coordinateFrameProjected
```

marker CoSy projected from 3D to 2D camera image CoSy

2.10.2.7 currentMinIndex

```
int currentMinIndex = 0
```

helper variable set to the point order that holds the current minimum point distance

2.10.2.8 currentPointDistance

```
double currentPointDistance = 5000
```

distance from the projected 3D points (hence in 2d) to the real 2d marker positions in camera image CoSy

2.10.2.9 data

```
QByteArray data
```

data package that's sent to the safety receiver

2.10.2.10 datagram

```
QByteArray datagram
```

data package that is sent to receiver 1 and 2

2.10.2.11 distCoeffs

```
Mat distCoeffs
```

distortion coefficients of the camera

2.10.2.12 distModel

```
Core::DistortionModel distModel
```

distortion model of the camera

2.10.2.13 eulerAngles

```
Vec3d eulerAngles = Vec3d()
```

Roll Pitch Heading in this order, units in degrees.

2.10.2.14 eulerRef

```
Vec3d eulerRef = Vec3d()
```

initial euler angle of object respectivley to camera CoSy

2.10.2.15 exitRequested

```
bool exitRequested = true
```

variable if tracking loop should be exited

2.10.2.16 frameTime

```
double frameTime = 0.01
```

100 Hz CoSy rate, is later on replaced with the hardware timestamp delivered by the camera

2.10.2.17 gotOrder

```
bool gotOrder = false
```

order of the list_points3d and list_points3d already tetermined or not, has to be done once

2.10.2.18 headingOffset

```
double headingOffset = 0
```

heading offset variable for aligning INS heading with tracking heading

2.10.2.19 intExposure

```
int intExposure = 1
```

max is 480 increase if markers are badly visible but should be determined automatically during setReference()

2.10.2.20 intFrameRate

```
int intFrameRate = 100
```

CoSy rate of camera, maximum is 100 fps.

2.10.2.21 intIntensity

```
int intIntensity = 15
```

max infrared spot light intensity is 15 1-6 is strobe 7-15 is continuous 13 and 14 are meaningless

2.10.2.22 intThreshold

```
int intThreshold = 200
```

threshold value for marker detection. If markers are badly visible lower this value but should not be necessary

2.10.2.23 invertZ

```
int invertZ = 1
```

dummy variable to invert Z direction on request

2.10.2.24 IPAdressObject

```
QHostAddress IPAdressObject = QHostAddress("127.0.0.1")
```

IPv4 adress of receiver 1.

2.10.2.25 IPAdressSafety

```
QHostAddress IPAdressSafety = QHostAddress("192.168.4.1")
```

IPv4 adress of safety receiver.

2.10.2.26 IPAdressSafety2

```
QHostAddress IPAdressSafety2 = QHostAddress("192.168.4.4")
```

IPv4 adress of receiver 2.

2.10.2.27 list_points2d

```
std::vector<Point2d> list_points2d
```

marker positions projected in 2D in camera image CoSy

2.10.2.28 list_points2dDifference

```
std::vector<double> list_points2dDifference
```

difference of the old and new 2D marker position to determine the order of the points

2.10.2.29 list_points2dOld

```
std::vector<Point2d> list_points2dOld
```

marker positions in previous picture in 2D in camera image CoSy

2.10.2.30 list_points2dProjected

```
std::vector<Point2d> list_points2dProjected
```

3D marker points projected to 2D in camera image CoSy with the algorithm projectPoints

2.10.2.31 list_points2dUnsorted

```
std::vector<Point2d> list_points2dUnsorted
```

marker points in 2D camera image CoSy, sorted with increasing x (camera image CoSy) but not sorted to correspond with list_points3d

2.10.2.32 list_points3d

```
std::vector<Point3d> list_points3d
```

marker positions in marker CoSy

2.10.2.33 logDate

```
SYSTEMTIME logDate
```

Systemtime struct that saves the current date and time thats needed for the log file name creation.

2.10.2.34 logfile

```
std::ofstream logfile
```

file handler for writing the log file

2.10.2.35 logFileName

```
QString logFileName
```

Filename for the logfiles.

2.10.2.36 logName

```
std::string logName
```

Filename for the logfiles as standard string.

2.10.2.37 M_CN

```
Mat M_CN = cv::Mat_<double>(3, 3)
```

rotation matrix from camera to ground, fixed for given camera position

2.10.2.38 M_HeadingOffset

```
Mat M_HeadingOffset = cv::Mat_<double>(3, 3)
```

rotation matrix that turns the ground system to the INS magnetic heading for alignment

2.10.2.39 methodPNP

```
int methodPNP = 0
```

solvePNP algorithm 0 = iterative 1 = EPNP 2 = P3P 4 = UPNP //!< 4 and 1 are the same and not implemented correctly by OpenCV

2.10.2.40 minPointDistance

```
double minPointDistance = 5000
```

minimum distance from the projected 3D points (hence in 2d) to the real 2d marker positions in camera image CoSy

2.10.2.41 numberMarkers

```
int numberMarkers = 4
```

number of markers. Is loaded during start up from the marker configuration file

2.10.2.42 pointOrderIndices

```
int pointOrderIndices[] = { 0, 1, 2, 3 }
```

old correspondence from list_points3d and list_points_2d

2.10.2.43 pointOrderIndicesNew

```
int pointOrderIndicesNew[] = { 0, 1, 2, 3 }
```

new correspondence from list_points3d and list_points_2d

2.10.2.44 portObject

```
int portObject = 9155
```

Port of receiver 1.

2.10.2.45 portSafety

```
int portSafety = 9155
```

Port of the safety receiver.

2.10.2.46 portSafety2

```
int portSafety2 = 9155
```

Port of receiver 2.

2.10.2.47 position

```
Vec3d position = Vec3d()
```

position vector x,y,z for object position in O-CoSy, unit is meter

2.10.2.48 positionOld

```
Vec3d positionOld = Vec3d()
```

old position in O-CoSy for finite differences velocity calculation

2.10.2.49 posRef

```
Vec3d posRef = Vec3d()
```

initial position of object in camera CoSy

2.10.2.50 Rmat

```
Mat Rmat = (cv::Mat_<double>(3, 1) << 0.0, 0.0, 0.0)
```

Rotation, translation etc. matrix for PnP results.

rotation matrix from camera CoSy to marker CoSy

2.10.2.51 RmatRef

```
Mat RmatRef = (cv::Mat_<double>(3, 3) << 1., 0., 0., 0., 1., 0., 0., 0., 1.)
```

reference rotation matrix from camera CoSy to marker CoSy

2.10.2.52 Rvec

```
Mat Rvec = (cv::Mat_<double>(3, 1) << 0.0, 0.0, 0.0)
```

rotation vector (axis-angle notation) from camera CoSy to marker CoSy

2.10.2.53 RvecOriginal

```
Mat RvecOriginal
```

initial values as start values for algorithms and algorithm tests

2.10.2.54 safety2Enable

```
bool safety2Enable = false
```

is the second receiver enabled

2.10.2.55 safetyAngle

```
int safetyAngle = 30
```

bank and pitch angle protection in degrees

2.10.2.56 safetyBoxLength

```
double safetyBoxLength = 1.5
```

length of the safety area cube in meters

2.10.2.57 safetyEnable

```
bool safetyEnable = false
```

is the safety feature enabled

2.10.2.58 ss

```
std::stringstream ss
```

stream that sends the strBuf buffer to the Qt GUI

2.10.2.59 strBuf

```
std::string strBuf
```

buffer that holds the strings that are sent to the Qt GUI

2.10.2.60 timeFirstFrame

```
double timeFirstFrame = 0
```

Time stamp of the first frame. This value is then subtracted for every other frame so the time in the log start at zero.

2.10.2.61 timeOld

```
double timeOld = 0.0
```

old time for finite differences velocity calculation. Is later on replaced with the hardware timestamp delivered by the camera

2.10.2.62 Tvec

```
Mat Tvec = (cv::Mat_<double>(3, 1) << 0.0, 0.0, 0.0)
```

translation vector from camera CoSy to marker CoSy in camera CoSy

2.10.2.63 TvecOriginal

```
Mat TvecOriginal
```

initial values as start values for algorithms and algorithm tests

2.10.2.64 udpSocketObject

```
QUdpSocket* udpSocketObject
```

socket for the communication with receiver 1

2.10.2.65 udpSocketSafety

```
QUdpSocket* udpSocketSafety
```

socket for the communication with safety receiver

2.10.2.66 udpSocketSafety2

```
QUdpSocket* udpSocketSafety2
```

socket for the communication with receiver 3

2.10.2.67 useGuess

```
bool useGuess = true
```

set to true and the algorithm uses the last result as starting value

2.10.2.68 velocity

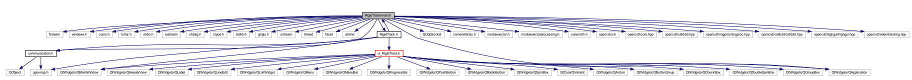
```
Vec3d velocity = Vec3d()
```

velocity vector of object in o-CoSy in respect to o-CoSy

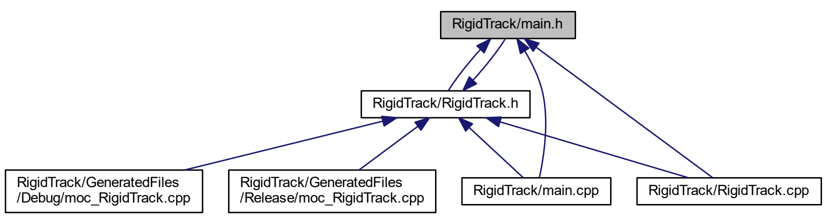
2.11 RigidTrack/main.h File Reference

```
#include <fstream>
#include <windows.h>
#include <conio.h>
#include <tchar.h>
#include <stdio.h>
#include <iostream>
#include <stdarg.h>
#include <ctype.h>
#include <stdlib.h>
#include <gl/glu.h>
#include <sstream>
#include <thread>
#include <future>
#include <atomic>
#include "communication.h"
#include "RigidTrack.h"
#include <QtWidgets/QApplication>
#include <QUdpSocket>
#include "cameralibrary.h"
#include "modulevector.h"
#include "modulevectorprocessing.h"
#include "coremath.h"
#include <opencv\cv.h>
#include "opencv2\core.hpp"
#include "opencv2\calib3d.hpp"
#include <opencv2/imgproc/imgproc.hpp>
#include <opencv2/calib3d/calib3d.hpp>
#include <opencv2/highgui/highgui.hpp>
#include <opencv2\video\tracking.hpp>
```

Include dependency graph for main.h:



This graph shows which files directly or indirectly include this file:



Functions

- int startTracking ()
- void startStopCamera ()

    Start or stop the tracking depending on if the camera is currently running or not.
- int setReference ()
- int calibrateCamera ()

    Start the camera calibration routine that computes the camera matrix and distortion coefficients.
- void loadCalibration (int method)
- void testAlgorithms ()
- void projectCoordinateFrame (Mat pictureFrame)
- void setUpUDP ()

    Open the UDP ports for communication.
- void setHeadingOffset (double d)
- void sendDataUDP (cv::Vec3d &Position, cv::Vec3d &Euler)
- void closeUDP ()
- void loadMarkerConfig (int method)
- void drawPositionText (cv::Mat &Picture, cv::Vec3d &Position, cv::Vec3d &Euler, double error)
- void loadCameraPosition ()
- int determineExposure ()
- void determineOrder ()
- int calibrateGround ()

Variables

- int methodPNP

    solvePNP algorithm 0 = iterative 1 = EPNP 2 = P3P 4 = UPNP //!< 4 and 1 are the same and not implemented correctly by OpenCV
- bool safetyEnable

    is the safety feature enabled
- bool safety2Enable

    is the second receiver enabled
- double safetyBoxLength

    length of the safety area cube in meters
- int safetyAngle

    bank and pitch angle protection in degrees
- QHostAddress IPAdressObject

    IPv4 adress of receiver 1.
- QHostAddress IPAdressSafety

    IPv4 adress of safety receiver.
- QHostAddress IPAdressSafety2

    IPv4 adress of receiver 2.
- int portObject

    Port of receiver 1.
- int portSafety

    Port of the safety receiver.
- int portSafety2

    Port of receiver 2.
- int invertZ

    dummy variable to invert Z direction on request
- commObject commObj

    class that handles the communication from main.cpp to the GUI

2.11.1 Function Documentation

2.11.1.1 calibrateCamera()

```
int calibrateCamera ( )
```

Start the camera calibration routine that computes the camera matrix and distortion coefficients.

Initialize Camera SDK ==–

At this point the Camera SDK is actively looking for all connected cameras and will initialize them on it's own.

Get a connected camera ================-—

Determine camera resolution

Set Video Mode ==–

We set the camera to Segment Mode here. This mode is support by all of our products. Depending on what device you have connected you might want to consider a different video mode to achieve the best possible tracking quality. All devices that support a mode that will achieve a better quality output with a mode other than Segment Mode are listed here along with what mode you should use if you're looking for the best head tracking:

```
V100:R1/R2    Precision Mode
TrackIR 5     Bit-Packed Precision Mode
V120          Precision Mode
TBar          Precision Mode
S250e         Precision Mode
```

If you have questions about a new device that might be conspicuously missing here or have any questions about head tracking, email support or participate in our forums.

Start camera output ==–

Camera Matrix creation ==–

Ok, start main loop. This loop fetches and displays ===— camera frames. ===— But first set some camera parameters

the user has to provide the size of one square in mm

Fetch a new frame from the camera ===—

which is why we also set this constant to 8

later on, when we get the frame as usual:

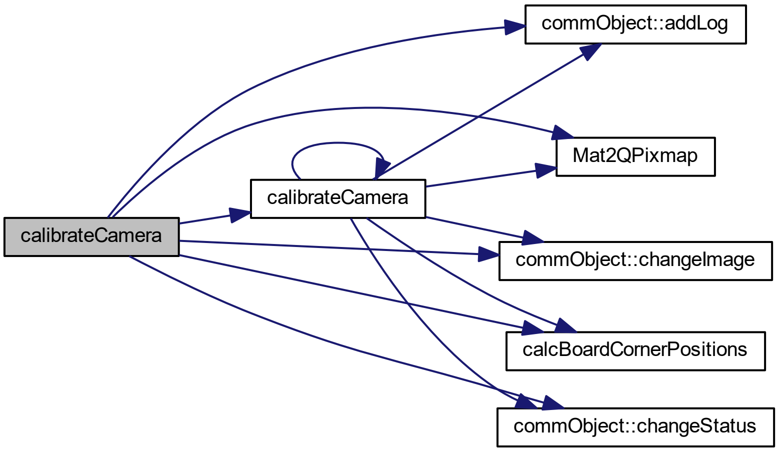
Lets have the Camera Library raster the camera's image into our texture.

$<$ If done with success,

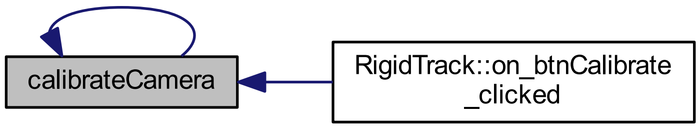
improve the found corners' coordinate accuracy for chessboard

Release camera ==–

Save the obtained calibration coefficients in a file for later use Here is the call graph for this function:



Here is the caller graph for this function:



2.11.1.2 calibrateGround()

```
int calibrateGround ( )
```

Get the pose of the camera w.r.t the ground calibration frame. This frame sets the navigation frame for later results. The pose is averaged over 200 samples and then saved in the file referenceData.xml. This routine is basically the same as setReference. initialize the variables with starting values

Initialize Camera SDK ==–

At this point the Camera SDK is actively looking for all connected cameras and will initialize them on it's own.

Get a connected camera ================-—

If no device connected, pop a message box and exit ==–

Determine camera resolution to size application window ==-—

Set camera mode to precision mode, it directly provides marker coordinates

Start camera output ==–

Turn on some overlay text so it's clear things are ===— working even if there is nothing in the camera's view. ===— Set some other parameters as well of the camera

sample some frames and calculate the position and attitude. then average those values and use that as zero position

Fetch a new frame from the camera ===—

Ok, we've received a new frame, lets do something with it.

for(int i=0; i<frame->ObjectCount(); i++)

sort the 2d points with the correct indices as found in the preceeding order determination algorithm

Compute the pose from the 3D-2D corresponses

project the marker 3d points with the solution into the camera image CoSy and calculate difference to true camera image

<Iterative Method needs time to converge to solution

< That are not the values of yaw, roll and pitch yet! Rodriguez has to be called first.

<– one sample more :D

Release camera ==–

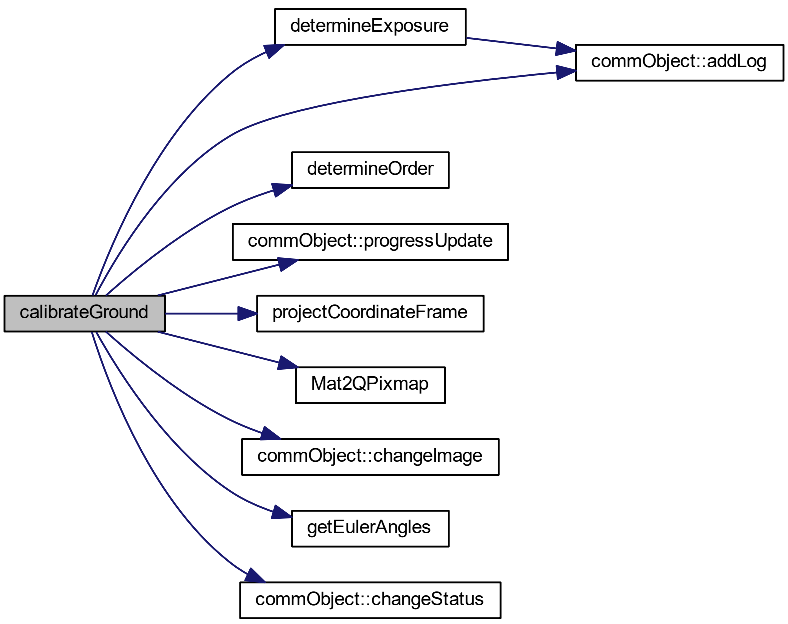
Divide by the number of samples to get the mean of the reference position

< eulerRef is here in Axis Angle notation

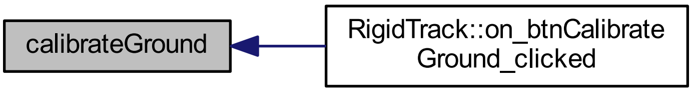
< axis angle to rotation matrix

< rotation matrix to euler

Save the obtained calibration coefficients in a file for later use Here is the call graph for this function:



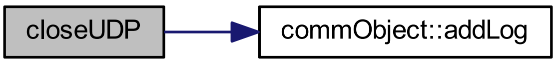
Here is the caller graph for this function:



2.11.1.3 closeUDP()

```
void closeUDP ( )
```

Close the UDP ports again to release network interfaces etc. If this is not done the network resources are still occupied and the program can't exit properly. check if the socket is open and if yes close it Here is the call graph for this function:



Here is the caller graph for this function:

2.11.1.4 determineExposure()

```
int determineExposure ( )
```

Get the optimal exposure for the camera. For that find the minimum and maximum exposure were the right number of markers are detected. Then the mean of those two values is used as exposure. For OptiTrack Ethernet cameras, it's important to enable development mode if you want to stop execution for an extended time while debugging without disconnecting the Ethernet devices. Lets do that now:

Initialize Camera SDK ==–

At this point the Camera SDK is actively looking for all connected cameras and will initialize them on it's own.

Get a connected camera ================-—

If no device connected, pop a message box and exit ==–

Determine camera resolution to size application window ==-—

set the camera mode to precision mode, it used greyscale imformation for marker property calculations

Start camera output ==–

Turn on some overlay text so it's clear things are ===— working even if there is nothing in the camera's view. ===—

set the camera exposure

set the camera infrared LED intensity

set the camera framerate to 100 Hz

enable the filter that blocks visible light and only passes infrared light

enable high power mode of the leds

enable continuous LED light

set threshold for marker detection

set exposure such that num markers are visible

Number of objects (markers) found in the current picture with the given exposure

exposure when objects detected the first time is numberMarkers

exposure when objects detected is first time numberMarkers+1

set the exposure to the smallest value possible

if the markers arent found after numberTries then there might be no markers at all in the real world

Determine minimum exposure, hence when are numberMarkers objects detected

get a new camera frame

frame received

how many objects are detected in the image

if the right amount if markers is found, exit while loop

not the right amount of markers was found so increase the exposure and try again

Now determine maximum exposure, hence when are numberMarkers+1 objects detected

if the markers arent found after numberTries then there might be no markers at all in the real world how many objects are detected in the image

if the right amount if markers is found, exit while loop

not the right amount of markers was found so decrease the exposure and try again

set the exposure to the mean of min and max exposure determined

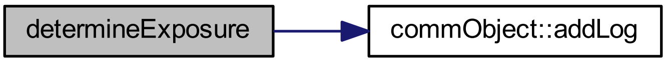
and now check if the correct amount of markers is detected with that new value

how many objects are detected in the image

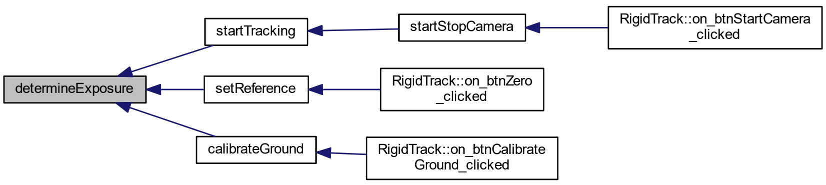
are all markers and not more or less detected in the image

Release camera ==–

all markers and not more or less are found Here is the call graph for this function:



Here is the caller graph for this function:



2.11.1.5 determineOrder()

```
void determineOrder ( )
```

Compute the order of the marker points in 2D so they are the same as in the 3D array. Hence marker 1 must be in first place for both, list_points2d and list_points3d. determine the 3D-2D correspondences that are crucial for the PnP algorithm Try every possible correspondence and solve PnP Then project the 3D marker points into the 2D camera image and check the difference between projected points and points as seen by the camera the corresponce with the smallest difference is probably the correct one

the difference between true 2D points and projected points is super big now try every possible permutation of correspondence

reset the starting values for solvePnP

sort the 2d points with the current permutation

Call solve PNP with P3P since its more robust and sufficient for start value determination

set the current difference of all point correspondences to zero

project the 3D points with the solvePnP solution onto 2D

now compute the absolute difference (error)

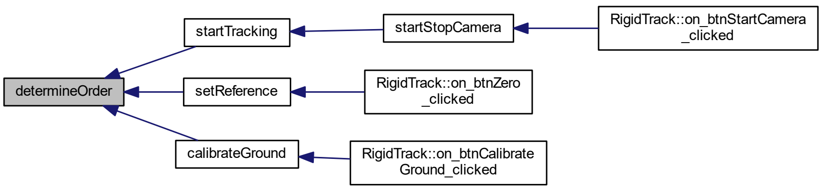
if the difference with the current permutation is smaller than the smallest value till now it is probably the more correct permutation

< set the smallest value of difference to the current one

< now safe the better permutation

try every permutation

now that the correct order is found assign it to the indices array Here is the caller graph for this function:



2.11.1.6 drawPositionText()

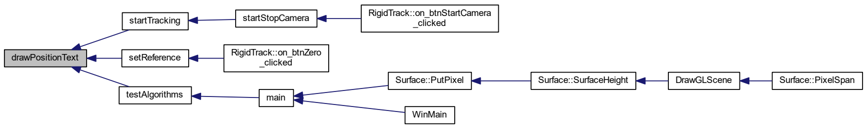
```
void drawPositionText (
            cv::Mat & Picture,
            cv::Vec3d & Position,
            cv::Vec3d & Euler,
            double error )
```

Draw the position, attitude and reprojection error in the picture.

Parameters

in	*Picture*	is the camera image in OpenCV matrix format.
in	*Position*	is the position of the tracked object in navigation CoSy.
in	*Euler*	are the Euler angles with respect to the navigation frame.
in	*error*	is the reprojection error of the pose estimation.

Here is the caller graph for this function:



2.11.1.7 loadCalibration()

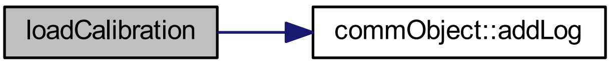
```
void loadCalibration (
            int method )
```

Load a previously saved camera calibration from a file.

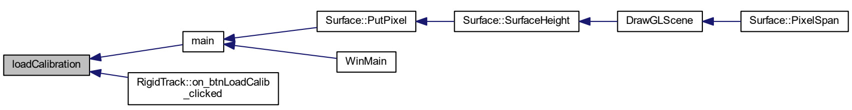
Parameters

in	*method*	whether or not load the camera calibration from calibration.xml. If ==0 then yes, if != 0 then let the user select a different file.

Here is the call graph for this function:



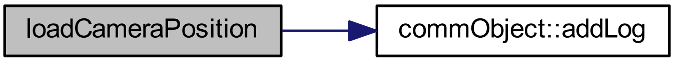
Here is the caller graph for this function:



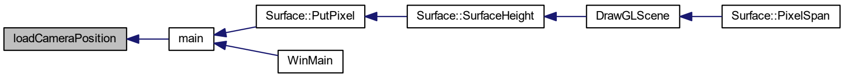
2.11.1.8 loadCameraPosition()

```
void loadCameraPosition ( )
```

Load the rotation matrix from camera CoSy to ground CoSy It is determined during calibrateGround() and stays the same once the camera is mounted and fixed. Open the referenceData.xml that contains the rotation from camera CoSy to ground CoSy Here is the call graph for this function:



Here is the caller graph for this function:



2.11.1.9 loadMarkerConfig()

```
void loadMarkerConfig (
            int method )
```

Load a marker configuration from file. This file has to be created by hand, use the standard marker configuration file as template.

Parameters

in	*method*	whether or not load the configuration from the markerStandard.xml. If ==0 load it, if != 0 let the user select a different file.

during start up of the programm load the standard marker configuration

open the standard marker configuration file

copy the values to the respective variables

inizialise vectors with correct length depending on the number of markers

save the marker locations in the points3d vector

if the load marker configuration button was clicked show a open file dialog

was cancel or abort clicked

if yes load the standard marker configuration open the selected marker configuration file

copy the values to the respective variables

inizialise vectors with correct length depending on the number of markers

save the marker locations in the points3d vector

Print out the number of markers and their position to the GUI

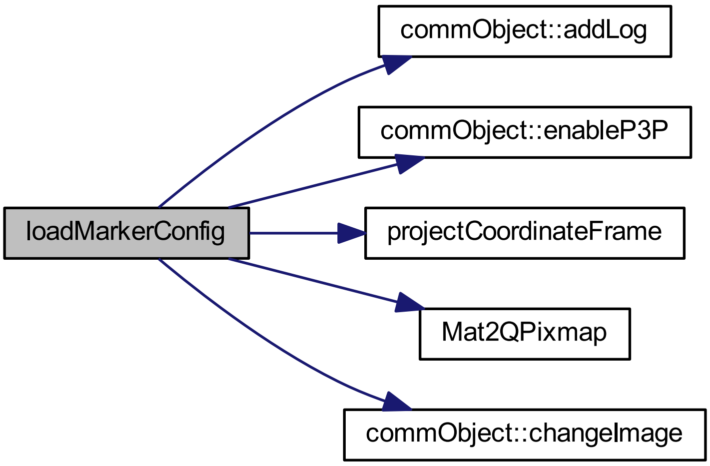
check if P3P algorithm can be enabled, it needs exactly 4 marker points to work

if P3P is possible, let the user choose which algorithm he wants but keep iterative active

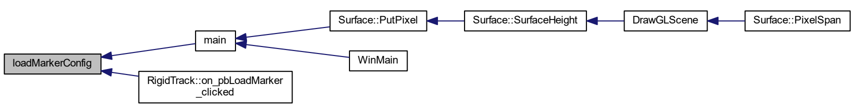
More (or less) marker than 4 loaded, P3P is not possible, hence user cant select P3P in GUI

now display the marker configuration in the camera view

Set the camera pose parallel to the marker coordinate system Here is the call graph for this function:



Here is the caller graph for this function:



2.11.1.10 projectCoordinateFrame()

```
void projectCoordinateFrame (
            Mat pictureFrame )
```

Project the coordinate CoSy origin and axis direction of the marker CoSy with the rotation and translation of the object for visualization.

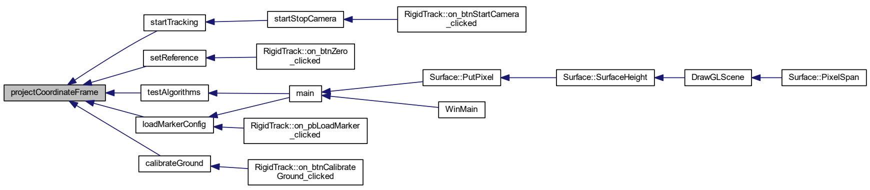
Parameters

in	*pictureFrame*	the image in which the CoSy frame should be pasted.

<z-axis

<x-axis

<y-axis Here is the caller graph for this function:



2.11.1.11 sendDataUDP()

```
void sendDataUDP (
            cv::Vec3d & Position,
            cv::Vec3d & Euler )
```

Send the position and attitude over UDP to every receiver, the safety receiver is handled on its own in the start↩ Tracking function because its send rate is less than 100 Hz. Roll Pitch Heading

if second receiver is activated send it also the tracking data Here is the caller graph for this function:

2.11.1.12 setHeadingOffset()

```
void setHeadingOffset (
            double d )
```

Add a heading offset to the attitude for the case it is wanted by the user.

Parameters

in	*d*	denotes heading offset in degrees.

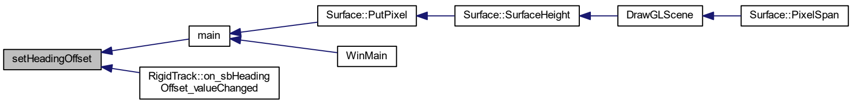
Convert heading offset from degrees to rad

Calculate rotation about x axis

Calculate rotation about y axis

Calculate rotation about z axis

Combined rotation matrix Here is the caller graph for this function:



2.11.1.13 setReference()

```
int setReference ( )
```

Determine the initial position of the object that serves as reference point or as ground frame origin. Computes the pose 200 times and then averages it. The position and attitude are from now on used as navigation CoSy. initialize the variables with starting values

Initialize Camera SDK ==–

At this point the Camera SDK is actively looking for all connected cameras and will initialize them on it's own.

Get a connected camera ================-—

If no device connected, pop a message box and exit ==–

Determine camera resolution to size application window ==-—

Set camera mode to precision mode, it directly provides marker coordinates

Start camera output ==–

Turn on some overlay text so it's clear things are ===— working even if there is nothing in the camera's view. ===— Set some other parameters as well of the camera

sample some frames and calculate the position and attitude. then average those values and use that as zero position

< difference between the marker points as seen by the camera and the projected marker points with Rvec and Tvec

Fetch a new frame from the camera ===—

Ok, we've received a new frame, lets do something with it.

for(int i=0; i<frame->ObjectCount(); i++)

sort the 2d points with the correct indices as found in the preceeding order determination algorithm

Compute the pose from the 3D-2D corresponses

project the marker 3d points with the solution into the camera image CoSy and calculate difference to true camera image

<Iterative Method needs time to converge to solution

< That are not the values of yaw, roll and pitch yet! Rodriguez has to be called first.

< one sample more :D

Release camera ==–

Divide by the number of samples to get the mean of the reference position

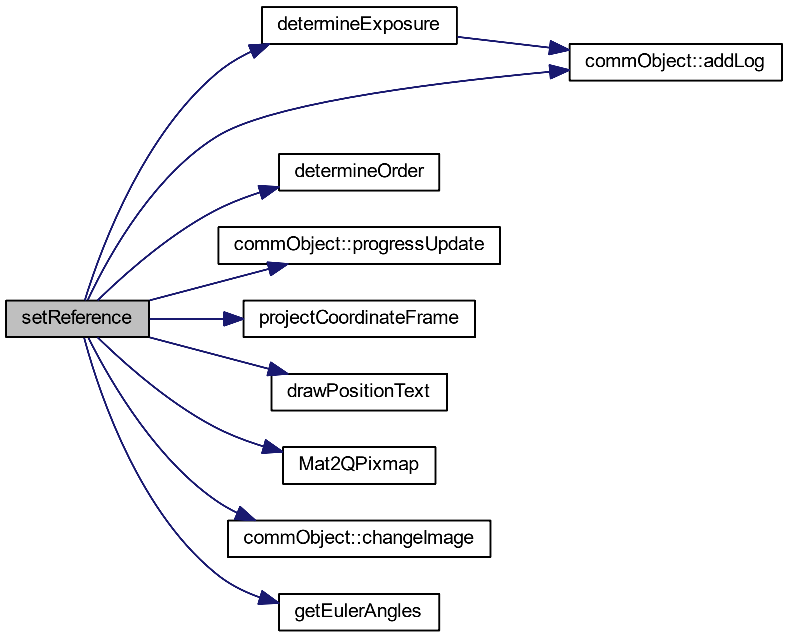
< eulerRef is here in Axis Angle notation

< axis angle to rotation matrix

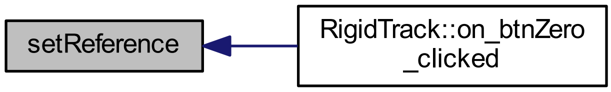
– Euler Angles, finally

< rotation matrix to euler

compute the difference between last obtained TVec and the average Value When it is large the iterative method has not converged properly so it is advised to start the setReference() function once again Here is the call graph for this function:



Here is the caller graph for this function:



2.11.1.14 setUpUDP()

```
void setUpUDP ( )
```

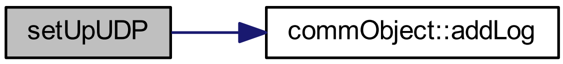
Open the UDP ports for communication.

Initialise the QDataStream that stores the data to be send

Create UDP slots

if the safety feature is activated open the udp port

if the second receiver feature is activated open the udp port Here is the call graph for this function:



Here is the caller graph for this function:

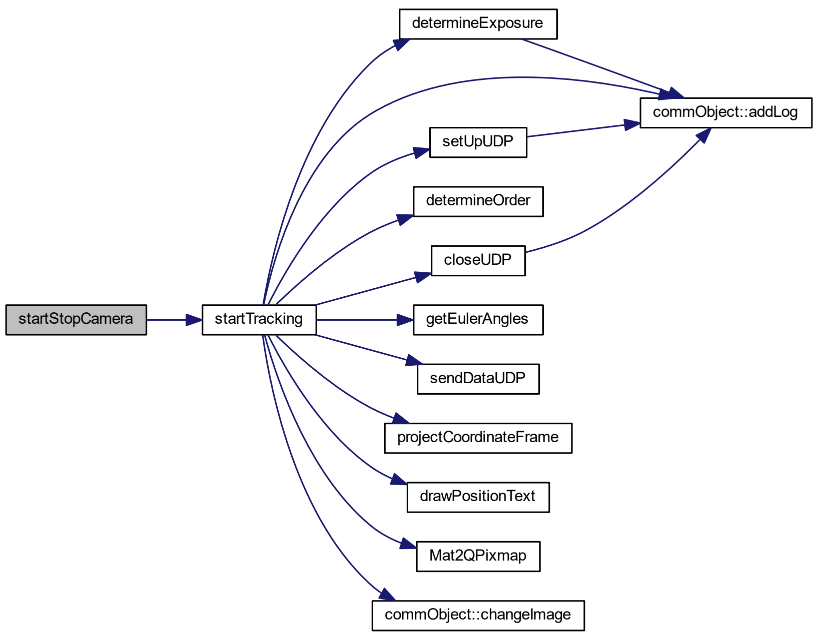
2.11.1.15 startStopCamera()

```
void startStopCamera ( )
```

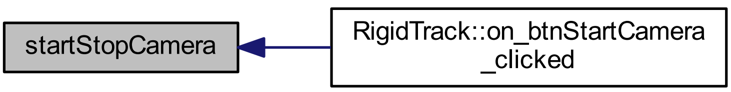
Start or stop the tracking depending on if the camera is currently running or not.

tracking is not running so start it

< tracking is currently running, set exitRequest to true so the while loop in startTracking() exits Here is the call graph for this function:



Here is the caller graph for this function:



2.11.1.16 startTracking()

```
int startTracking ( )
```

Start the loop that fetches frames, computes the position etc and sends it to other computers. This function is the core of this program, hence the pose estimation is done here. The order of points, hence which entry in list_points3d corresponds to which in list_points2d is not calculated yet

Use the value of Rvec that was set in main() as starting value for the solvePnP algorithm

Use the value of Tvec that was set in main() as starting value for the solvePnP algorithm

Get the current date and time to name the log file

Concat the log file name as followed. The file is saved in the folder /logs in the Rigid Track installation folder

Convert the QString to a standard string

Get the exposure where the right amount of markers is detected

For OptiTrack Ethernet cameras, it's important to enable development mode if you want to stop execution for an extended time while debugging without disconnecting the Ethernet devices. Lets do that now:

Initialize Camera SDK

At this point the Camera SDK is actively looking for all connected cameras and will initialize them on it's own

Get a connected camera

If no camera can be found, inform user in message log and exit function

Determine camera resolution to size application window

Set the camera mode to precision mode, it used greyscale imformation for marker property calculations

Start camera output

Turn on some overlay text so it's clear things are working even if there is nothing in the camera's view

Set the camera exposure

Set the camera infrared LED intensity

Set the camera framerate to 100 Hz

Enable the filter that blocks visible light and only passes infrared light

Enable high power mode of the LEDs

Disable continuous LED light

Set threshold for marker detection

Create a new matrix that stores the grayscale picture from the camera

QPixmap is the corresponding Qt class that saves images

Matrix that stores the colored picture, hence marker points, coordinate frame and reprojected points

Helper variable used to kick safety switch

Variables for the min and max values that are needed for sanity checks

Ff a marker is not visible or accuracy is bad increase this counter

Equals the quality of the tracking

Open sockets and ports for UDP communication

If the safety feature is enabled send the starting message

Send enable message, hence send a 9 and then a 1

Fetch a new frame from the camera

Get the timestamp of the first frame. This time is subtracted from every subseeding frame so the time starts at 0 in the logs

While no new frame is received loop

Get a new camera frame

There is actually a new frame

Get the time stamp for the first frame. It is subtracted for the following frames

Release the frame so the camera can continue

Exit the while loop

Now enter the main loop that processes each frame and computes the pose, sends it and logs stuff

Check if the user has not pressed "Stop Tracking" yet

Fetch a new frame from the camera

Did we got a new frame or does the camera still need more time

Increase by one, if everything is okay it is decreased at the end of the loop again

Only use this frame it the right number of markers is found in the picture

Get the marker points in 2D in the camera image frame and store them in the list_points2dUnsorted vector The order of points that come from the camera corresponds to the Y coordinate

Was the order already determined? This is false for the first frame and from then on true

Now compute the order

Sort the 2d points with the correct indices as found in the preceeding order determination algorithm

pointOrderIndices was calculated in determineOrder()

The first time the 2D-3D corresspondence was determined with gotOrder was okay. But this order can change as the object moves and the marker objects appear in a different order in the frame->Object() array. The solution is that: When a marker point (in the camera image, hence in 2D) was at a position then it wont move that much from one frame to the other. So for the new frame we take a marker object and check which marker was closest this point in the old image frame? This is probably the same (true) marker. And we do that for every other marker as well. When tracking is good and no frames are dropped because of missing markers this should work every frame.

The sum of point distances is set to something unrealistic large

Calculate N_2 norm of unsorted points minus old points

If the norm is smaller than minPointDistance the correspondence is more likely to be correct

Update the array that saves the new point order

Now the new order is found, set the point order to the new value

Save the unsorted position of the marker points for the next loop

Compute the object pose from the 3D-2D corresponses

Project the marker 3d points with the solution into the camera image CoSy and calculate difference to true camera image

Difference of true pose and found pose

Increase the framesDropped variable if accuracy of tracking is too bad

Set number of subsequent frames dropped to zero because error is small enough and no marker was missing

Get the min and max values from TVec for sanity check

Sanity check of values. negative z means the marker CoSy is behind the camera, that's not possible.

Release the frame so the camera can move on

Release the camera

Close all UDP connections so the programm can be closed later on and no resources are locked

Exit the function

Next step is the transformation from camera CoSy to navigation CoSy Compute the relative object position from the reference position to the current one given in the camera CoSy: $T_C^{NM} = Tvec - Tvec_{Ref}$

Transform the position from the camera CoSy to the navigation CoSy with INS alligned heading and convert from [mm] to [m] $T_N^{NM} = M_{NC} \times T_C^{NM}$

Position is the result of the preceeding calculation

Invert Z if check box in GUI is activated, hence height above ground is considered

Realtive angle between reference orientation and current orientation

Convert axis angle respresentation to ordinary rotation matrix

The difference of the reference rotation and the current rotation $R_{NM} = M_{NC} \times R_{CM}$

Euler Angles, finally

Get the euler angles from the rotation matrix

Add the heading offset to the heading angle

Compute the velocity with finite differences. Only use is the log file. It is done here because the more precise time stamp can be used

Time between the old frame and the current frame

Set the old frame time to the current one

Calculate the x velocity with finite differences

Calculate the y velocity with finite differences

Calculate the z velocity with finite differences

Set the old position to the current one for next frame velocity calcuation

Send position and Euler angles over WiFi with 100 Hz

Save the values in a log file, values are: Time sinc tracking started Position Euler Angles Velocity

Open the log file, the folder is RigidTrackInstallationFolder/logs

Close the file to save values

Check if the position and euler angles are below the allowed value, if yes send OKAY signal (1), if not send shutdown signal (0) Absolute x, y and z position in navigation CoSy must be smaller than the allowed distance

Absolute Euler angles must be smaller than allowed value. Heading is not considered

Send the OKAY signal to the desired computer every 5th time

Send the 1

reset the counter that is needed for decimation to every 5th time step

The euler angles of the object exceeded the allowed euler angles, send the shutdown signal (0)

Send the shutdown signal, a 0

Inform the user

The position of the object exceeded the allowed position, shut the object down

Send the shutdown signal, a 0

Inform the user

Inform the user if tracking system is disturbed (marker lost or so) or error was too big

Also send the shutdown signal

Send the shutdown signal, a 0

Inform the user

Rasterize the frame so it can be shown in the GUI

Convert the frame from greyscale as it comes from the camera to rgb color

Project (draw) the marker CoSy origin into 2D and save it in the cFrame image

Project the marker points from 3D to the camera image frame (2d) with the computed pose

Draw a circle around the projected points so the result can be better compared to the real marker position In the resulting picture those are the red dots

Write the current position, attitude and error values as text in the frame

Send the new camera picture to the GUI and call the GUI processing routine

Update the picture in the GUI

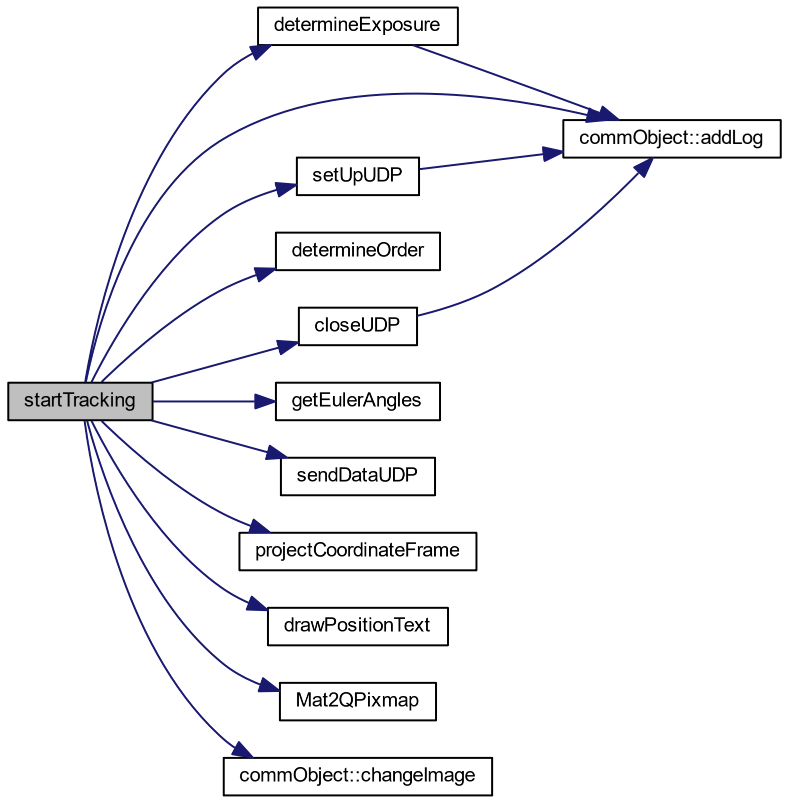
Give Qt time to handle everything

Release the camera frame to fetch the new one

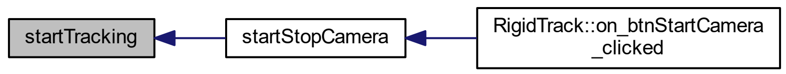
User choose to stop the tracking, clean things up

Close the UDP connections so resources are deallocated

Release camera Here is the call graph for this function:



Here is the caller graph for this function:



2.11.1.17 testAlgorithms()

```
void testAlgorithms ( )
```

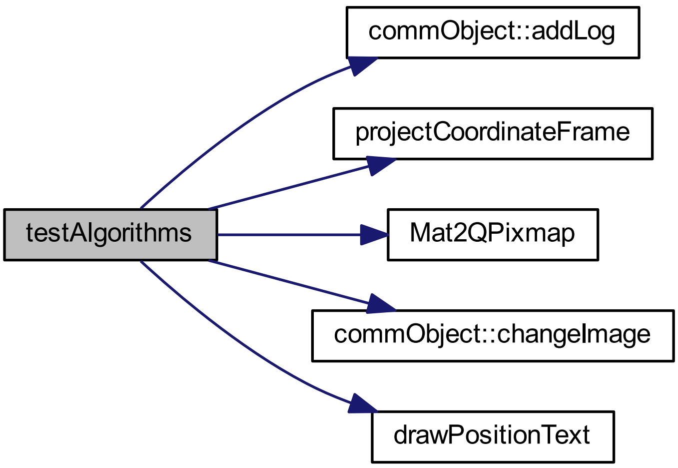
Project some points from 3D to 2D and then check the accuracy of the algorithms. Mainly to generate something that can be shown in the camera view so the user knows everything loaded correctly. < in mm

< 0 = iterative 1 = EPNP 2 = P3P 4 = UPNP //!< not used

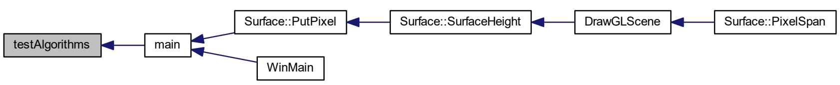
< 0 = iterative 1 = EPNP 2 = P3P 4 = UPNP UPnP not used

< 0 = iterative 1 = EPNP 2 = P3P 4 = UPNP //!< not used

< 0 = iterative 1 = EPNP 2 = P3P 4 = UPNP //!< not used Here is the call graph for this function:



Here is the caller graph for this function:



2.11.2 Variable Documentation

2.11.2.1 commObj

```
commObject commObj
```

class that handles the communication from main.cpp to the GUI

Now declare variables that are used across the main.cpp file. Basically almost every variable used is declared here.

2.11.2.2 invertZ

```
int invertZ
```

dummy variable to invert Z direction on request

2.11.2.3 IPAdressObject

```
QHostAddress IPAdressObject
```

IPv4 adress of receiver 1.

2.11.2.4 IPAdressSafety

```
QHostAddress IPAdressSafety
```

IPv4 adress of safety receiver.

2.11.2.5 IPAdressSafety2

```
QHostAddress IPAdressSafety2
```

IPv4 adress of receiver 2.

2.11.2.6 methodPNP

```
int methodPNP
```

solvePNP algorithm 0 = iterative 1 = EPNP 2 = P3P 4 = UPNP //!< 4 and 1 are the same and not implemented correctly by OpenCV

2.11.2.7 portObject

```
int portObject
```

Port of receiver 1.

2.11.2.8 portSafety

```
int portSafety
```

Port of the safety receiver.

2.11.2.9 portSafety2

```
int portSafety2
```

Port of receiver 2.

2.11.2.10 safety2Enable

```
bool safety2Enable
```

is the second receiver enabled

2.11.2.11 safetyAngle

```
int safetyAngle
```

bank and pitch angle protection in degrees

2.11.2.12 safetyBoxLength

```
double safetyBoxLength
```

length of the safety area cube in meters

2.11.2.13 safetyEnable

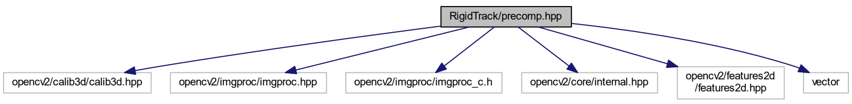
```
bool safetyEnable
```

is the safety feature enabled

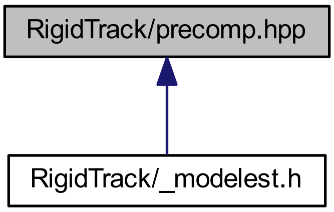
2.12 RigidTrack/precomp.hpp File Reference

```
#include "opencv2/calib3d/calib3d.hpp"
#include "opencv2/imgproc/imgproc.hpp"
#include "opencv2/imgproc/imgproc_c.h"
#include "opencv2/core/internal.hpp"
#include "opencv2/features2d/features2d.hpp"
#include <vector>
```

Include dependency graph for precomp.hpp:



This graph shows which files directly or indirectly include this file:



Macros

- #define GET_OPTIMIZED(func) (func)

2.12.1 Macro Definition Documentation

2.12.1.1 GET_OPTIMIZED

```
#define GET_OPTIMIZED(
              func ) (func)
```

2.13 RigidTrack/resource.h File Reference

Macros

- #define IDI_ICON1 101

  /<{{NO_DEPENDENCIES}} /< Von Microsoft Visual C++ generierte Includedatei. /< Verwendet durch RigidTrack.rc /<

2.13.1 Macro Definition Documentation

2.13.1.1 IDI_ICON1

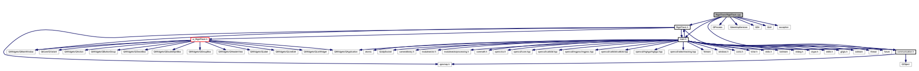
```
#define IDI_ICON1 101
```

/<{{NO_DEPENDENCIES}} /< Von Microsoft Visual C++ generierte Includedatei. /< Verwendet durch Rigid↩
Track.rc /<

2.14 RigidTrack/RigidTrack.cpp File Reference

```
#include "RigidTrack.h"
#include <QProcess>
#include <QdesktopServices>
#include <QDir>
#include <QUrl>
#include "main.h"
#include "communication.h"
#include <exception>
```

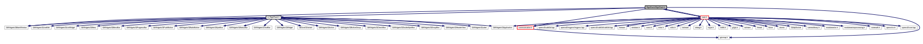
Include dependency graph for RigidTrack.cpp:



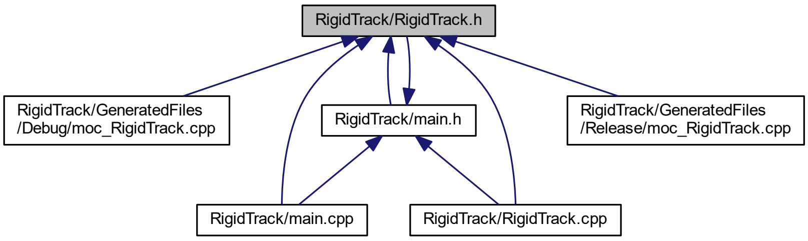
2.15 RigidTrack/RigidTrack.h File Reference

```
#include <QtWidgets/QMainWindow>
#include "ui_RigidTrack.h"
#include <qpixmap.h>
#include "main.h"
#include "communication.h"
```

Include dependency graph for RigidTrack.h:



This graph shows which files directly or indirectly include this file:



Classes

- class RigidTrack

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