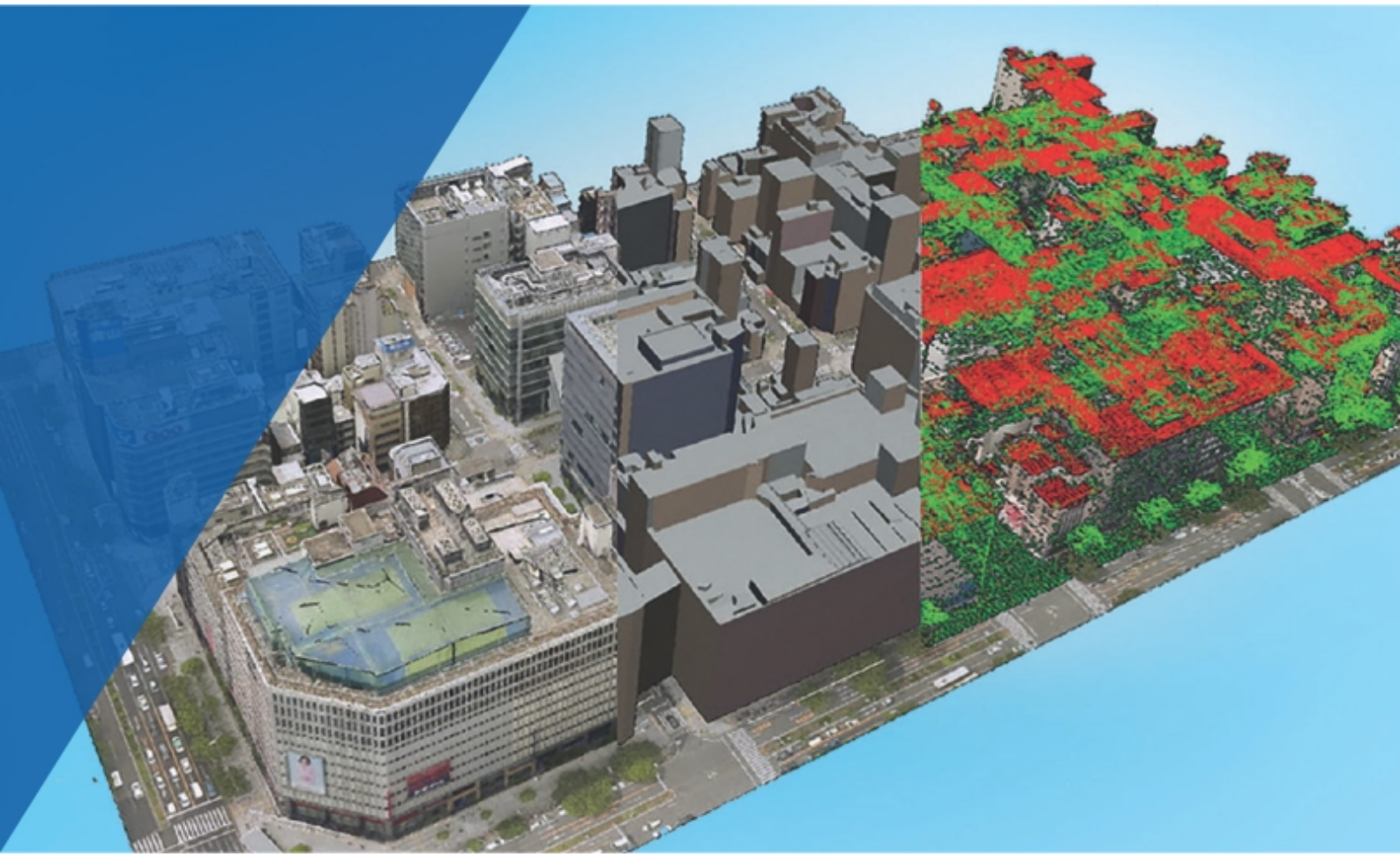
TerraMatch USER GUIDE

64-bit version



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Terra solid
POINT CLOUD INTELLIGENCE

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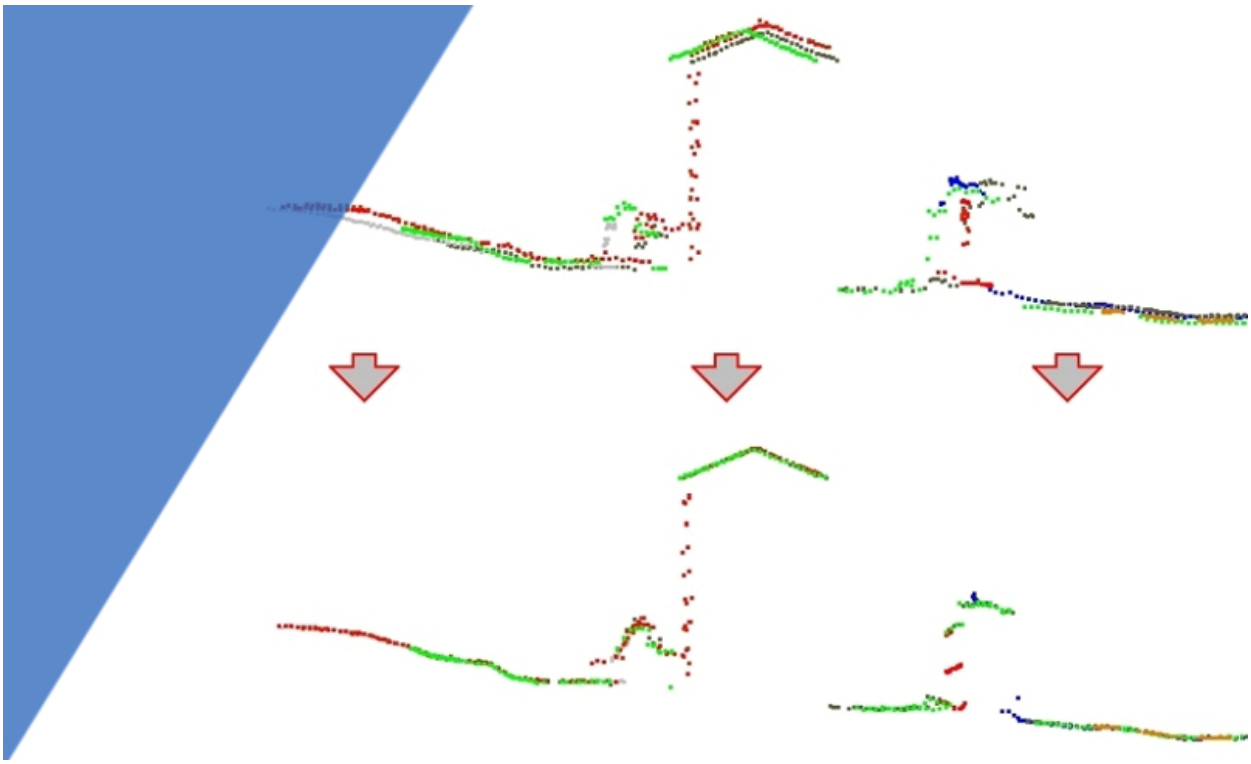
TERRAMATCH USER GUIDE

64-bit TerraMatch



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About this User Guide

This document serves as a user's guide for the 64-bit versions of TerraMatch. TerraMatch UAV is aiming to users who process point clouds collected with UAS (Unmanned Airborne Systems, also referred to systems carried by Drones). Tools available in TerraMatch and TerraMatch UAV work identically in all versions. Tools that are not available in TerraMatch UAV are marked with "*Not UAV*" in the documentation.

This user guide is written under the assumption that the reader knows how to use the basic features of the used CAD platform. You should refer to any documentation of your respective CAD platform whenever you need information about tools and functionality of the CAD platform itself.

The PDF version of the user guide is created in order to provide an offline version of the online webhelp. It shall be updated together with the webhelp. Some parts of the webhelp may be left out on purpose in the PDF document. In case of inconsistency, the online webhelp is the primary source of information. The user is responsible for keeping his/her offline version updated.

Document conventions

The following conventions and symbols appear in this guide:

- **Data click** - click on the data button, usually the left mouse button on a right-hand mouse.
- **Reset click** - click on the reset button, usually the right mouse button on a right-hand mouse.
- < > - angle brackets are used to refer to keyboard keys, for example, <Enter>.
- *Command* - type a command in the Spaccels window of Spatix or the key-in line of Bentley CAD and then press <Enter>.
- OR - alternate procedures or steps in a procedure.
- C:/TERRA - paths to directories of files on a hard disk are written with capital letters.
- ***To do*** - the beginning of a workflow is introduced with bold-italic letters.
- When no distinction between platform versions (Spatix or Bentley) is necessary, this document refers to the CAD environment simply as "CAD platform".

Notes and hints are highlighted in light blue boxes.

Spatix documentation

The User Guide for Spatix is published by GISware Integro and delivered as PDF with the software. It can be opened with the **Manual** command from the **Help** menu of Spatix.

Terrasolid software runs on top of Spatix. The functionality of Terrasolid software is the same as on top of Bentley products whenever possible. Any differences are clearly mentioned in the User Guide.

Bentley CAD documentation

Terrasolid software runs on top of the full version of Bentley CAD products, such as MicroStation, PowerDraft, or OpenCities Map PowerView. Compatible Bentley products are listed on Terrasolid's webpage. The CAD platform causes no difference in functionality of Terrasolid software. Therefore, only the term "Bentley CAD" is used when referring to any Bentley product.

Introduction

TerraMatch is a sophisticated tool for improving the accuracy and quality of the raw laser point cloud. It compares laser data from overlapping flight or drive paths and calculates correction values for the misalignment angles as well as xyz location errors. The comparison and correction value calculation can be either based on surface matching or on different types of tie lines. Tie line matching comprises points or lines on horizontal, vertical or sloped surfaces that can be used for matching flight/drive paths to each other, but also known point or line locations that enable the adjustment of the laser point cloud to control measurements.

Especially in mobile ground-based laser scanning, the mismatch between overlapping drive paths usally changes over time during a surveying campaign, depending on the quality of the GPS signal on different locations. This requires a fluctuating correction solution which can be achieved with control measurements and TerraMatch tie lines.

TerraMatch is also used for misalignment angle calibration which should be checked and possibly improved at the beginning of data processing. For this purpose, data is collected on a specific calibration side which offers a point cloud dedicated for the calibration task to the software. If the system includes several laser scanners, the calibration involves scanner-to-scanner matching.

TerraMatch must be accompanied by TerraScan or TerraScan Lite.

General data requirements

The input data must meet some requirements to enable the algorithms to work properly:

- The data set must contain multiple strips which overlap each other. Alternatively, a single strip can be compared against a dense set of known points.
- The data set must contain some well-defined surfaces or other identifiable features for placing tie lines -- matching can not be performed if all the data are hits in forest canopy where no meaningful surfaces or features can be detected.
- Time-stamped trajectory information must be imported into TerraScan.
- For systematic shift corrections (positional or angular), a trajectory must not overlap itself. Any trajectories which make a 180 degree turn and return over itself, have to be split into separate parts using TerraScan.
- Laser points must be linked to trajectory positions so that TerraMatch can derive the laser scanner position and orientation for each laser point. This requires that laser points and trajectories use the same time stamp format.

The specific data requirements for different processing workflows are described in Methods of line adjustment.

TerraMatch UAV

TerraMatch UAV is a lighter version of TerraMatch. It is dedicated to users that process only point clouds collected by Unmanned Airborne Vehicles (UAVs, also called Drones). UAV systems produce relatively small point clouds from a low altitude. The system is more unstable

in the air. Often, less capable/expensive hardware is used which leads to a higher inaccuracy level of the raw data. Therefore, the improvement of the data accuracy by eliminating boresight misalignment and positional inaccuracies caused by a bad trajectory solution plays an important role in the processing workflow. The UAV version of TerraMatch is well suited for processing point clouds up to a few million of points.

TerraMatch UAV does not have any project capabilites. Tools can be performed on points loaded in memory but not on project level.

Tools/Commands without project option

- Apply correction
- Tie lines/Import points
- Tie lines/Search tie lines
- Tie lines/Search cloud-to-cloud
- Find match
- Find fluctuations
- Match forward and backward
- Measure match

TerraMatch UAV is available only in a bundle with other Terrasolid UAV software versions, such as TerraScan UAV, TerraPhoto UAV and/or TerraModeler UAV. TerraMatch UAV must be accompanied by either TerraScan UAV or TerraScan.

The Function matrix provides a complete overview of the tools in the different TerraMatch versions.

Hardware and software requirements

TerraMatch is built on top of a CAD platform, such as Spatix or Bentley CAD. You must have a computer system capable of running any compatible CAD platform.

To run TerraMatch, you must have the following:

- quad-core or better processor, good frequency rate
- 64-bit version of Windows 7, 8, 10
- 1024*768 resolution display or better
- 8 GB RAM minimum, 16 GB RAM or more recommended
- Any of the compatible CAD platforms:

GISware Integro, purchased by Terrasolid	Bentley
• Spatix	• MicroStation CONNECT Edition • PowerDraft CONNECT Edition • OpenCities Map PowerView CONNECT Edition • OpenCities Map CONNECT Edition • OpenCities Map Enterprise CONNECT Edition • ContextCapture Editor CONNECT Edition • OpenRoads Designer

Installation of TerraMatch requires about 1 MB of free hard disk space.

Installation

Terrasolid applications may be delivered as a zip file or on a USB-Stick. The installation package of Terrasolid applications for Spatix includes the setup for Spatix itself as well. Therefore, you can install Spatix and Terrasolid software in one step.

A **zip package** contains the software - it does not include the User Guides. This is the normal delivery method of the software if you download it from the Terrasolid website.

A **USB-Stick** may include the User Guides in PDF format in addition to the installation files. The USB-Stick may further include versions for multiple environments. You choose the version which corresponds to your operating system and platform version. You install Terrasolid software from an USB-Stick probably only if you participate in a training event.

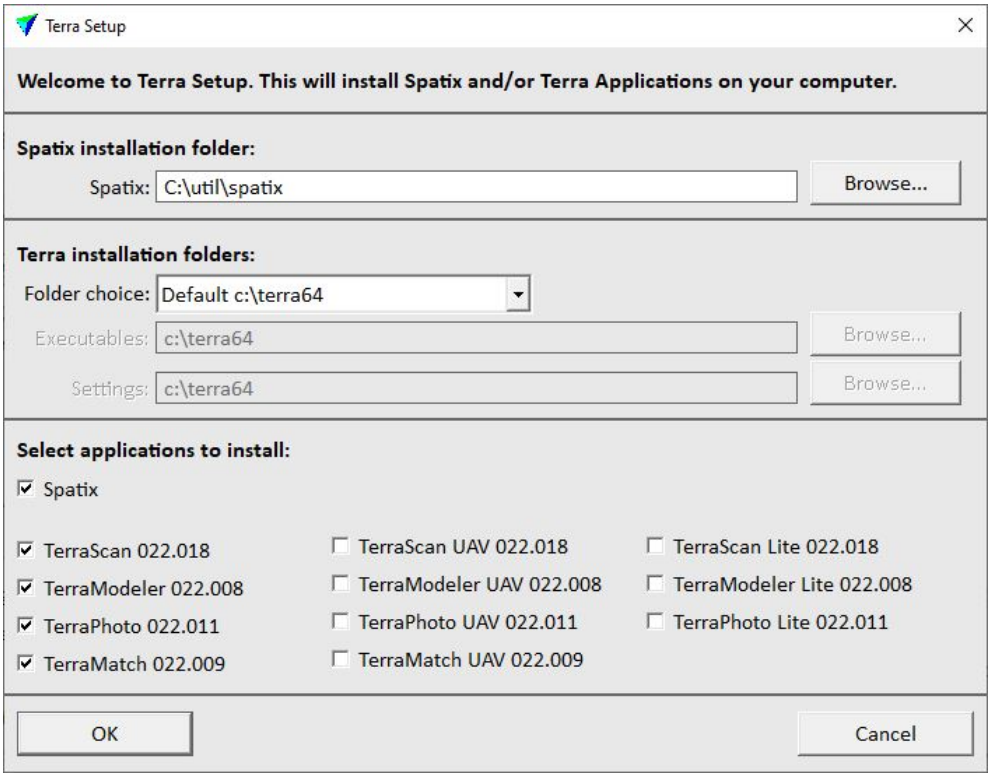
Terrasolid applications for Bentley products and Spatix may be installed on the same computer and run parallel. The applications should be installed in the same directory (e.g. c:\terra64). This enables the use of the same configuration files, settings, etc. for both platforms.

To install TerraMatch from a zip file together with or on top of Spatix:

1. Unpack the zip archive with any zip file manager.

2. Start **SETUP.EXE** which is part of the zip archive. You must have administrator permissions in order to run setup successfully.

   The installation program tries to determine where Spatix has been installed and opens the **Terra Setup** dialog:



3. Check and possibly change the installation folder of **Spatix**. Click on the **Browse** button next to the input field in order to select a new installation folder for Spatix. The folder is created automatically, if it does not exist.

4. Define the installation folder(s) where to install TerraMatch and maybe other Terra applications.

   The default **Folder choice** is **Default c:\terra64**. This installs all executables and setting files into the same folder C:\TERRA64. The folder is created automatically, if it does not exist.

   As an alternative, if executables and settings files need to be separated, select another **Folder choice**:

   - **Default 'Program files'** - executables are installed into C:\PROGRAM FILES\TERRASOLID, setting files are installed into C:\TERRA64.
   - **Freely selectable folders** - the user defines a folder for **Executables** and **Settings** in the corresponding input fields. Click on the **Browse** button next to each input field in order to select a folder.

5. Select all Terrasolid applications that you want to install.

   Select either the full version, the UAV version or the Lite version of an application. The versions do not run parallel on the same CAD platform.

6. Click OK to start the installation.

   A message is displayed when the installation is finished.

Install all Terrasolid applications into the same folder(s) in order to ensure interaction between the applications without trouble.

To install TerraMatch from a zip file on top of any Bentley product:

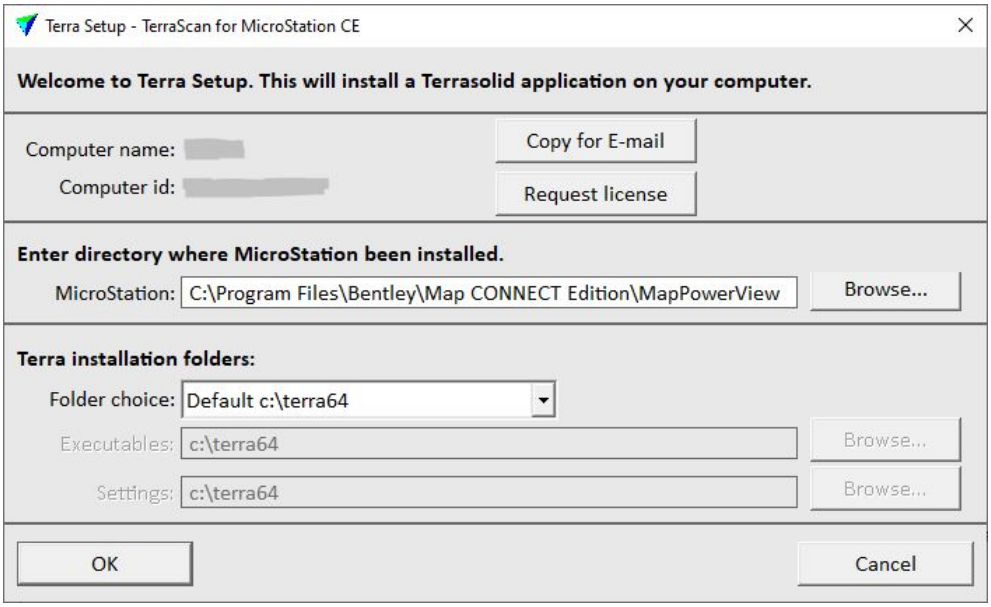
1. Unpack the zip archive with any zip file manager.

2. Start **SETUP.EXE** which is part of the zip archive.

   This may open a dialog confirming the execution of SETUP.EXE and/or prompting for the administrator password.

   The installation program needs to know where the Bentley product (MicroStation, Map PowerView or any other compatible product) has been installed. It automatically searches all local hard disks to find the Bentley installation directory.

   The installation dialog opens:



The dialog is the same for all Bentley products and Terra applications. The labels in the dialog always refer to "MicroStation", no matter what Bentley product is used.

3. Check the **MicroStation** directory. Replace the path if the correct location was not found automatically.

4. Define the installation folder(s) where to install TerraMatch and maybe other Terra applications.

   The default **Folder choice** is **Default c:\terra64**. This installs all executables and setting files into the same folder C:\TERRA64. The folder is created automatically, if it does not exist.

   As an alternative, if executables and settings files need to be separated, select another **Folder choice**:

   - **Default 'Program files'** - executables are installed into C:\PROGRAM FILES\TERRASOLID, setting files are installed into C:\TERRA64.
   - **Freely selectable folders** - the user defines a folder for **Executables** and **Settings** in the corresponding input fields. Click on the **Browse** button next to each input field in order to select a folder.

5. Click OK to start the installation.

   A message is displayed when the installation is finished.

Install all Terrasolid applications into the same folder(s) in order to ensure interaction between the applications without trouble.

The installation folder contains a README.TXT file which explains the installation of the software in batch mode. The allows to install several Terrasolid applications in one step.

To install TerraMatch from USB-Stick on top of a Bentley product:

The process is the same for all Bentley products. The labels in all dialogs always refer to "MicroStation", no matter what Bentley product is used.

1. Insert the USB-Stick.

2. Locate the correct installation directory on the stick.

3. Start **SETUP.EXE** from that directory.

   The installation program tries to determine where MicroStation has been installed and opens the **Terra Setup** dialog.

4. Define the directory where to install TerraMatch and maybe other Terra applications.

   The default path is C:\TERRA64. You can change this to another location. The specified directory is created automatically, if it does not exist.

5. Check the **MicroStation** directory. Replace the path if the correct location was not found automatically.

   You can use the **Scan** button to automatically search the hard disk for the Bentley CAD installation. Alternatively, you can use the **Browse** button to locate the Bentley CAD platform installation folder yourself.

6. Click OK to continue.

   This opens another **Terra Setup** dialog.

7. Select the TerraMatch **for MicroStation** item in the dialog.

   You may select all applications for which you have installation files.

8. Click OK to start the installation.

   A message is displayed when the installation is finished.

Starting TerraMatch

TerraMatch is an application that runs on top of Spatix (Ix App) or Bentley CAD (MDL Application).

To start TerraMatch in Spatix:

1. Select **Execute** command from the **Ix Apps** menu in Spatix.

   The **Choose Ix app to execute** dialog opens, a standard Windows dialog to open a file.

2. Browse to the /APP folder of the Terrasolid software installation directory.

   By default, the path is C:/TERRA64/APP.

3. Select the **tmatch.ix** file.

   You may select other applications as well.

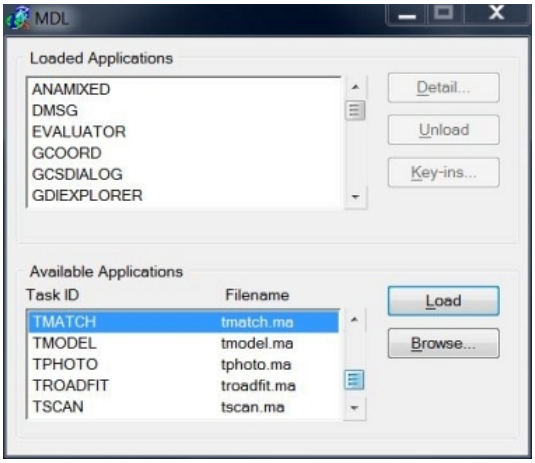
4. Click **Open** in order to start all selected applications.

   TerraMatch opens the **Main** tool box.

To start TerraMatch on Bentley CAD:

1. Select **MDL Applications** command from the **Utilities** ribbon in Bentley CAD.

   The **MDL** dialog opens:



2. In the **Available Applications** list, select TMATCH.

3. Click on the **Load** button.

   OR

1. Key in *mdl load tmatch*.

   TerraMatch opens the **Main** tool box.

If the **TerraMatch Main** toolbox is accidentally closed, it can be re-opened with the keyin command:

match app maintool

The **Available Applications** list shows all MDL applications that Bentley CAD is able to locate. Bentley CAD searches for MDL applications in the directories listed in **MS_MDLAPPS** configuration variable. If Bentley CAD can not find TMATCH.MA, you should check the variable in the **Configuration Variable** dialog of Bentley CAD. Make sure the directory path of the TMATCH.MA file is included in the variable values. See also Installation Directories and Configuration Variables for more information.

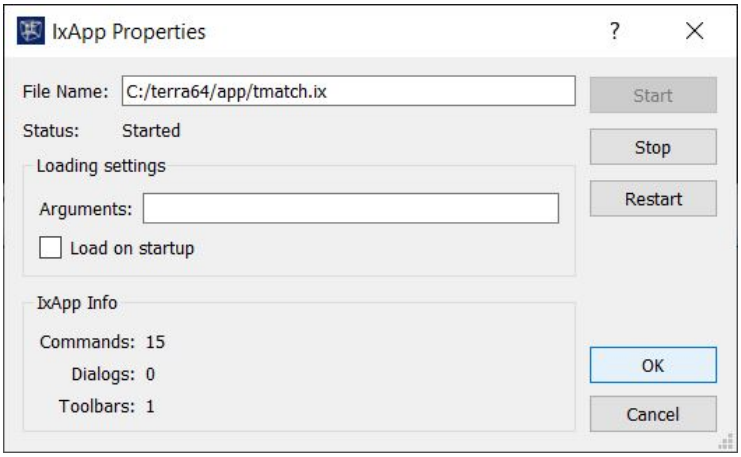
Unload TerraMatch

TerraMatch is unloaded automatically when you exit Spatix or Bentley CAD. Sometimes you may want to unload the application while continuing to work with the CAD platform. This frees up the memory reserved by TerraMatch.

To unload TerraMatch in Spatix:

1. Select **tmatch.ix** command from the **Ix Apps** menu in Spatix.

   The **IxApp Properties** dialog opens:



2. Click on the **Stop** button.

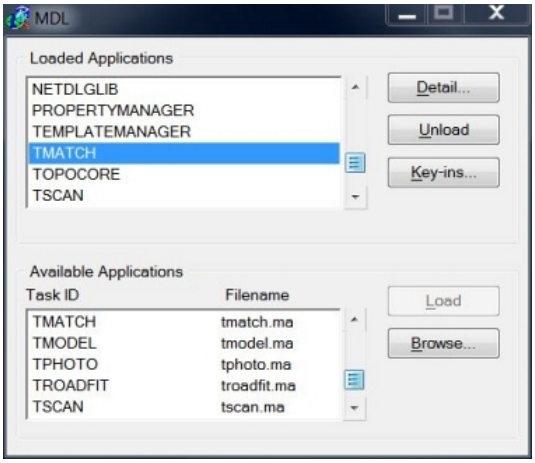
   This unloads TerraMatch, closes the **Main** tool box and updates the Status and IxApp Info in the **IxApp Properties** dialog.

3. Close the dialog with **OK** or **Cancel**.

To unload TerraMatch in Bentley CAD:

1. Select **MDL Applications** command from the **Utilities** ribbon in Bentley CAD.

   The **MDL** dialog opens:



2. In the **Loaded Applications** list, select TMATCH.

3. Click on the **Unload** button.

   OR

1. Key in *mdl unload tmatch*.

   This unloads the application.

TerraMatch Settings

Settings control the way how tools and commands of TerraMatch work. They are organized in logical categories. The TerraMatch **Settings** dialog is opened by the Match Settings tool.

SETTINGS CATEGORY
Default trajectory accuracy
Iteration convergence
Operation
Signal markers
Standard deviations
Target objects
Tie line detail views
Tie lines

Default trajectory accuracy

Default trajectory accuracy category defines estimates for the accuracy of trajectory positions. They are used for smoothing the correction curve in Find Tie Line Fluctuations if no other accuracy estimate values for trajectory positions are available.

The default values are recommended estimates for mobile data collected along rural roads. Larger values might provide better estimates for data collected inside urban areas.

Iteration convergence

Iteration convergence category determines the stage at which the iterations in finding match tools stop. The iteration stops if the improvements are smaller than these threshold values or the match no longer improves.

You may use bigger values if you want to stop the iteration sooner and just find an indication for the type of error in the data set. You should use small values when you want to find the exact correction parameters.

SETTING	EFFECT
Easting	Easting convergence (m) - typically between 0.001 and 0.10.
Northing	Northing convergence (m) - typically between 0.001 and 0.10.

SETTING	EFFECT
Elevation	Elevation convergence (m) - typically between 0.001 and 0.10.
Heading	Heading convergence (deg) - typically between 0.0001 and 0.10.
Roll	Roll convergence (deg) - typically between 0.0001 and 0.010.
Pitch	Pitch convergence (deg) - typically between 0.0001 and 0.010.

Operation

Operation category defines the maximum number of threads that are used by TerraMatch processes. This effects some of the processes in TerraMatch which can run on several threads.

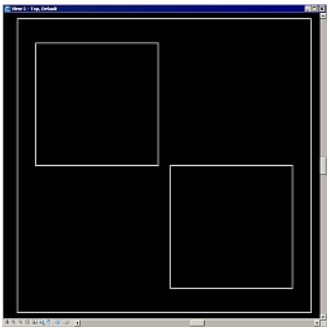
In addition, you can select whether the Main tool box of TerraMatch is opened at startup or not.

Signal markers

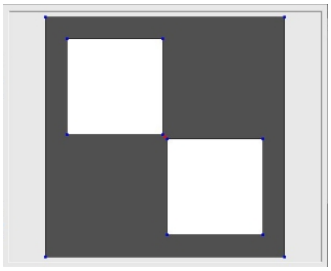
Signal markers category lets you define signal markers which can be used for automatic tie line placement. Signal markers are bright paintings on dark ground surfaces, e.g. on a road surface, at the location of a control measurement. The signal marker can be identified in the intensity values of a dense laser point cloud. This enables the automatic placement of known xyz or known xy tie points.

The signal marker has to be drawn into a CAD file before it can be defined in TerraMatch. It may be advantageous to use an empty CAD file for the drawing and to place the signal marker in a way that the point of measurement corresponds to the CAD file origin. The drawing must include a larger rectangle that represents the dark background and the shape of the bright painting. An example is illustrated in the figures below.

Signal marker painting on a tram track



Signal marker drawing in CAD file



Signal marker definition in TerraMatch

To define a signal marker:

1. Create a drawing of the signal marker in a CAD file.

2. Select the drawing.

3. Open **Signal markers** category from TerraMatch **Settings**.

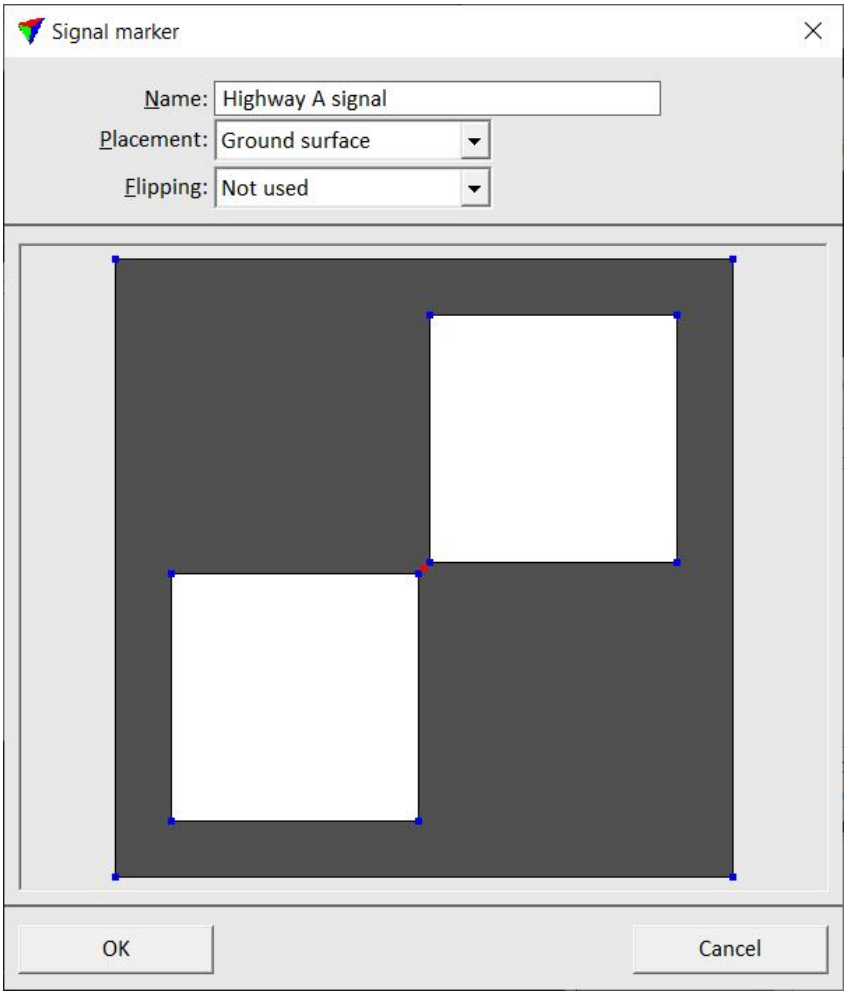
4. Click **Add** in the **Settings** dialog.

5. Define the exact measurement coordinate of the signal marker by either snapping to the drawing origin (= point of measurement on the signal marker location) or by typing the command:

   xy=0:0 (Spatix) OR *xyz = 0,0,0 (Bentley CAD)*

   where 0,0,0 is the origin coordinate of the drawing.

   This opens the **Signal marker** dialog:



6. Define settings and click OK.

   This adds the new signal marker to the list.

SETTING	EFFECT
Name	Name of the signal marker.
Placement	Location of the signal marker: • **Ground surface** - signal painted on a horizontal surface, such as the ground. • **Vertical surface** - signal painted on a vertical surface, such as a tunnel wall or pole.
Flipping	Defines the signal marker pattern relative to the movement direction: • **Not used** - no flipping used. • **Horizontally** - signal can be flipped horizontally. • **Vertically** - signal can be flipped vertically.

A signal marker's settings can be modified by selecting the marker and clicking the **Edit** button in the **Settings** dialog. It can be deleted using the **Delete** button.

Standard deviations category

Standard deviations category specifies the assumed accuracy of orientation parameters. These settings help the algorithm to avoid singularity and to better translate observed mismatches into corrections.

SETTING	EFFECT
Easting	Easting (m) - typically between 0.020 and 0.250.
Northing	Northing (m) - typically between 0.020 and 0.250.
Elevation	Elevation (m) - typically between 0.020 and 0.250.
Heading	Heading (deg) - typically between 0.010 and 0.200.
Roll	Roll (deg) - typically between 0.010 and 0.200.
Pitch	Pitch (deg) - typically between 0.010 and 0.200.
Known points	Known points (m) - typically between 0.005 and 0.05.

Target objects category

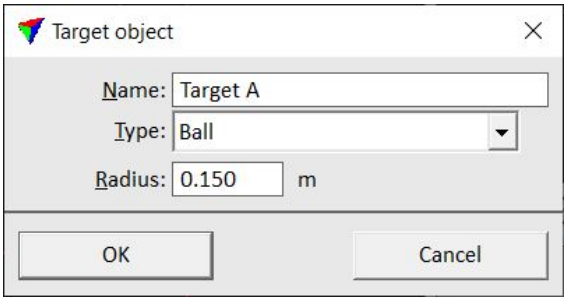
Target objects category lets you define target objects for adjusting the position of mobile laser scanning data. Target objects are objects with a known three dimensional shape placed at a control point location. From target objects, you can import Known XYZ, Known XY, or Known Z tie points.

To define a target object:

1. Open **Target objects** category from TerraMatch **Settings**.

2. Click **Add** in the **Settings** dialog.

   This opens the **Target object** dialog:

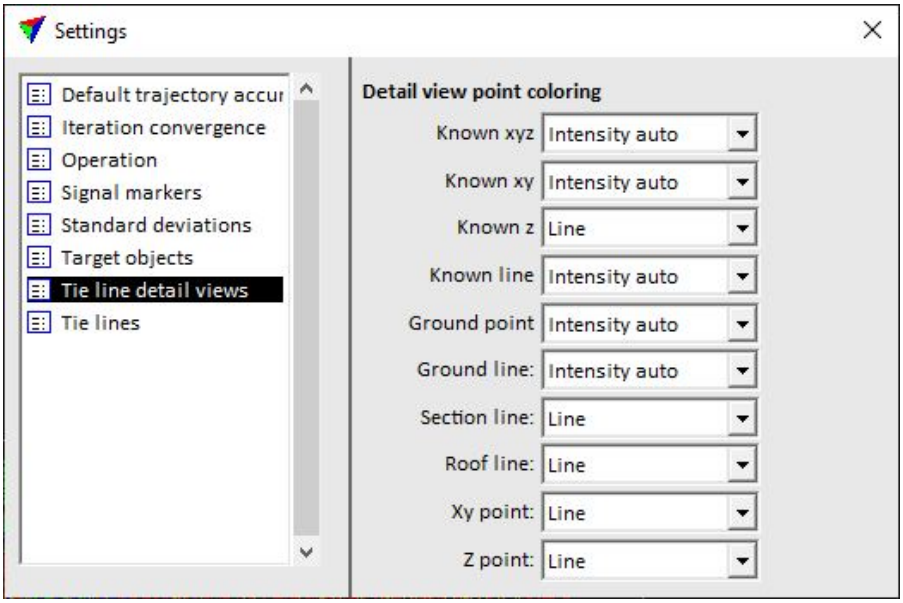


3. Enter settings and click OK.

SETTING	EFFECT
Name	Name of the target object.
Type	Type or shape of the target object. Currently, the only support type is **Ball**.
Radius	Radius of a target object of type **Ball**.

Tie line detail views category

Tie line detail views category defines how the point cloud is displayed in CAD file views for the different tie line types. The settings effect only the detail views for tie line display. For each tie line type, a point attribute can be selected from a list in the settings dialog. A detailed description of the display options for point clouds is provided in the TerraScan User Guide. The default settings are shown below.



Tie lines category

Tie lines category specifies what tie lines of type **Section line** following surface slopes are used for solving XY and Z mismatch. The settings mainly effect fluctuating XYZ solutions. Anyway, the values should be set in a reasonable way for a data set. The default values (XY when slope > 45 deg, Z when slope < 45 deg) are for mobile data sets where vertical walls are available for XY matching. It is recommended to change them to smaller values for airborne point cloud data, such as XY between 15 and 30 degree and Z accordingly. The steeper slopes there are in the data set (in the terrain and/or building roofs, potential places for searching **Section** tie lines), the larger the value for XY can be. A larger value for XY leads to a more reliable fluctuating XY solution for a data set.

SETTING	EFFECT
Xy when slope >	Section lines are used to solve XY mismatch if the slope gradient is larger than the given degree value.
Z when slope <	Section lines are used to solve Z mismatch if the slope gradient is smaller than the given degree value.

Find match vs. Tie Lines

There are two methods of strip adjustment in TerraMatch, **Find Match** and **Tie Lines**. The methods are compared in the following table.

FIND MATCH	TIE LINES
Tool Find Match Tool Find Fluctuations	Tool Find Tie Line Match Tool Find Tie Line Fluctuations
Surface-to-surface matching	Feature-to-feature matching
Only one type of observation	Several types of observations
More time consuming adjustment	Less time consuming adjustment
New (better) observations for each iteration	Old observations included for each iteration
No manual observations	Manual observations possible
INPUT DATA	
• trajectories with time stamp • laser points linked to trajectories and classified into ground (and optional buildings) per strip • (optional) ground control points	• trajectories with time stamp • tie lines derived from laser points, linked to trajectories by time stamp • (optional) ground control points
SOLVABLE PARAMETERS	
• easting, northing, elevations shifts • heading, roll, pitch shifts • mirror scale • easting, northing, elevations drifts • heading, roll, pitch drifts • fluctuating elevation	• easting, northing, elevations shifts • heading, roll, pitch shifts • mirror scale • fluctuating easting/northing, elevation, heading, roll, pitch
OBSERVATIONS	
• triangulated model from each strip surface • compares overlapping laser points and ground control points against this surface • translates observed difference and gradient to heading, roll, pitch, elevation difference	• surface/section lines - follow direction of a surface • ground lines/points - located on paint markings • roof intersection lines - located at an intersection of two roof surfaces • known lines/points - located at known point locations

ALS Calibration

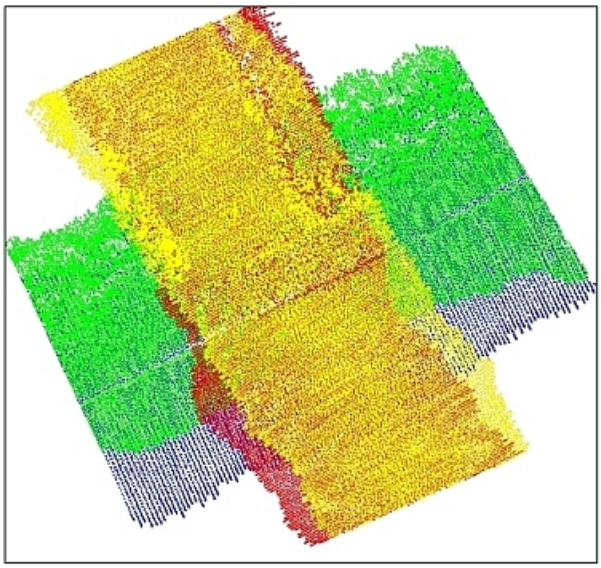
TerraMatch can be used to solve the mirror scale parameter and the misalignment between the laser scanner and the inertial measurement unit (IMU). The misalignment is expressed as heading, roll and pitch angular correction values which need to be known for every laser scanner system.

Different laser scanners may require additional calibration parameters as well. Those must be solved using more manual methods with TerraScan or with system specific software.

Flight pattern

The optimal site for a calibration flight contains both flat and sloped surfaces which do not have disturbing surface objects such as low vegetation. The most commonly used target area for calibration is an airport as it is easily accessible and most often contains suitable surfaces, such as the run ways and sloped building roofs.

The minimum flight pattern for calibration is four flight passes over the same area in a cross like pattern where the slopes surfaces are located at the center of the cross, as shown in the figure below.



You may consider some additional flight passes which may improve the quality of the calibration:

- An additional flight pass for which the sloped surfaces are located at the right of left edge of the corridor covered. This helps to differentiate pitch and heading from each other.
- Additional flight passes at a higher or a lower altitude.

Processing steps

The processing of a calibration flight can be outlined with the following steps:

1. Solve GPS trajectories.

2. Compute xyz laser points with system specific software using the last known calibration values.

3. Import trajectories into TerraScan and transform them to any coordinate system.

4. Split any trajectories which overlap themselves.

5. Import time-stamped laser points into TerraScan and transform them to the same coordinate system.

6. Make sure that the flightline numbering of the laser points matches trajectory numbers (in TerraScan, use Deduce using time command from **Line** pulldown menu).

   Continue according to the matching method.

Surface-to-surface matching:

7. Classify low points.

8. Classify ground separately for each flightline.

9. (Optional) Classify some buildings separately for each flightline.

10. Smoothen ground surface if most of it is asphalt or some other hard surface.

11. Run Find Match and solve for heading, roll, pitch and mirror scale corrections for the whole data set.

12. Add the result values to the correction values used when computing the xyz points in step 2.

Tie line-based matching:

7. Search for tie lines of type **Surface** lines. This does not require any classification of the laser points.

8. Run Find Tie Line Match and solve for heading, roll, pitch and mirror scale corrections for the whole data set.

9. Add the result values to the correction values used when computing the xyz points in step 2.

The laser scanner may have operation modes which make calibration easier such as profile mode. If such a mode is available, it should be used to solve the pitch correction value first. Then TerraMatch should be used to solve for heading and roll correction only.

ALS Project workflow

Even though the system has been calibrated, you may still find systematic errors in project data. TerraMatch can be used with actual project data to solve mismatches between laser data from different flightlines or between laser data and known points.

All parallel flightlines covering a project area should have a crossing flightline at both ends. For large project areas it is recommended to fly at least two or more crossing flightlines over sloped open terrain in order to provide good data for the matching task. Known points (ground control points) should be distributed close to the corners or edges of the project area.

As the project data volume can be huge, it is desirable to minimize the number of steps in the processing workflow. You probably want to run TerraMatch only if you notice that there are significant mismatches in the laser data.

Another difficulty with project data is that you do not know the nature of the errors beforehand. Mismatches may be a result of mistakes made during the setup of GPS reference stations, during computing trajectories or during operation of the airborne system. At some point within the correction workflow you must establish what parameters need to be corrected.

Processing steps

The general project workflow can be outlined with the following steps:

1. Solve GPS trajectories.

2. Compute xyz laser points with system specific software using the last known calibration values.

3. Import trajectories into TerraScan.

   Split trajectories if necessary.

4. Import time stamped laser points into TerraScan.

   Make sure that the flightline numbering of the laser points matches trajectory numbers (in TerraScan, set **Line** to **Deduce using time** in the Import points into project dialog for laser points or use Deduce using time command from **Line** pulldown menu or the corresponding Macro step).

5. Compare flightlines visually in cross sections. Try to locate sloped surfaces both along flight direction and perpendicular to flight direction.

6. If no significant mismatches are visible, you may skip the consecutive steps and continue with the normal processing workflow.

7. Classify low points.

8. Classify ground for each fligthline. If necessary, exclude water areas from the ground class.

9. (Optional) Locate areas which are best suited for matching (crossing flightlines, visible clean sloped surfaces). Create a TerraScan project with blocks only in those areas.

10. (Optional) Classify buildings for each flightline at the locations which are best suited for matching.

    Continue according to the matching method.

Surface-to-surface matching:

11. Run Find Match and solve for heading, roll, pitch and mirror scale corrections for the whole data set.

    Apply the correction if it is significant.

12. Run Find Match and solve for elevation or roll + elevation correction for individual flightlines.

    Apply the correction if it is significant.

13. Run Find Fluctuations and solve for fluctuating elevation correction.

    Apply the correction if it is significant.

Tie line-based matching:

11. Search for tie lines of type **Surface** lines based on ground and (optional) building class.

12. Run Find Tie Line Match and solve for heading, roll, pitch and mirror scale corrections for the whole data set.

    Apply the correction to the tie lines and the laser data if it is significant.

13. Check the tie lines for worse observations.

14. Run Find Tie Line Match and solve for heading, roll, pitch and elevation corrections for flightline groups (if there are any). Depending on the system, solve for mirror scale corrections per flightline groups as well.

    Apply the correction to the tie lines and the laser data if it is significant.

15. Check the tie lines for worse observations.

16. Run Find Tie Line Match and solve for heading, roll, pitch and elevation corrections for individual flightlines.

    Apply the correction to the tie lines and the laser data if it is significant.

17. Check the tie lines for worse observations.

18. Run Find Tie Line Fluctuations and solve for fluctuating elevation corrections.

    Apply the correction to the laser data if it is significant.

After each **Apply corrections** step you should check the flightlines visually in cross sections or using distance coloring to determine if the correction step improved the data. You have to decide if the correction was good or if you need to go back one step and try solving parameters with different settings.

Multi-day projects

Use GPS standard time to avoid conflicts between flight sessions with identical GPS seconds-of-week time stamps. There are tools in TerraScan for converting between GPS seconds-of-week and GPS standard time and vice versa. The tools are applicable to trajectories and to laser data.

Apply a group number to trajectories for each flight session (day 1 = trajectory group 1, day 2 = trajectory group 2, etc.). Optionally apply also a quality tag to trajectories of a flight session, e.g. if flight conditions are worse on one of the days.

Reduce the amount of data for processing as much as possible. This includes thinning of trajectories during the import, but also reducing the number of blocks for matching in a TerraScan project. Use only blocks that are suitable for the matching task and only classes that are necessary (e.g. ground, building classes).

For adding a new data set to an already matched data set, apply quality “bad” to the trajectories of the new data set and quality “normal” or “good” to the trajectories of the old data set. Use Find Match or Find Tie Line Match and solve for corrections for the “bad” flightlines only.

MLS Calibration

The task of mobile scanner calibration includes solving misalignment angles heading, roll and pitch for each scanner in a system. Misalignment issues are visible in the point cloud as differences between points of different drive paths and points of different scanners. The misalignment is more and more noticeable in the data the longer the distance is from the scanner. It has practically no effect on close-by objects, for which rather trajectory xyz inaccuracies dominate.

Potential objects for mobile scanner calibration are vertical planar surfaces, such as building walls, building corners and horizontal hard planar surfaces. A heading misalignment effects the xy location of a vertical surface or a building corner while roll and pitch effect the verticality of vertical surfaces as well as the elevation of horizontal surfaces in left/right (roll), forward/backward (pitch) direction. Other usable objects are vertical poles and overhead wires, but those objects have disadvantages, such as being off from vertical or varying diameters (poles) and possible movement (wires).

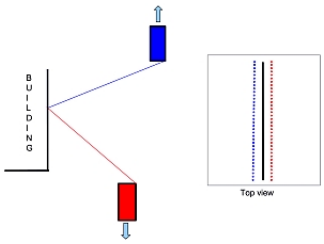
The tie line types used for calibration are **Section** lines on planar horizontal or vertical surfaces and **Xy** points , for example on building corners. More information about different tie line types can be found in section Tie line types.

Drive pattern

A good calibration side is an open space with hard surface ground and without disturbing objects such as cars, trees, etc. At least on one side there should be a larger building wall or another large vertical surface without many detailed structures.

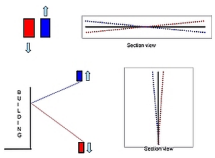
The calibration drive may includes two drive paths in opposite direction parallel to the vertical surface, two drive paths in opposite direction perpendicular to the vertical surface and (optionally) two diagonal drive paths towards or away from the vertical surface. Another option is to drive over an intersection of two road with at least two buildings next to the crossing, both roads in opposite directions. The two calibration drive pattern are illustrated below.

Only a suitable drive pattern for the appropriate scanner configuration ensures that all calibration parameters can be solved based on the laser data. The drive pattern described here are optimized for calibrating scanner systems that contain two scanners which are rotated horizontally by about 45 degree off from the driving direction. For any significantly different scanner configuration, the drive pattern must be adjusted accordingly.



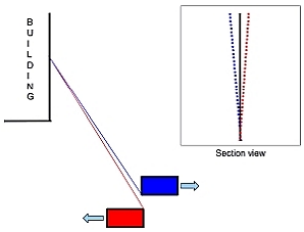
Scan direction for solving Heading

- *mismatch visible at a longer distance from scanner*
- *mismatch visible on vertical walls if scanned from different angles (preferable close to 45 degree)*
- *mismatch visible on point-like objects (building corners, poles, etc.)*



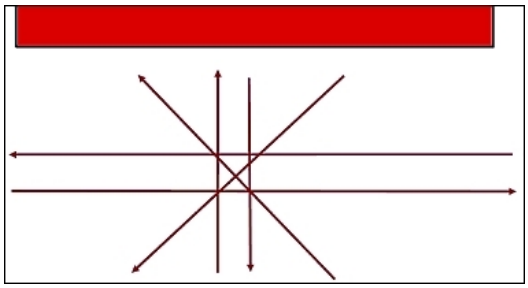
Scan direction for solving Roll

- *mismatch visible at a longer distance from scanner*
- *mismatch visible on vertical walls that are leaning in the point cloud if scanned in left/right direction relative to the drive direction*
- *mismatch visible as elevation difference on the ground*

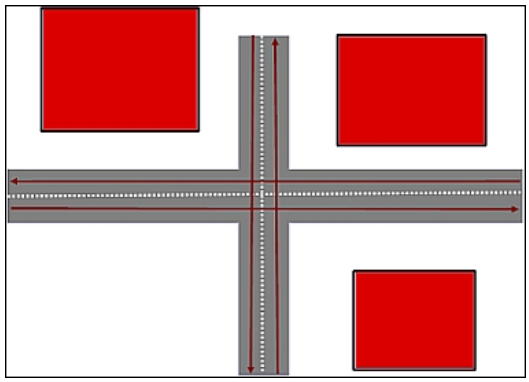


Scan direction for solving Pitch

- *mismatch visible at a longer distance from scanner*
- *mismatch visible on vertical walls that are leaning in the point cloud if scanned in forward/backward direction relative to the drive direction*
- *mismatch visible as elevation difference on the ground*



Drive pattern option 1, e.g. on a parking lot



Drive pattern option 2, road crossing

Processing steps

The processing of a calibration data set can be outlined with the following steps:

1. Generate trajectories with the GPS-IMU post-processing software of your system.

2. Generate a point cloud with system specific software using the last known calibration values.

3. Define a scanner system in TerraScan Settings that stores the lever arms from IMU to each scanner of your system.

4. Import trajectories into TerraScan. Assign the correct scanner system.

5. (Optional) Import the accuracy estimate file for the trajectory.

6. Import the laser cloud into TerraScan. In ideal case, you can load all points from the calibration drive into memory and thus, work on loaded points. Assign the scanner number during the import, e.g. based on the file or folder name. The scanner number for laser points must be the same as the scanner number in the scanner system definition. Point cloud and trajectories must be in the same coordinate system.

7. Save the laser points in LAS or TerraScan Fast Binary format which are able to store a scanner number for each laser point.

8. Split trajectories to create separate trajectory lines for each drive path.

9. Make sure that the drive path numbering of the laser points matches trajectory numbers (TerraScan Deduce using time command).

10. Remove unnecessary points from the point cloud, e.g. from stops, sharp turns or long range measurements.

11. Classify points on hard planar ground surface close to the trajectory lines (by centerline) and maybe point on building walls (by range above scanner).

12. Search tie lines of type **Section** lines on vertical walls.

13. Search tie lines of type **Section** lines on flat ground.

14. (Optional) Add more tie lines manually if the automatically found tie lines do not give a good result. This may be the case if the drive pattern was not optimal for the calibration task.

15. Run Find Tie Line Match and solve for heading, roll, and pitch for the whole data set. Separate scanners if your system contains multiple scanners.

16. Add the reported correction values to the correction values used when generating the point cloud in step 2.

MLS Project workflow

For mobile scanning projects, the quality of GPS positioning and thus, the quality of the trajectory is usually not as good and constant as for airborne projects. This is caused by GPS failures due to large buildings, trees, rock formations, etc. along the roads or rails. The positioning accuracy of the trajectory can vary a lot during a drive session. Thus, the dominant

error source for inaccurate data is the trajectory xyz positioning which shows up close to the scanner location.

Positional adjustment of mobile laser data in TerraMatch is based on tie line observations. These are typically collected on flat ground and/or on high intensity features such as paint markings.

A tie line observation can utilize ground control points or it can be for internal comparison only (multiple drive passes seeing the same location). It is recommended to measure ground control points along the road or other survey corridor at regular distances. The distances between control measurements can vary depending on the required accuracy level and the accuracy of the trajectory. Internal tie line observations should be added between the control measurements whenever the same location has been seen by multiple drive paths.

Ground control points can be located on corners of strong paint markings, at end points of thin strong paint markings or in the center of weaker paint markings. The latter type of control points is then used for partial xy control.

Instead of using paint markings for control measurements, signal markers of a specific pattern can be used as ground control points. This has the advantage that the software can find a bright signal marker on a dark surface automatically based on the intensity information of the laser points. See Signal markers category for more information about signal markers in TerraMatch.

More information about the different tie line types and the positional adjustment of mobile laser scanner project data can be found in Sections Tie line types and Fluctuating corrections with tie lines.

General project strategy

The general strategy of a mobile scanning project can be outlined as follows:

1. Collect some control measurements.

2. Execute LiDAR / image survey. Drive every place at least twice.

3. Check the system calibration.

4. Find locations of bad trajectory accuracy using color by RMS values for trajectories. Compare the drive paths visually.

5. Collect additional control measurements at locations where the trajectory positioning is bad.

6. Adjust xyz positioning of the laser data by matching drive paths to each other and to control measurements. This probably involves several processing steps.

7. Remove less accurate data, e.g. long range measurements where short range measurements exist, and cut off overlapping drive paths.

8. Continue processing the data according to the project requirements.

MLS to ALS matching

This Chapter outlines example workflows for matching MLS data to ALS data. The ALS data is used as reference assuming that the positioning is accurate. The MLS data positioning may be inaccurate due to positional errors described in Section MLS project workflow. The MLS and ALS data sets may be collected at different points of time and cover the same area.

The described methods may also work for matching any point cloud to another reference point cloud. However, the most common case is probably that an older ALS data set exists and a newly collected MLS point cloud needs to be matched to this ALS data set. The methods are only suitable for improving the positioning of the newer point cloud up to the accuracy level of the older/reference point cloud.

Cloud to cloud matching

This method tries to match one point cloud to a reference point cloud by using only planar surfaces that are detectable in both point clouds. This requires a good amount of points that represent the planar surfaces. Best candidates for matching an MLS point cloud to an ALS point cloud are the ground, mainly for vertical matching, and building walls for horizontal matching. Horizontal matching is only possible if there are enough points from vertical walls also in the ALS point cloud.

1. Set the TerraScan project for the ALS point cloud as the reference project for the MLS project. See Reference project exists option in the **Project information** dialog of TerraScan. If loaded points are used, the reference points can be loaded into TerraScan with the Read reference points command. If a project block is loaded, the Load reference points option must be switched on.

2. Compute normal vector and dimension attributes for the MLS data set by using either the macro step or the menu command for loaded points in TerraScan.

3. Start Define tie lines. In the **Tie line settings** dialog, set the class numbers of potential point classes (such as ground, walls, etc.) in the ALS and MLS point cloud as **Cloud classes**.

4. Start the cloud-to-cloud tie line search in TerraMatch.

5. Check worst tie point positions and delete, if bad. Filter bad tie lines, if necessary.

6. Solve fluctuating corrections using a smooth curve.

7. Apply correction to MLS data.

   You may write a new copy of the data set.

This matching method can be extended by introducing **Known Xy** tie points for a better horizontal match, especially if there are not enough building walls that can be used. The additional tie points for horizontal matching may be produced as described in the Using orthophotos and ground points section.

Using objects

Objects that are detectable in both point clouds, such as poles, can be used to match an MLS point cloud to a reference point cloud. TerraMatch can find tie lines for objects, if points from the single objects are grouped and if groups of one object type are classified into a separate class (e.g. each pole is one point group and all poles are in point classes "MLS Poles" and "ALS Poles", respectively). The shape of the object is not considered when the software finds the groups in the different lines. Therefore, the search works also for other types of objects than poles.

1. Make sure that the line numbers in the ALS and the MLS point clouds are distinguishable.

2. Assign groups and classify points on objects that you want to use for matching. This must be done for both, the MLS and ALS point clouds. See TerraScan User Guide for more information about grouping and classification.

3. Start Define tie lines. In the **Tie line settings** dialog, set the class numbers of objects in the ALS and MLS point cloud as **Object classes**.

4. Start Search tie lines and search for **Group objects**. The software places **Xyz** tie points for objects.

5. Check tie lines. Check worst tie point positions and delete, if bad.

6. Select Fix lines command and define the line number range of the ALS point cloud. This defines the ALS lines as reference for matching the MLS lines and the type of the tie points is changed to **Known xyz**.

7. Select Find tie line fluctuations tool to match the MLS lines to the ALS point cloud.

Using orthophotos and ground points

Orthophotos or intensity images and ALS ground points can be used as reference for matching MLS data. The orthophotos or intensity images may provide features for collecting tie points for XY correction while the ground points can be used for collecting tie points for Z correction.

1. Attach orthophotos or intensity images as raster reference in TerraPhoto.

2. Collect Known xy tie points or lines manually from any objects that can be sees in the attached raster images and the MLS point cloud (corners of paint markings, manhole covers, paint lines, etc.). The known XY location is derived from the raster images and TerraMatch computes the horizontal difference between the MLS data and the known location.

3. Use Report gaps tool to see if there are longer Xy gaps. Add tie lines in places of long gaps if possible.

4. Solve fluctuating Xy correction.

5. Apply correction to MLS data.

You may write a new copy of the data set.

6. Check for remaining internal XY mismatch. If there is any, apply another internal XY correction derived from **Wall** tie lines or another tie line type applicable to the data set.

7. For collecting Z tie points/lines, you can use, for example, the trajectories of the MLS data set. Draw the xy-corrected trajectories into the CAD file. Drape the lines to the ALS ground points. The trajectory lines now represent the ground level of the ALS data set.

8. Select trajectory lines draped to the ALS ground points.

9. Select Import points / From selected vectors and collect **Known Z** points. Each vertex of the selected lines becomes a tie point.

10. Delete tie line observations with longer than about 8.0 m range. For elevation adjustment, use only observations close to scanner.

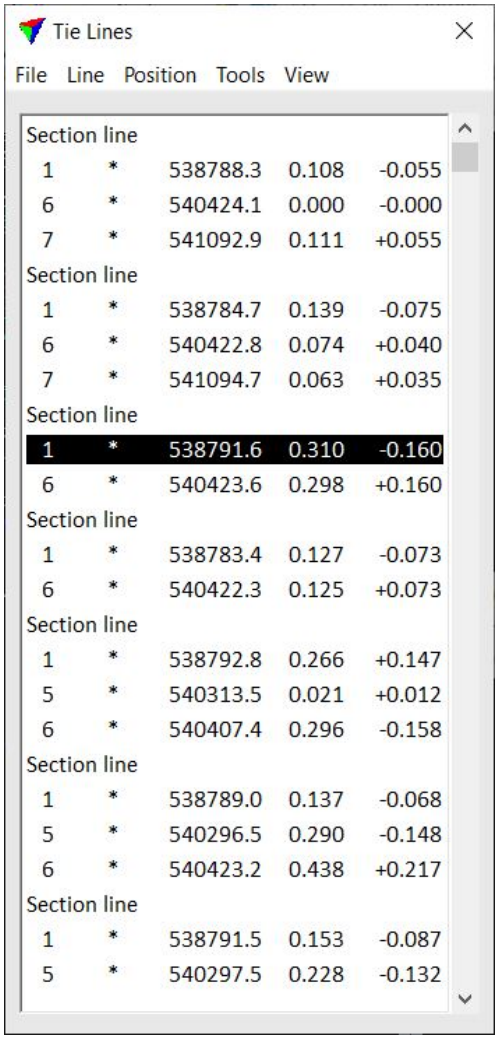
11. Check worst tie point positions and delete, if bad. Filter bad tie lines, if necessary.

12. Solve fluctuating Z correction using a smooth curve.

13. Apply correction to MLS data.

You may write a new copy of the data set.

Working with tie lines



The tie line mode is started with the Define Tie Lines tool. The tool opens the **Tie lines** window.

The window provides pulldown menus with commands for working with tie lines. These commands are described on the following pages. If a tie line file is loaded, it shows for each tie line the tie line type and the following information in columns 1-5:

1 strip number
2 scanner number
3 time stamp
4 XY mismatch at tie line location
5 Z mismatch at tie line location

The Define Tie Lines tool can also arrange the views in the CAD file in a way that is suitable for working with tie lines. The view setup includes:

- **Full view** - all tie lines are displayed in a top view.
- **Entry view** - one selected tie line position is displayed in a horizontal section or top view. This view is used for viewing or placing close-to-horizontal tie lines manually.
- **Detail view** - one selected tie line with all its positions is displayed in a horizontal section or top view.
- **Wall entry view** - one selected tie line position is displayed in a vertical section view. This view is used for viewing or placing close-to-vertical tie lines manually.
- **Wall detail view** - one selected tie line with all its positions is displayed in a vertical section view.

The views are updated automatically depending on the selected tie line type.

Asterisk symbol in the scanner column indicates points from multiple scanners were used to fit the observation

Tie line types

There are different types of tie lines which can be created depending on the objects and features available in the laser data set. An overview of the tie line types is given in the following table and examples are shown below in another table.

ABBREVIATIONS

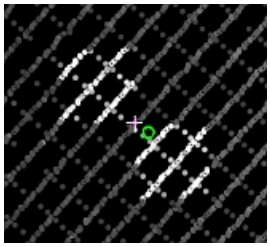
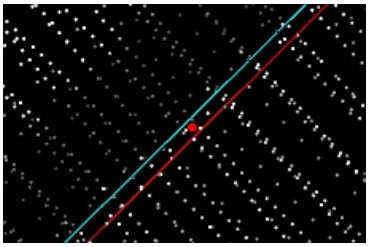
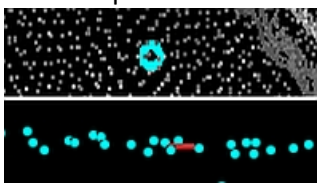
(G)CP - (ground) control point
ALS - airborne laser scanning data
MLS - mobile laser scanning data

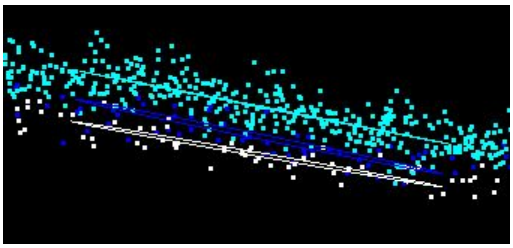
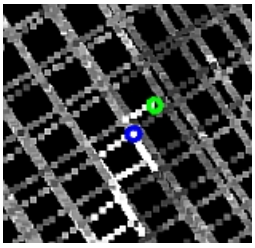
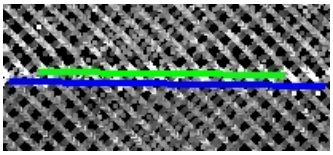
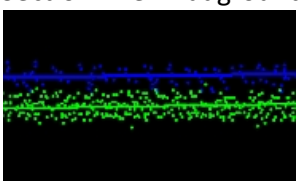
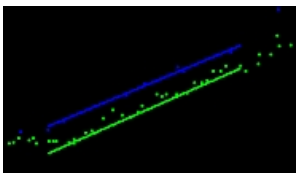
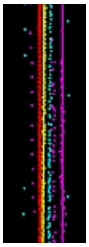
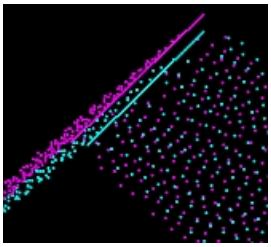
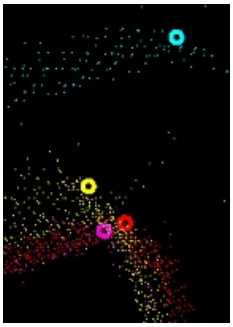
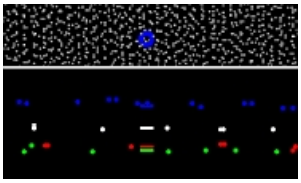
h - heading
r - roll
p - pitch

x - easting
y - northing
z - elevation

TIE LINE TYPE	PLACEMENT METHOD	POSSIBLE LOCATIONS	ADDED VALUE FOR SOLVING	INPUT DATA
Ground point	• manual	• end point of paint markings on the ground • circular objects on the ground	• h r p • xy z	• high point density ALS • MLS
Known xyz point Known xy point	• import from text file or selected vectors • automatic/manual	• CP on bright signal marker on dark hard surface (horizontal or vertical surface) • GCP on endpoints of paint markings on the ground • CP defined on target objects • Xyz point if reference lines are defined	• h r p • absolute xy z or xy	• high point density ALS • MLS • signal marker definition or target object definition • GCP text file or vector data
Known z point	• import from text file or selected vectors • manual	• GCP on the ground without known xy	• h r p • absolute z	• ALS • MLS • GCP text file or vector data
Xyz point	• automatic	• objects represented by grouped and classified points	• absolute xy z	• ALS • MLS
Xy point	• manual	• building corners • poles	• h • internal xy	• high point density ALS • MLS
Elevation point	• import from text file or selected vectors	• surfaces	• internal z	• ALS • MLS

TIE LINE TYPE	PLACEMENT METHOD	POSSIBLE LOCATIONS	ADDED VALUE FOR SOLVING	INPUT DATA
	• half-automatic			
Ground line	• manual	• along paint markings on the ground	• h r p • xy z	• high point density ALS • MLS
Plane point	• automatic search	• surfaces	• h r p • xy z	• high point density ALS • MLS
Section line • flat ground	• automatic search • manual	• flat, hard surfaces	• r • z	• ALS • MLS • flat ground classification
Section line • surface	• automatic search • manual	• surfaces	• h r p • z	• ALS
Section line • vertical walls	• automatic search • manual	• building walls • vertical poles	• h r p • xy z	• MLS
Known line	• import from text file • automatic/manual	• point on linear paint markings	• h • r p (ALS) • xy z	• high point density ALS • MLS
Roof intersection line	• automatic search	• intersection of two roof surfaces	• h r p • xy z	• ALS • building classification

EXAMPLES	
Known xyz or xy point 	Known line 
Known z point 	Plane point

EXAMPLES	
	
Ground point 	Ground line 
Section line - flat ground 	Section line - surface 
Section line - vertical wall 	Roof intersection line 
Xy point 	Elevation point 

Fluctuating corrections with tie lines

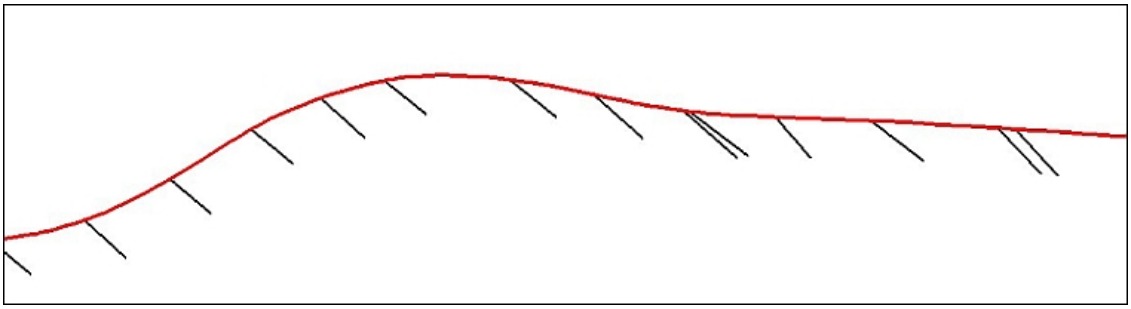
Besides the correction of systematic shifts, tie lines can be used for applying corrections that change over time (fluctuating corrections, drifts). This is essential for correcting local drifts of the trajectory solution which occur, for example, if there is a failure of GPS signal during a flight

or drive. Fluctuating corrections are the most important part of improving the accuracy of mobile laser data, but they are useful for airborne data as well.

If no control measurements are involved, the software computes a guessed location for the tie line feature which corresponds to the average of the feature location between the laser data strips. If the trajectory solution provides estimates of the positional accuracy for each drive pass, these estimates translate to weight factors when computing the average location. This results in lower accuracy strips getting a bigger correction and better accuracy paths getting a smaller correction.

If a control measurement is used, the observed correction is the difference between the tie line feature location in the laser data and the location of the control measurement.

The actual correction for the laser data is applied as a correction curve which changes over time. The correction curve is built by computing a correction for each tie line observation. The correction is a linear interpolation between two consecutive observations.



Exaggerated xyz correction vectors for one strip.

The user can specify how much the correction curve is smoothed. The smoothing of the correction curve involves the accuracy estimates for trajectory positions. Bigger corrections values are applied for positions where the accuracy estimate is worse. A factor determines, how fast the corrections curve changes can be. A small factor results in a smoother curve. This should be used if the tie lines are not so good and may contain outliers. A bigger factor results in a less smooth curve and the single tie line observations get more influence in the final solution. This should be used for good tie lines.

If no smoothing is applied, each tie line observation fully effects the final correction values. This is recommended for checking the tie lines and finding out erroneous tie lines. Otherwise, a smoother correction curve is less sensible to remaining inaccurate tie line observations. No smoothing may also be used if correction values are computed based on accurate tie points collected from ground control points for which the exact xyz coordinate values are known.

File pulldown menu

The **File** pulldown menu contains commands for creating, opening and saving tie line files, for restoring observations, for importing control measurements, for searching tie lines automatically, and for creating a statistical report.

TO	CHOOSE MENU COMMAND
Create a new tie line file	New
Open a tie line file	Open
Save an existing tie line file	Save
Save tie lines to a new file	Save as
Restore observations from a tie line file	Restore observations
Import control points as known lines	Import known lines
Import control points as known or elevation points	Import points
Search tie lines automatically	Search tie lines
Search cloud-to-cloud tie lines	Search cloud-to-cloud
Create a statistical report from tie lines	Output report

Clean all

Clean all command is used to remove all undefined positions from loaded tie lines. It performs the same action for all tie lines as the Clean command for a selected tie line.

To clean undefined positions from loaded tie lines:

1. Select **Clean all** command from the **File** pulldown menu.
2. Click OK to the **Alert** dialog.

   This removes all undefined positions from the tie lines. An information dialog shows the amount of deleted tie lines and tie line positions.

Fix lines

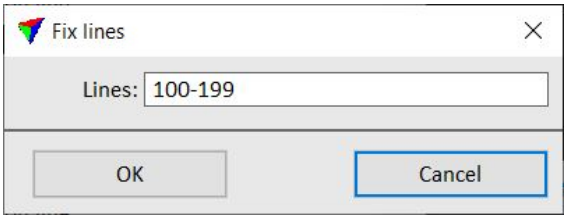
Fix lines command sets certain lines as fixed. As a result, the fixed lines are used as reference lines for matching other lines.

This can be used, for example, to match an MLS point cloud to an ALS point cloud. The line numbers of the two point clouds must be distinguishable. After searching tie lines, fix the lines of the ALS point cloud in order to use it as reference. Then, the lines of the MLS point cloud can be matched to the ALS data by using Find tie line match or Find tie line fluctuations tools.

To fix lines:

1. Select **Fix lines** command from the **File** pulldown menu.

   This opens the **Fix lines** dialog:



2. Select settings and click OK.

   This sets the given lines as fixed.

SETTING	EFFECT
Lines	Line number(s) that are fixed and used as reference for matching other lines.

Import known lines

Import known lines command starts the import of control measurements that have been measured on linear paint markings. The import results in tie lines of the type **Known line** which provide a partial xy control.

The control measurements have to be stored in a text file where each line includes the separated x, y, and z coordinates for one control point.

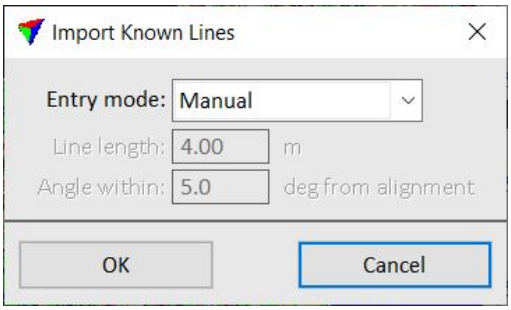
The command requires that a project is loaded in TerraScan where the laser data provides the input for placing the tie lines.

To import control measurements as known lines:

1. (Optional) Select a vector element which defines the direction in which paint markings run if you want to use the automatic tie line placement mode.

2. Select **Import known lines** command from the **File** pulldown menu.

   This opens the **Import Known Lines** dialog:



SETTING	EFFECT
Entry mode	Defines how tie lines for control measurements are placed: • **Manual** - all positions are digitized manually. • **Auto line search** - the software places the tie lines automatically.
Line length	Length of a tie line that the software places automatically. This is only active if **Entry** mode is set to **Auto line search**.
Angle within	Maximum angle difference between observed tie line and selected vector element. This is only active if **Entry** mode is set to **Auto line search**.

3. Select settings and click OK.

   This opens another dialog for selecting the text file with control measurement coordinates.

4. Select the text file and click **Open**.

   If the entry mode is **Manual**, the control measurements are added to the tie line list in the **Tie lines** window. Continue with placing the tie line locations manually.

   If the entry mode is **Auto line search**, the software tries to place the tie lines automatically at the location of the control measurements. Continue with checking the tie lines and placing tie lines manually where the automatic line search has failed.

Import points

Import points command starts the import of control measurements that have been measured on corners or end points of paint markings, on signal marker locations or on target objects. The import results in tie lines of the type **Known xyz**, **Known xy**, **Known z**, or **Elevation point**.

The control measurements can be provided in a text file where each line includes the separated x, y, and z coordinates for one control point. Another option are point elements drawn in the CAD file at the control measurement locations.

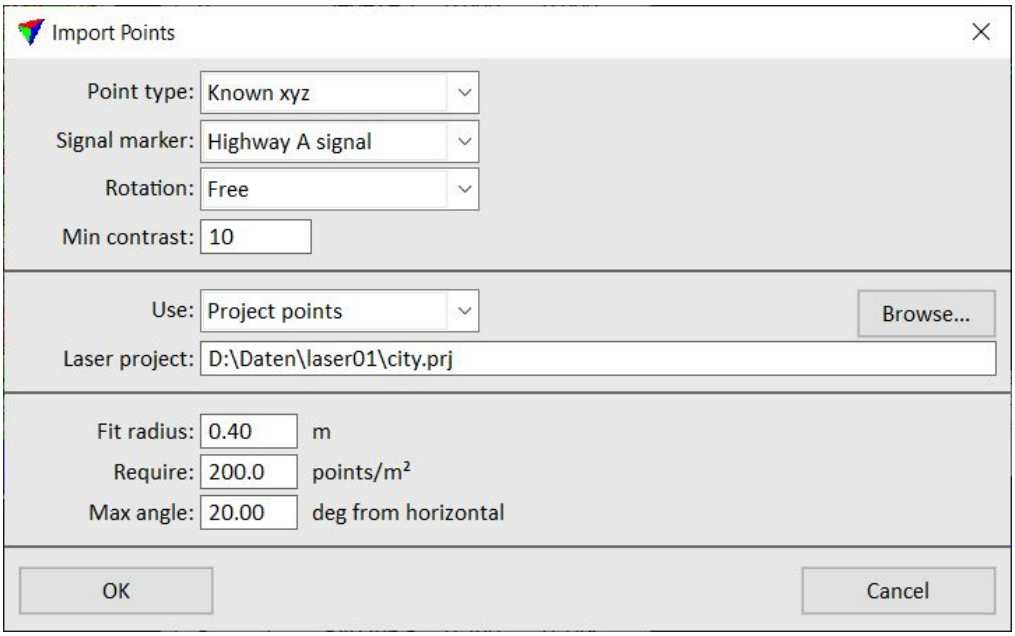
The command requires that a project is loaded in TerraScan where the laser data provides the input for placing the tie lines. If signal markers are used for placing **Known xyz** or **xy** points, the shape of the signal marker must be defined in TerraMatch **Settings**.

To import control measurements as points:

1. (Optional) Select the control points in the CAD file if you want to import the control points based on selected vectors.

2. Select **From text file** or **From selected vectors** command from **Import points** command of the **File** pulldown menu.

   This opens the **Import Points** dialog:



SETTING	EFFECT
Point type	Type of tie lines that are created from the control measurements.
Signal marker	Signal marker or target object name defined in TerraMatch **Settings**. Required for importing **Known xyz** or **Known xy** points.
Rotation	Defines the rotation for a signal marker: • **Free** - the signal marker can be rotated freely compared to the travel direction. • **Travel direction** - the rotation of the signal marker is fixed. The travel direction is extracted from the closest trajectory.
Min contrast	Intensity contrast between bright parts of a signal marker and the dark background.
Use	Laser points used for placing the tie lines: **Project points** *(Not UAV)* or **Loaded points**.
Laser project	Path to a TerraScan project. This is only active if **Use** is set to **Project points**.
Fit radius	Area within which points are used to calculate the tie line location.
Require	Point density required for placing the tie line.

SETTING	EFFECT
Max angle	Maximum allowed angle of the surface at a tie line location.

3. Define settings and click OK.

   If the import is based on selected vectors, the software starts the import and places the tie lines at the control measurement locations. Continue with checking the tie lines and placing tie line positions manually where the automatic placement failed.

   If the import is based on text file, another dialog opens for selecting the text file.

4. Select the text file and click **Open**.

   This starts the import and the software places tie lines at the control measurement locations. After the import has finished, an information dialog is shown. It displays the number of created known points vs. the number of control measurements found in the text file or selection set.

5. Continue with checking the tie lines and placing tie line positions manually where the automatic placement failed.

New

New command empties the tie line window and thus, opens a new tie line file. It also removes the active tie lines from the memory.

Open

Open command lets you open a tie line file from the hard disk. Opening a tie line file replaces any active tie lines with tie lines stored in the file.

Output report

Output report command displays a statistical report that is created based on the active tie lines. The content of the report varies depending on the types of tie lines that are available for calculating the statistics. The report can include information about:

- average mismatches in 3d, xy, z
- average leaning of walls
- statistics for known points/lines including amount of tie points/lines; transformation value recommendations; average magnitude, RMS values, maximum values, observation weights for x, y, and z
- statistics for internal observations including amount of tie points/lines; average magnitude, RMS values, maximum values, observation weights for x, y, and z
- average magnitudes per line for x, y, and z

- average magnitudes per trajectory group

A text file can be saved or the report can be printed from the **Tie line report** window by using the **Save as text file** command or **Print** command from the **File** pulldown menu. The window size can be changed using the commands from the **View** pulldown menu.

Reduce to single line

Reduce to single line command reduces tie lines to single line observations. As a result, each tie line is placed in only one strip. This is useful for solving calibration issues of a multi-scanner system because trajectory drift issues do not effect the solution for the whole data set anymore.

To reduce tie lines to single lines:

1. Collect tie lines with setting **Separate scanners** on. See Define Tie Lines for more information.
2. Select **Reduce to single line** command from the **File** pulldown menu.

   A dialog is shown which asks for confirmation of the step.
3. Click OK in order to reduce the tie lines.
4. Save the tie lines into a new tie line file.

Restore observations

Restore observations command restores original observations from a tie line file that has been saved earlier. It can be used, for example, to restore the original observations after applying corrections temporarily and removing bad tie lines.

To filter bad tie lines and restore observations:

1. Collect tie lines and save them into a file.
2. Solve correction(s).
3. Apply Correction to the loaded tie lines.
4. Search for worst observations and remove bad tie lines.

   Erroneous tie lines usually stand out more clearly after corrections have been applied.
5. Restore original observations from the tie lines file saved in step 1.
6. Save the filtered tie lines.

Save

Save command lets you save changes in the active tie lines to an already existing tie line file.

Save as

Save as command saves active tie lines to a tie line file. By default, tie lines are stored in a binary file with the extension .TIL.

The user can enforce the storage of tie lines in a text file by typing the extension .TXT in addition to the file name in the **Save tie lines** dialog. This is only recommended if the tie line file needs to be opened in x32 TerraMatch or another software that can not read the binary format for tie lines.

Search tie lines

Search tie lines command opens the **Search tie lines** dialog from which the automatic tie line search can be started. With the automatic tie line search you can search for tie lines of various types.

The automatic tie line search can be based either on laser points loaded into TerraScan or on a TerraScan project. Tie line search can also run as macro action in TerraScan. In this case, a settings file has to be stored from the **Search tie lines** dialog.

The different tie line types are searched for in different laser point classes depending on the settings in the Define Tie Lines dialog:

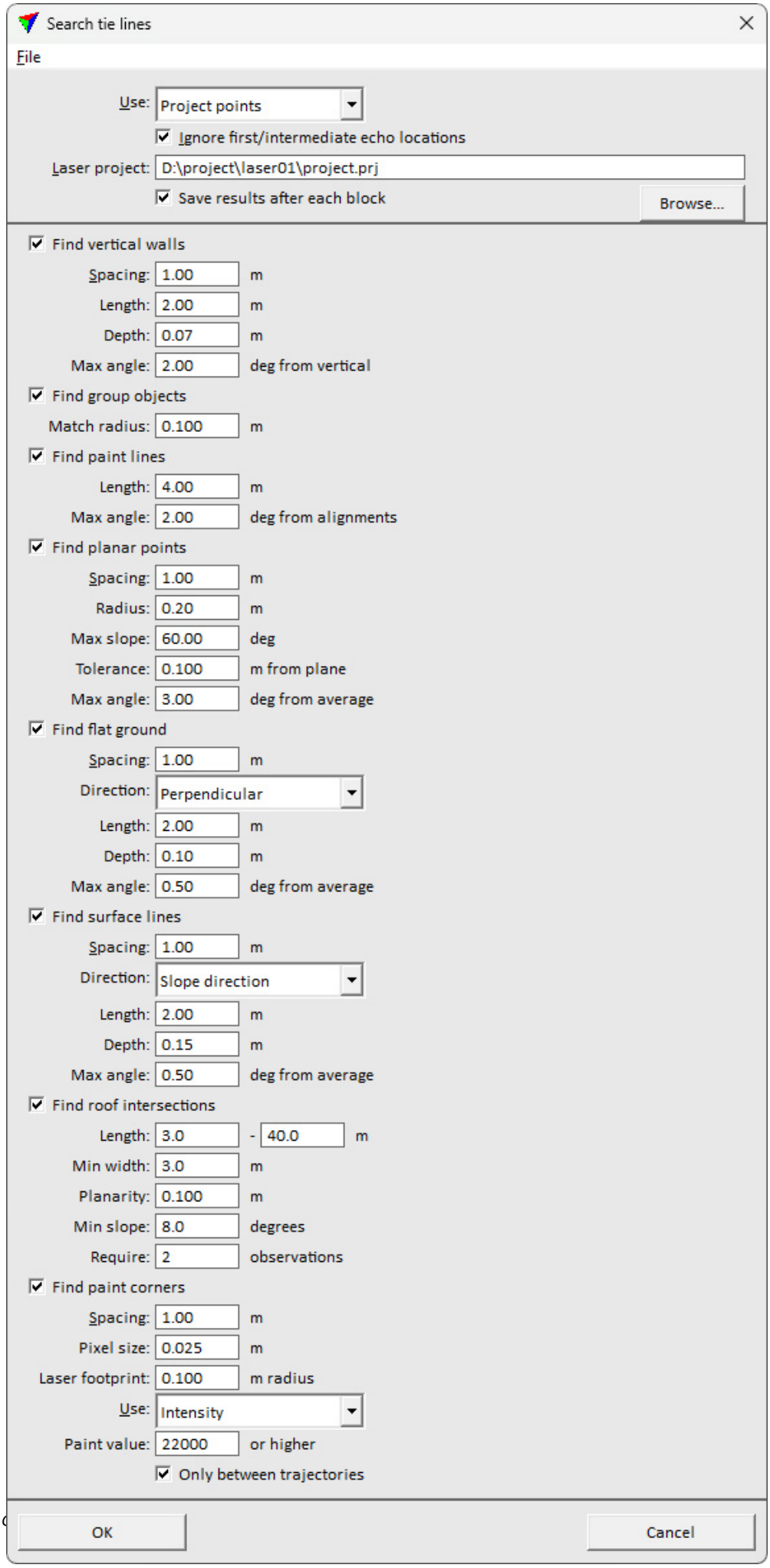
- **Vertical walls** - wall classes
- **Group objects** - object classes
- **Paint lines** - ground classes
- **Planar points** - ground classes
- **Flat ground** - ground classes
- **Surface lines** - ground classes
- **Roof intersections** - roof classes
- **Paint line corners** - ground classes

The tie line settings can be changed between several tie line searches using the Settings command from the **View** pulldown menu. When searching first for one tie line type and then for another, the new tie lines are added to the active tie lines at the end of the tie line list.

To search tie lines:

1. Select **Search tie lines** command from the **File** pulldown menu.

   This opens the **Search tie lines** dialog:


Search tie lines
File
Use: Project points
Ignore first/intermediate echo locations
Laser project: D:\project\laser01\project.prj
Save results after each block
Browse...
Find vertical walls
Spacing: 1.00 m
Length: 2.00 m
Depth: 0.07 m
Max angle: 2.00 deg from vertical
Find group objects
Match radius: 0.100 m
Find paint lines
Length: 4.00 m
Max angle: 2.00 deg from alignments
Find planar points
Spacing: 1.00 m
Radius: 0.20 m
Max slope: 60.00 deg
Tolerance: 0.100 m from plane
Max angle: 3.00 deg from average
Find flat ground
Spacing: 1.00 m
Direction: Perpendicular
Length: 2.00 m
Depth: 0.10 m
Max angle: 0.50 deg from average
Find surface lines
Spacing: 1.00 m
Direction: Slope direction
Length: 2.00 m
Depth: 0.15 m
Max angle: 0.50 deg from average
Find roof intersections
Length: 3.0 - 40.0 m
Min width: 3.0 m
Planarity: 0.100 m
Min slope: 8.0 degrees
Require: 2 observations
Find paint corners
Spacing: 1.00 m
Pixel size: 0.025 m
Laser footprint: 0.100 m radius
Use: Intensity
Paint value: 22000 or higher
Only between trajectories
OK
Cancel

2. Define settings and click OK.

   The software starts the search for tie lines. As a result, tie lines of the selected type are added to the list of active tie lines. The amount of tie lines found is displayed in an information dialog after the search is completed.

SETTING	EFFECT
Use	Laser points used for placing the tie lines: **Project points** *(not UAV)* or **Loaded points** .
Ignore first/intermediate echo locations	If on, locations where there are laser points of first or intermediate echo types are ignored.
Laser project	Path to a TerraScan project. This is only active if **Use** is set to **Project points**.
Save results after each block	If on, the tie lines are saved automatically into a file after the search is completed for a block of a project. This is only active if **Use** is set to Project **points**.
Find vertical walls	Search for tie lines on vertical walls or structures within the **Wall classes** defined in the settings. • **Spacing** - distance between two tie line locations. The value determines the maximum density of the tie lines. • **Length** - length of a tie line. • **Depth** - depth of a section where the software tries to fit the tie line to the laser points. • **Max angle** - maximum allowed angle off from vertical for a tie line placed on a vertical structure.
Find group objects	Search for tie lines based on groups of points that represent a certain object type. Objects are defined by classified and grouped points in TerraScan. Each object must be assigned to one group and groups of one object type must be classified into a separate class. • **Match radius** - maximum distance between a point in the object group in one line and the closest point in the object group in another line.
Find paint lines	Search for tie lines on bright paint markings using a selected vector of known points along the center of paint marking. • **Length** - length of a tie line. • **Max angle** - maximum allowed angle off from average between the tie lines at the same location.
Find planar points	Search for tie lines on planar surfaces within the **Ground classes** defined in the settings.

SETTING	EFFECT
	• **Spacing** - distance between two tie line locations. The value determines the maximum density of the tie lines. • **Radius** - size for point sampling footprint in local plane extraction. • **Max slope** - maximum allowed angle off from horizontal for a plane fit. • **Tolerance** - distance tolerance between points and plane equation for outlier filtering. • **Max angle** - maximum allowed angle off from average between the tie lines at the same location.
Find flat ground	Search for tie lines on flat ground or horizontal surfaces within the **Ground classes** defined in the settings. • **Spacing** - distance between two tie line locations. The value determines the maximum density of the tie lines. • **Direction** - direction of a tie line relative to the movement direction: Along movement or Perpendicular. • **Length** - length of a tie line. • **Depth** - depth of a section where the software tries to fit the tie line to the laser points. • **Max angle** - maximum allowed angle off from average between the tie lines at the same location.
Find surface lines	Search for tie lines on surfaces within the **Ground classes** defined in the settings. • **Spacing** - distance between two tie line locations. The value determines the maximum density of the tie lines. • **Direction** - direction of a tie line relative to the movement direction or terrain slope: **Along movement**, **Perpendicular**, or **Slope direction**. • **Length** - length of a tie line. • **Depth** - depth of a section where the software tries to fit the tie line to the laser points. • **Max angle** - maximum allowed angle off from average between the tie lines at the same location.
Find roof intersection lines	Search for tie lines along intersections of roof planes within the **Roof classes** defined in the settings. • **Length** - length range of a tie line. • **Min width** - minimum width of the roof planes on both sides of the tie line.

SETTING	EFFECT
	• **Planarity** - distance tolerance between point and plane equation of the planar roof patch it belongs to. • **Min slope** - minimum slope off from horizontal of the roof planes. • **Require** - number of observations required for accepting a tie line location. Minimum is 2 observations (from 2 strips).
Find paint corners	Search for tie lines based on intensity (alternatively reflectance or amplitude) values in MLS point clouds. The software tries to identify corners of paint markings on the road surface. This requires good intensity values. If there are systematic issues with intensity values (such as weeker intensity for points at a longer distance from scanner or smaller angle of incidence), an intensity correction may be required, e.g. with the Find intensity correction tool of TerraMatch. • **Spacing** - distance between two tie line locations. The value determines the maximum density of the tie lines. • **Pixel size** - pixel size of the intensity raster that is internally created from each drive path. Use a smaller size than the scan line distance in the point cloud. • **Laser footprint** - for each pixel in the intensity raster, a circular area of the given radius is used to compute a distance-weighted average intensity value from the laser points. • **Use** - point attribute used for placing the tie lines. Alternatives for the **Intensity** attribute are the **Reflectance** or **Amplitude** attributes (e.g. from Riegl Extra Bytes). • **Paint value** - intensity values that represent bright paint markings in a point cloud. The minimum value is given in the text field. This needs to be tested for each point cloud, e.g. with the TerraScan option to classify points by intensity. • **Only between trajectories** - if on, the search for tie lines is reduced to the area between trajectories which corresponds to the road center area.

File / Load settings

Load settings command can be used to open a previously stored settings file.

To open a tie line search settings file:

1. Select **Load settings** command from the **File** pulldown menu.

   This opens the **Tie line settings file** dialog, a standard Windows dialog for opening files.

3. Select a settings file and click **Open**.

File / Save settings

Save settings command lets you save tie line search settings into a file. The file can be used by the TerraScan macro action for searching tie lines. The file can also be loaded into TerraMatch using the **Load settings** command from the **Search tie lines** dialog. The settings are stored into a text file with the extension .SET. The settings file includes settings from the Seach tie lines dialog as well as settings from the **Define tie lines** dialog.

To save a tie line search settings file:

1. Define settings for the tie line search in the **Search tie lines** dialog.

2. Select **Save settings** command from the **File** pulldown menu.

   This opens the **Tie line settings file** dialog, a standard Windows dialog for saving files.

3. Define a location and name for the settings file and click **Save**.

Search cloud-to-cloud

Search cloud-to-cloud command searches tie lines for matching a mobile ground-based (MLS) point cloud to a reference point cloud, such as airborne laser data. The tie lines are placed for the MLS point cloud in user-defined time intervals. For each time interval, the software computes an XYZ shift for matching the MLS data better to the reference data. Consecutive observations must not differ too much in correction values, and only observations that do not differ too much from closest more reliable observations are accepted. As a result, a fluctuating XYZ correction curve can be computed from the tie lines.

Requirements for the cloud-to-cloud matching process:

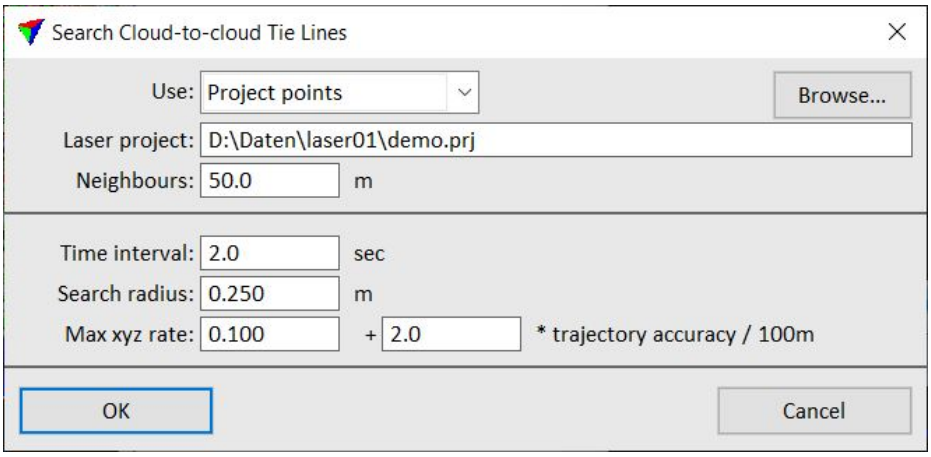
- Both data sets, the MLS data set for matching and the reference data set must include points on vertical surfaces, such as building walls. Only with points on wall-like surfaces the software is able to compute an XY correction automatically. Otherwise, additional tie points are required for XY correction, for example **Known XY** points derived from orthophotos or from ground control points.
- The reference point cloud must be available together with the MLS point cloud. In a TerraScan project, the reference point cloud is defined as reference project in the project definition of the MLS project. See **Reference project exists** option in the **Project information** dialog of TerraScan. If loaded points are used, the reference points can be loaded into TerraScan with the **Read reference points** command. If a project block is loaded, the **Load reference points** option must be switched on.

- The normal vector and dimension attributes must be computed for the MLS data set. The cloud-to-cloud matching is derived from points of **Planar** dimension. The computation can be done with TerraScan, either with a macro step or with a menu command for loaded points. The attributes can be stored permanently in TerraScan **Fast Binary** files.

To search cloud-to-cloud tie lines:

1. Select **Search cloud-to-cloud** command from the **File** pulldown menu.

   This opens the **Search Cloud-to-cloud Tie Lines** dialog:



2. Define settings and click OK.

   The software starts the search for tie lines. As a result, tie lines are added to the list of active tie lines. The amount of tie lines found is displayed in an information dialog after the search is completed.

   Although the tie lines can be displayed on top of the point cloud, there is not much use in checking the tie lines. Each tie line drawing just represents the given time interval for which the software tries to compute the XYZ shift. The tie line drawing does not represent any specific XYZ location in the point clouds.

3. Use the **Find tie line fluctuations** tool in order to compute, check, and save the XYZ correction curve for matching.

SETTING	EFFECT
Use	Laser points used for placing the tie lines: **Project points** *(not UAV)* or **Loaded points**.
Laser project	Path to a TerraScan project. This is only active if **Use** is set to **Project points**.
Neighbours	Area for which points from neighbouring blocks are used. This is only active if **Use** is set to **Project points**.
Time Interval	Time difference between consecutive tie lines.

SETTING	EFFECT
Search radius	Determines the 3D radius around a point within which the software searches for points in the reference data set. The search radius is taken into account after the maximum XY shift from the tie lines settings and some thinning are already applied to the MLS data set. The value relates to the point density and point-to-point spacing in the data sets. The value should be larger than the point-to-point spacing in the MLS data set and the reference data set. If the value is chosen too big, the tie line search is very slow. Recommended values: 0.25 m if matching MLS to ALS data, up to 1.0 m if more distant and sparse points on walls in MLS data should be used for matching, < 0.25 m if both data sets are really dense, e.g. when matching MLS data to another MLS reference data set.
Max xyz rate	This first value determines the minimum change in the correction curve independently of the trajectory accuracy. The second value determines how fast the correction curve is allowed to change in relation to the trajectory accuracy and travelled distance. A smaller factor leads to slow changes in the correction curve (= more smoothing applied), a larger factor allows faster changes in the correction curve (= less smoothing applied).

Line pulldown menu

The **Line** pulldown menu contains commands for adding tie lines manually or half-automatically, for modifying the type of a tie line, for cleaning up tie lines, and for deleting tie lines.

TO	CHOOSE MENU COMMAND
Add tie lines of a specific type manually or half-automatically based on laser data that is loaded in TerraScan. See Tie line types for more information about the different tie line types.	Add ground point Add xy point Add elevation point Add known point Add ground line Add section line Add known line

TO	CHOOSE MENU COMMAND
Modify the type of a tie line	Edit
Delete undefined tie line positions	Clean
Delete tie lines	Delete

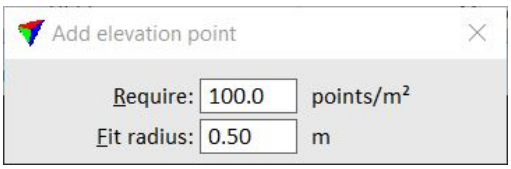
Add elevation point

Add elevation point command lets you place a tie line of the type **Elevation point**.

To add an elevation point:

1. Select **Add elevation point** command from the **Line** pulldown menu.

   This opens the **Add elevation point** dialog:



SETTING	EFFECT
Require	Point density required for placing the tie point.
Fit radius	Area within which laser points are used to calculate the tie point's elevation.

2. Define settings that fit to the laser data.

3. Select an approximate location for the tie point in the **Full view**.

   This updates the **Entry view** and **Detail view** and adds the tie point to the list.

4. Place the tie point in the **Entry view** according the the laser data for each tie point position.

If you are not able to place all tie point positions, you can skip a position by selecting the next observation for this tie point. Then use the Clean command to remove undefined positions.

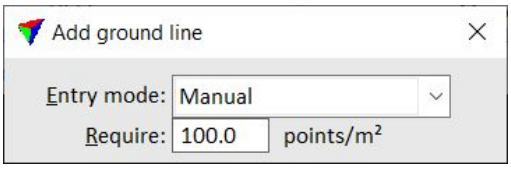
Add ground line

Add ground line command lets you place a tie line of the type **Ground line**.

To add a ground line:

1. Select **Add ground line** command from the **Line** pulldown menu.

   This opens the **Add ground line** dialog:



SETTING	EFFECT
Entry mode	Defines how the tie line is placed: • **Manually** - all positions are digitized manually. • **Auto line search** - only the first position is placed manually, the other positions are found automatically.
Require	Point density required for placing the tie point.

2. Select settings that fit to the laser data.

3. Select an approximate location for the tie line in the **Full view**.

   This updates the **Entry view** and **Detail view** and adds the tie line to the list.

4. (Manual mode) Place the tie line in the **Entry view** according the the laser data for each tie line position.

   OR

5. (Auto line search mode) Place the tie line in the **Entry view** according the the laser data for the first tie line position. The software tries to find the other tie line positions automatically.

If you are not able to place all tie point positions, you can skip a position by selecting the next observation for this tie point. Then use the Clean command to remove undefined positions.

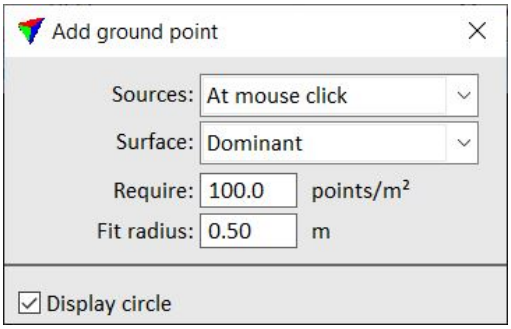
Add ground point

Add ground point command lets you place a tie line of the type **Ground point**.

To add a ground point:

1. Select **Add ground point** command from the **Line** pulldown menu.

   This opens the **Add ground point** dialog:



SETTING	EFFECT
Sources	Determines where the software looks for data for placing a tie point: • **At mouse click** - data from lines/scanners with required point density around the data click location is considered. This is the preferred setting. • **Within max error** - data from all lines/scanners are considered for tie point placement if they are within the maximum error limits given in the tie line settings. This slows down the tie point placement and should be used only in exceptional cases (e.g. tunnel data sets with large mismatch).
Surface	If a point cloud contains multiple surfaces at the location of a tie point, the tie point is fitted to: • **High** - the highest surface. • **Dominant** - the dominant surface. Use this in all cases where there is only one surface in a point cloud at a tie point location. • **Low** - the lowest surface.
Require	Point density required for placing the tie point.
Fit radius	Area within which laser points are used to calculate the tie point's elevation.
Display circle	If on, a circle of the specified **Diameter** is displayed at the mouse pointer location. This helps to place a tie point accurately, for example on circular objects.

2. Define settings that fit to the laser data.

3. Select an approximate location for the tie point in the **Full view**.

   This updates the **Entry view** and **Detail view** and adds the tie point to the list.

4. Place the tie point in the **Entry view** according the the laser data for each tie point position.

If you are not able to place all tie point positions, you can skip a position by selecting the next observation for this tie point. Then use the Clean command to remove undefined positions.

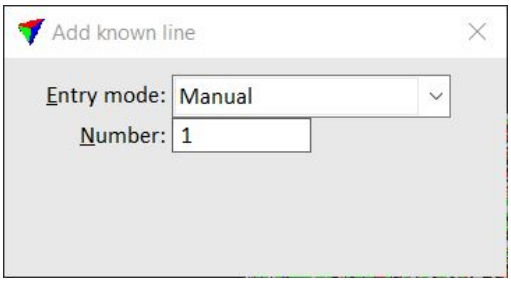
Add known line

Add known line command lets you place a tie line of the type **Known line**. This requires that control measurements are available and drawn as point elements into the CAD file.

To add a known line:

1. Select **Add known line** command from the **Line** pulldown menu.

   This opens the **Add known line** dialog:



SETTING	EFFECT
Entry mode	Defines how the tie line is placed: • **Manual** - all positions are digitized manually. • **Auto line search** - only the first position is placed manually, the other positions are found automatically.
Number	Number of the known line. Counts up automatically.

2. Define settings.

3. Snap to the known point and draw a line at the approximate location of the tie line in the **Full view**.

   This updates the **Entry view** and **Detail view** and adds the tie line to the list.

4. (Manual mode) Place the tie line in the **Entry view** according the the laser data for each tie line position.

   OR

4. (Auto line search mode) Place the tie line in the **Entry view** according the the laser data for the first tie line position. The software tries to find the other tie line positions automatically.

If you are not able to place all tie point positions, you can skip a position by selecting the next observation for this tie point. Then use the Clean command to remove undefined positions.

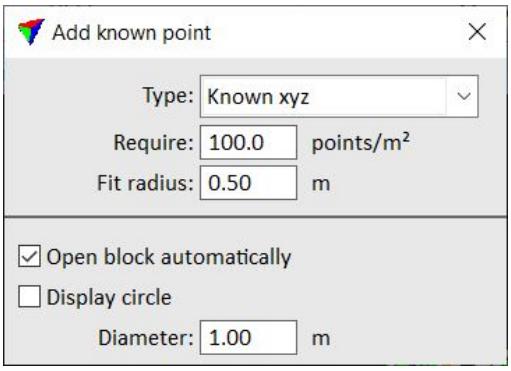
Add known point

Add known point command lets you place a tie line of the type **Known xyz**, **Known xy**, or **Known z** point. This requires that control measurements are available and drawn as point elements into the CAD file.

To add a known point:

1. Select **Add known point** command from the **Line** pulldown menu.

   This opens the **Add known point** dialog:



SETTING	EFFECT
Type	Known tie point type: • **Known xyz** - xyz coordinates are used for the tie point. • **Known xy** - xy coordinates are used for the tie point. • **Known z** - z coordinate is used for the tie point.
Require	Point density required for placing the tie point.
Fit radius	Area within which points are used to calculate the tie point location.

2. Select settings that fit to the laser data and to the known points that are used.

3. Snap to the control point drawn in the CAD file in order to define the location for the tie line in the **Full view**.

This updates the **Entry view** and **Detail view** and adds the tie point to the list.

4. Place the tie point in the **Entry view** according the the laser data for each tie point position.

If you are not able to place all tie point positions, you can skip a position by selecting the next observation for this tie point. Then use the Clean command to remove undefined positions. You may also change the type of the tie point using the Edit command, for example from **Known xyz** to **Known z**, if you are not able to place the tie point at the accurate xy location.

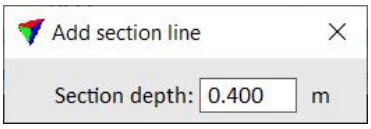
Add section line

Add section line command lets you place a tie line of the type S**ection line**.

To add a section line:

1. Select **Add section line** command from the **Line** pulldown menu.

   This opens the **Add Section Line** dialog:



SETTING	EFFECT
Section depth	Depth of the section that is used for fitting the tie line to the laser data.

2. Define settings that fit to the laser data.

3. Select an approximate location for the tie line in the **Full view**.

   This updates the **Entry view** and **Detail view** or the **Wall entry view** and **Wall detail view**, and adds the tie line to the list.

4. Place the tie line in the **Entry view** or **Wall entry** view according the the laser data for each tie line position.

If you are not able to place all tie point positions, you can skip a position by selecting the next observation for this tie point. Then use the Clean command to remove undefined positions.

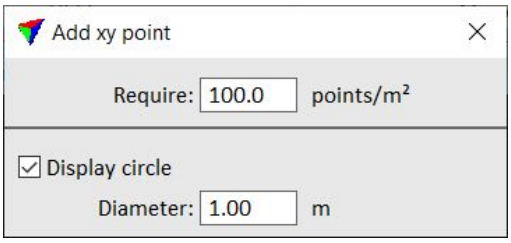
Add xy point

Add xy point command lets you place a tie line of the type **Xy point**.

To add an xy point:

1. Select **Add xy point** command from the **Line** pulldown menu.

   This opens the **Add Xy Point** dialog:



SETTING	EFFECT
Require	Point density required for placing the tie point. Refers to points in the **Wall classes** field in the Tie Line Settings dialog.
Display circle	If on, a circle of the specified **Diameter** is displayed at the mouse pointer location. This helps to place a tie point accurately, for example on circular objects.

2. Define settings that fit to the laser data.

3. Select an approximate location for the tie point in the **Full view**.

   This updates the **Entry view** and **Detail view** and adds the tie point to the list.

4. Place the tie point in the **Entry view** according the the laser data for each tie point position.

If you are not able to place all tie point positions, you can skip a position by selecting the next observation for this tie point. Then use the Clean command to remove undefined positions.

Clean

Clean command is used to remove undefined positions from a tie line. There are places where a tie line can not be defined for some strips due to obstructions, too low point densities, or inappropriate viewing angles. This results in undefined positions which should be deleted from the tie line list.

To clean undefined positions from a tie line:

1. Select the tie line or one of its positions.

2. Select **Clean** command from the **Line** pulldown menu.

   This removes all undefined positions from this tie line.

The Clean all command can be used to remove undefined positions from all loaded tie lines.

Delete

Delete command is used to delete tie lines from the list. In contrast to Delete command from the **Position** pulldown menu, this command deletes the tie line completely.

COMMAND	EFFECT
Selected tie line	The selected tie line is deleted.
Inside fence	All tie lines inside a fence or selected polygon are deleted.
Outside fence	All tie lines outside a fence or selected polygon are deleted.

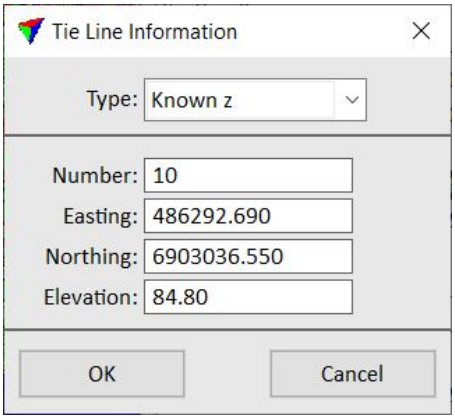
Edit

Edit command can be used to change the type of a tie line.

To change the tie line type:

1. Select the tie line.
2. Select **Edit** command from the **Line** pulldown menu.

   This opens the **Tie Line Information** dialog:



3. Select a new tie line **Type** from the selection list.
4. Click OK.

   This changes the type of the tie line and updates the information in the tie line list.

Position pulldown menu

The **Position** pulldown menu includes commands for correcting tie line positions manually, for identifying tie lines, for deleting tie line positions, for finding bad tie lines, and for identifying the position of the scanner at a tie line location.

A tie line position refers to a tie line at one specific flight or drive path.

TO	CHOOSE MENU COMMAND
Define the position of a tie line manually	Enter position
Select a tie line from a CAD file view	Identify
Delete tie line positions	Delete
Find the tie line with the biggest mismatch value	Find worst
Find tie lines with mismatch values up to a certain threshold	Find Find next
Show the scanner position for a tie line location	Show scanner
Remove closeby tie line observations	Thin by travel distance
Remove bad tie lines automatically	Filter bad

Delete

Delete command is used to delete positions of tie lines. In contrast to the Delete command from the **Line** pulldown menu, this command may not delete a tie line completely but only those positions that meet the defined settings.

COMMAND	EFFECT
Selected position	The selected position of a tie line is deleted.
By line	Tie line positions of selected strip(s) are deleted.
By scanner	Tie line positions of selected scanner(s) are deleted.
By criteria	Tie line positions that fit to specified criteria are deleted.
Bad line numbers	Tie lines that do not match a trajectory line number are deleted. Trajectory line numbers are checked from the active trajectory directory in TerraScan.

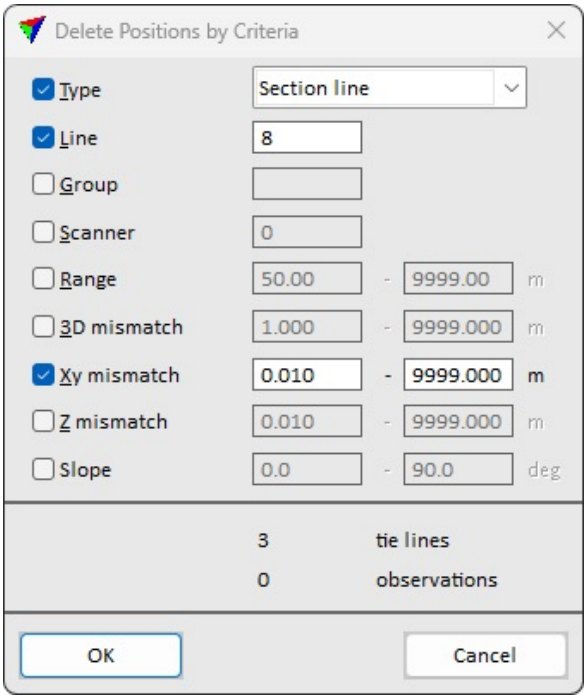
Delete / By criteria

By criteria command deletes tie line positions that fit to specific criteria. The criteria are defined in the command's dialog. The dialog also shows the number of effected tie lines and tie line positions as soon as the criteria is specified. Only tie line positions that fit to all criteria set in the dialog are deleted.

To delete tie line positions by criteria:

1. Select **By criteria** from the **Delete** command of the **Line** pulldown menu.

   This opens the **Delete Positions by Criteria** dialog:



2. Define one or several criteria for tie line removal.

   The number of effected tie lines and tie line positions is displayed dynamically in the dialog.

3. Click OK.

   This deletes the tie line positions. A dialog shows the number of deleted tie lines and tie line positons.

SETTING	EFFECT
Type	Tie line positions of a specified type. The list contains all tie line types.
Line	Tie line positions of a given line number.
Group	Tie line positions that belong to the given trajectory group. This relies on the trajectory group attribute defined in TerraScan.

SETTING	EFFECT
Scanner	Tie line positions of a given scanner number.
Range	Tie line positions within the given 3D distance range from the trajectory.
3D mismatch	Tie line positions with a 3D mismatch value within the given range.
Xy mismatch	Tie line positions with a Xy mismatch value within the given range.
Z mismatch	Tie line positions with a Z mismatch value within the given range.
Slope	Tie line positions with angle to the horizontal plane within the given range.

Enter position

Enter position command lets you place a tie line position manually. This can be used for correcting the position of a selected tie line, for example when the automatic placement did not work accurately.

To enter the position of a tie line:

1. Select the tie line position for which you want to place the tie line.
2. Load laser data at the tie line location.
3. Select **Enter position** command from the **Position** pulldown menu.
4. Digitize the new tie line location in the **Entry view** according to the laser data.

   This updates the location of the tie line and the values in the tie line list.

Filter bad

Filter bad command removes bad tie line observations automatically. This helps to reduce the manual effort for checking bad tie lines after the automatic tie line search.

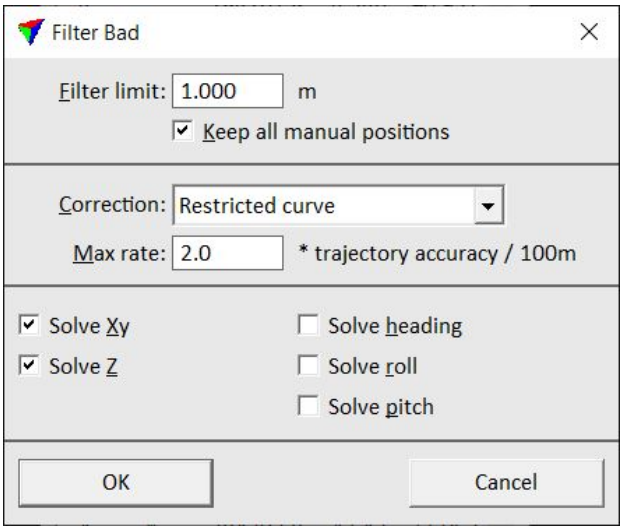
The routine first runs the Find tie line fluctuations process on the tie lines using the given method for smoothing and solving the selected parameters. Then, it removes tie line observations with the largest residual mismatches. These two processes are repeated until there are no mismatch distances in tie line observations bigger than the given filter limit.

The filter limit should be defined in a way that valuable tie lines are not removed. It must not be set to a too small value, especially if heading, roll, and/or pitch corrections have to be solved.

To filter bad tie lines automatically:

1. Select **Filter bad** command from the **Position** pulldown menu.

   This opens the **Filter Bad** dialog:



2. Define settings and click OK.

   This starts the filtering process. An information dialog shows the number of deleted tie lines and tie line positions after the process has finished. Depending on the amount of tie lines, the process may take some time.

SETTING	EFFECT
Filter limit	Maximum allowed mismatch distance in tie line observations. This acts as a threshold for stopping the filtering process.
Keep all manual positions	If on, manually placed tie lines are not effected by the filtering process.
Correction	Determines the method for smoothing the correction curve in the internal Find tie line fluctuations process: • **Restricted curve** - smoothing based on trajectory accuracy estimates is applied. The amount of smoothing is determined by the **Max rate** factor and effected by the accuracy of trajectory positions. • **Smooth curve** - smoothing based on a 1D Gaussian filter is applied.
Max rate	Determines how fast the corrections curve changes can be. A smaller factor results in a smoother curve. Values can range between 0.1 and 100.0, the default value is 2.0. This is

SETTING	EFFECT
	only available if **Correction** is set to **Restricted curve**.
Range	Distance forward and backward from a tie line observation within which correction values are averaged. Values can range between 0.1 and 100.0, the default value is 50. This is only active if **Correction** is set to **Smooth curve**.
Solve Xy	Solves for a fluctuating xy correction.
Solve Z	Solves for a fluctuating z correction.
Solve heading	Solves for a fluctuating heading correction.
Solve roll	Solves for a fluctuating roll correction.
Solve pitch	Solves for a fluctuating pitch correction.

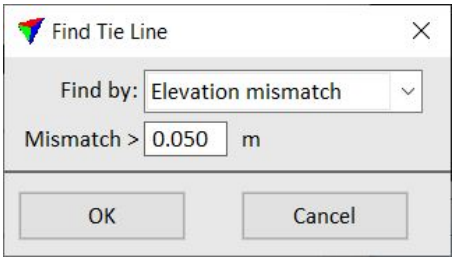
Find

Find command is used for searching tie lines that have a mismatch larger than a specific threshold value. The threshold can relate to different mismatch values, such as elevation, xy, 3D, angular, or wall angle mismatch.

To find tie lines:

1. Select **Find** command from the **Position** pulldown menu.

   This opens the **Find Tie Line** dialog:



2. Define settings and click OK.

   The first tie line position with a mismatch larger than the defined threshold is selected in the list.

3. Check the tie line and make corrections, if necessary.

4. Continue checking tie lines with Find next command.

SETTING	EFFECT
Find by	Mismatch values as search criteria: • **Elevation mismatch** - in CAD file master units. • **Xy mismatch** - in CAD file master units. • **3D mismatch** - in CAD file master units. • **Angle mismatch** - degree off from average. • **Wall angle** - degree off from vertical.
Mismatch >	Threshold value for searching bad tie lines.

Find next

Find next command is used to check tie lines with a mismatch larger than defined in the **Find tie line** dialog of Find command. It requires that the **Find** command has been used to define the parameters for the search of bad tie lines. After that, you can check all tie lines that meet the search criteria by using the **Find next** command.

Check tie lines that meet specific search criteria:

1. Define the parameters for the tie line search with Find command.
2. Check the first selected tie line and make corrections, if necessary.
3. Select **Find next** command from the **Position** pulldown menu.

   The next tie line position with a mismatch larger than the defined threshold is selected in the list.
4. Continue with step 3 until the end of the tie line list is reached.

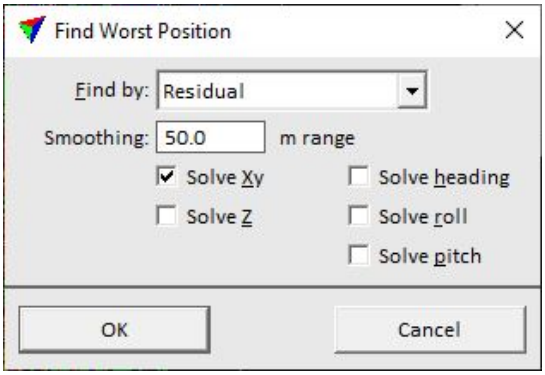
Find worst

Find worst command is used to select the tie line with the largest mismatch or residual value from the list. It helps to detect incorrect tie lines or tie lines with exceptionally high mismatch values.

To check the worst tie line in the list:

1. Select **Find worst** command from the **Position** pulldown menu.

   This opens the **Find Worst Position** dialog:



2. Define settings and click OK.

   This selects the tie line in the list that has been identified as the worst according to the given settings. The selected tie line is also shown in the CAD file views used for displaying the tie lines.

SETTING	EFFECT
Find by	Method of finding the worst tie line: • **Mismatch** - the tie line with the largest mismatch value (XY or Z) is shown. • **Residual** - the tie line with the largest residual mismatch after applying a fluctuating correction is shown.
Smoothing	Distance forward/backward from a tie line observation along the trajectory direction within which smoothing is applied. This effects the fluctuating correction curve for the residual computation. This is only active if **Find by** is set to **Residual**.
Solve Xy|Z|heading|roll|pitch	If on, a fluctuating correction is computed for the selected value(s). This is only active if **Find by** is set to **Residual**.

Identify

Identify command is used to identify a tie line in a CAD file view with a mouse click. The corresponding tie line is selected in the tie line list.

To identify a tie line:

1. Select **Identify** command from the **Position** pulldown menu.

2. Move the mouse pointer inside a CAD file view.

   The tie line closest to the mouse pointer is highlighted.

3. Place a data click in order to select the tie line in the list.

Show scanner

Show scanner command can be used to check the scanner position when the system captured the data at a selected tie line location. This is useful, for example for determining whether a tie line is placed at a short or long distance from a scanner.

To show the scanner position:

1. Select a tie line position in the tie lines list.
2. Select **Show scanner** command from the **Position** pulldown menu.
3. Move the mouse pointer inside a CAD file view.

   A line is displayed between the selected tie line location and the scanner position.
4. Place a data click in order to draw the line into the CAD file.

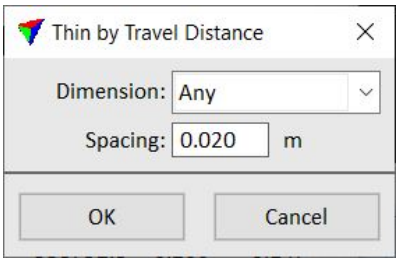
Thin by travel distance

Thin by travel distance command removes tie line observations that are very close to each other. The distance between tie lines is measured as travel distance along a trajectory.

To thin tie lines based on travel distance:

1. Select **Thin by travel distance** command from the **Position** pulldown menu.

   This opens the **Thin by Travel Distance** dialog:



SETTING	EFFECT
Dimension	Type of control provided by tie lines to be thinned: • **Any** - any dimension control. • **Xyz** - full 3D (XYZ) control. • **Xy** - horizontal (XY) control. • **Z** - vertical (Z) control.
Spacing	Minimum allowed distance between consecutive tie lines.

2. Define settings and click OK.

   This removes tie line observations that are closer to each other than the given distance. An information dialog shows the number of deleted tie lines and tie line positions.

Tools pulldown menu

The **Tools** pulldown menu contains commands for transforming tie lines, for drawing tie lines into the CAD file and for checking gaps between consecutive tie lines.

TO	CHOOSE MENU COMMAND
Transform tie lines	Transform tie lines
Change the format of tie line time stamps	Convert time stamps
Draw tie lines into the CAD file	Draw observations
Create a list of locations without tie lines	Report gaps

Convert time stamps

Convert time stamps command can be used to convert the format of time stamps. Supported conversions are:

INPUT FORMAT	CONVERTED FORMAT
GPS seconds-of-week	GPS standard time
	GPS time
GPS standard time	GPS seconds-of-week
	GPS time
GPS time	GPS seconds-of-week
	GPS standard time
GPS seconds-of-day	GPS seconds-of-week
	GPS standard time
	GPS time
Unix time	GPS seconds-of-week
	GPS standard time
	GPS time
UTC seconds-of-day	GPS seconds-of-week
	GPS standard time

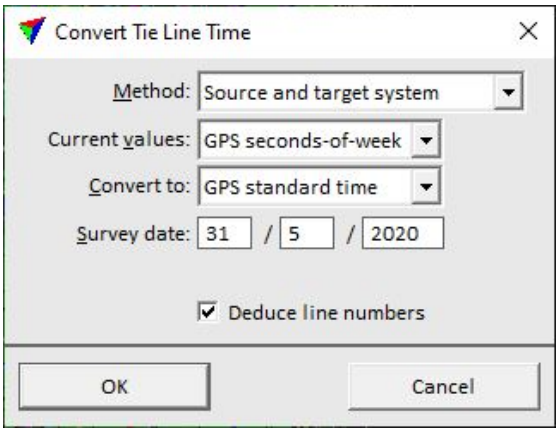
INPUT FORMAT	CONVERTED FORMAT
	GPS time
UTC seconds-of-week	GPS seconds-of-week
	GPS standard time
	GPS time

The conversion may be necessary if data was processed earlier using one time stamp format and then, the time stamp format of the trajectories has been changed for some reason. It is essential that time stamps of tie lines are the same as for trajectories and point cloud data.

To convert time stamps:

1. Select **Convert time stamps** command from the **Tools** pulldown menu.

   This opens the **Convert Tie Line Time** dialog:



3. Define settings and click OK.

   This converts the tie line time stamps to the new format. Save the tie line file in order to make the modification permanent.

SETTING	EFFECT
Method	Defines the computation method of modifying time stamps: • **Source and target system** - conversion from one time format to another. • **Multiply and add constant** - constant value by which time stamps are multiplied or that is added to current time stamps.
Current values	Original time stamp format of the trajectory positions. This is only active if **Method** is set to **Source and target system**.

SETTING	EFFECT
Convert to	Target time stamp format. This is only active if **Method** is set to **Source and target system**.
Survey date	Date when the data was captured for which the tie lines have been derived. The format is day/month/year (dd/mm/yyyy). This is only active for the conversion from **GPS seconds-of-week** or **UTC seconds-of-day/week** to **GPS standard time** or **GPS time**.
Multiply by	Factor by which current time stamps are multiplied. This is only active if **Method** is set to **Multiply and add constant**.
Add	Value to add to GPS time stamps when converted from UTC seconds-of-day time stamps. Refers to the leap-seconds that by which GPS time is ahead of UTC time. This is only active for the conversion from **UTC seconds-of-day** to any GPS time format. Value to add to current time stamps if **Method** is set to **Multiply and add constant**.
Deduce line numbers	If on, line numbers for the tie lines are deduced from the trajectories loaded in TerraScan. This is only successful, if the time stamps correspond to each other in both, tie lines and trajectories.

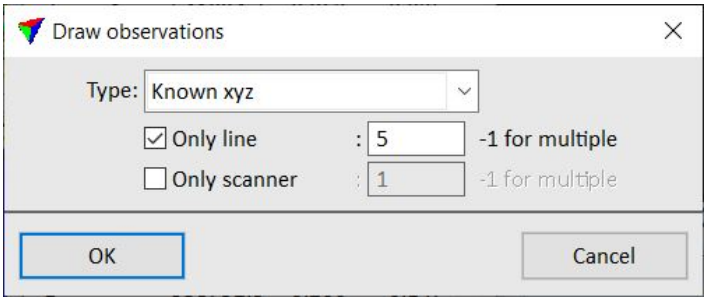
Draw observations

Draw observations command draws tie line observations into the CAD file. The observations are drawn as point or line elements using the active level and symbology settings of the CAD file.

To draw tie line observations:

1. Select **Draw observations** command from the **Tools** pulldown menu.

   This opens the **Draw observations** dialog:



2. Define settings and click OK.

   This draws the tie line observations into the CAD file.

SETTING	EFFECT
Type	Tie line type to be drawn: **Any** or one of the tie line types available in TerraMatch.
Only line	If on, only tie lines of the given flight line number are drawn.
Only scanner	If on, only tie lines of the given scanner number are drawn.

Report gaps

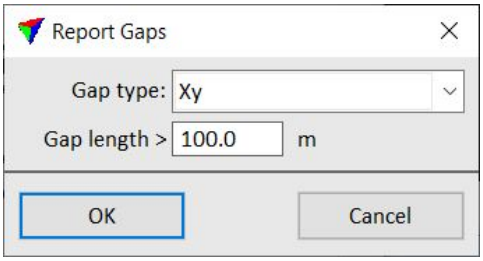
Report gaps command creates a list of locations where there are no tie lines for given types of corrections.

The gaps found in active tie lines are displayed in a dialog. The user controls of the dialog let you sort the list of gaps in different ways, show the location of a gap, and rebuild the list after changes have been made to the tie lines.

To create a report of gaps between tie lines:

1. Select **Report gaps** command from the **Tools** pulldown menu.

   This opens the **Report gaps** dialog:

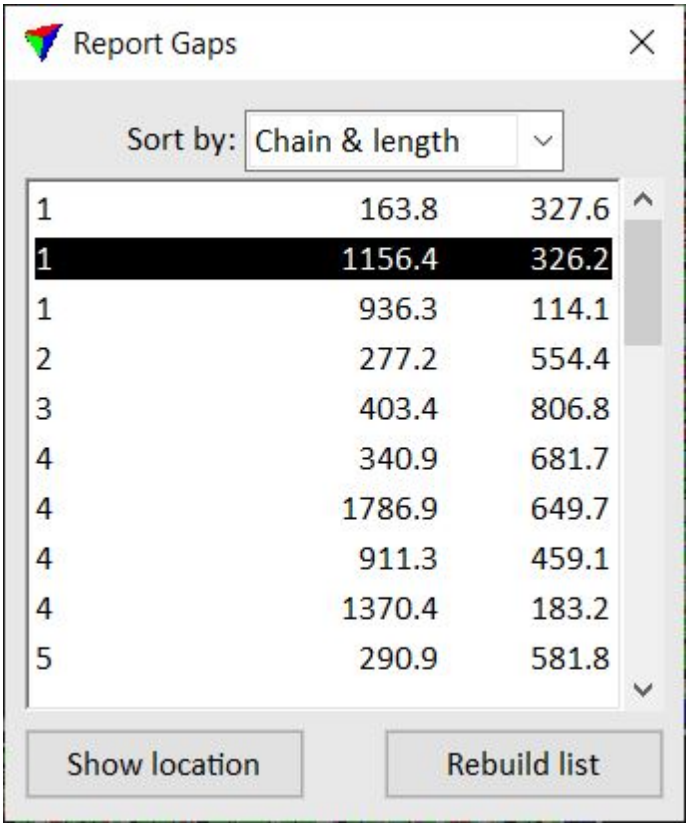


2. Define settings and click OK.

SETTING	EFFECT
Gap type	Determines which locations are defined as gaps: • **Xy** - places with no tie lines for XY correction. • **Xy longitudinal** - places with no tie lines for XY correction along the travel direction.

SETTING	EFFECT
	• **Xy perpendicular** - places with no tie lines for XY correction perpendicular to the travel direction. • **Z** - places with no tie lines for Z correction.
Gap length	Maximum allowed distance between tie lines. If the distance is bigger, it is reported as a gap.

This opens another **Report Gaps** dialog which shows the list of gaps:



The list contains the chain (trajectory) number, the position of the gap along the chain, and the length of the gap.

You can use the options in the **Sort by** list to sort the list:

- **Chain and position** - primarily by the chain number, secondarily by increasing positions along the chain.
- **Chain and length** - primarily by the chain number, secondarily by decreasing lengths of the gaps.
- **Length** - by decreasing lengths of the gaps.

Show location - highlights the location of a gap. Select a row in the list and click on the button. Move the mouse pointer inside a CAD file view. This highlights the selected gap by drawing a temporary dashed line. Place a data click in order to center the view at the gap's center point.

Rebuild list - recomputes gaps after tie lines have been changed, for example, after new tie lines were added.

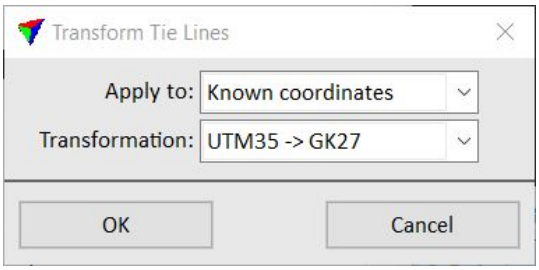
Transform tie lines

Transform tie lines command is used to transform the coordinates of tie lines. The transformation must be defined in **Coordinate transformations** category in the TerraScan **Settings**.

To transform tie lines:

1. Select **Transform tie lines** command from the **Tools** pulldown menu.

   This opens the **Transform Tie Lines** dialog:



2. Define settings and click OK.

   This transforms the tie lines to the new projection system. You may save the transformed tie lines into a new file.

SETTING	EFFECT
Apply to	Data to transform: • **Known coordinates** - transforms known point coordinate values (= values given by some other survey method). • **Laser positions** - transforms observation coordinate values (= values extracted from laser data). • **Both** - transforms known coordinates and laser positions.
Transformation	Name of the transformation to be applied. The name is defined in Coordinate transformations category of TerraScan Settings.

View pulldown menu

The **View** pulldown menu contains commands for defining the settings for tie lines, for displaying tie lines and for displaying tie line attributes in the **Tie Lines** window.

TO	CHOOSE MENU COMMAND
Change the settings for tie line placement	Settings
Define how tie lines are displayed in CAD file views	Display mode
Select attributes that are visible in the **Tie Lines** window	Fields

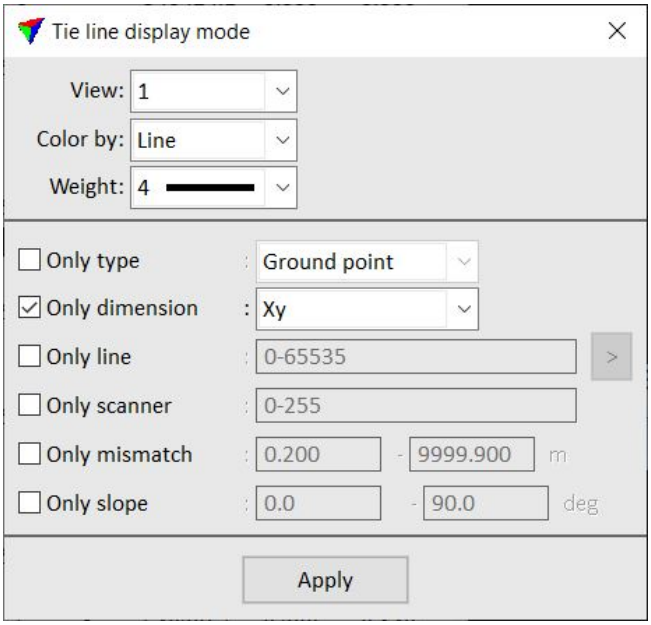
Display mode

Display mode command lets you define how tie lines are drawn in different CAD file views. For each view, you can select the coloring method, line weight, and limit the display of tie lines to certain criteria.

To set the display of tie lines:

1. Select **Display mode** command from the **View** pulldown menu.

   This opens the **Tie line display mode** dialog:



2. Define settings and click **Apply**.

   This applies the settings to the selected view. You can continue with the definition of settings for another view.

SETTING	EFFECT
View	Number of the CAD file view for which the settings are applied. The list contains view numbers 1-8.

SETTING	EFFECT
Color by	Determines the coloring method: • **Do not draw** - no tie lines are draw. • **Line** - tie lines are colored by line number. • **Scanner** - tie lines are colored by scanner number. This makes only sence if tie lines are collected separately for different scanners.
Weight	Line weight for drawing tie lines. The list contains the line weights of the CAD platform.
Only type	If on, only tie lines of the given type are drawn: • Any known - tie lines of any “known” tie line type, such as **Known xyz**, **Known xy**, **Known z**, **Known line**. • **Any common** - tie lines of any tie line type that is not “known”. • <type> - tie lines of the selected type.
Only dimension	If on, only tie lines of the given dimension are drawn: • **Xyz** - tie lines that provide full 3D (XYZ) control. • **Xy** - tie lines that provide horizontal (XY) control. • **Z** - tie lines that provide vertical (Z) control.
Only line	If on, only tie lines of the given line number(s) are drawn. You can define several line numbers by using minus and comma, for example, **1-5,7,10**.
>	Use the **Pick visible line** button to identify a trajectory line by a data click. The number of the line closest to the data click is used in the **Only line** field.
Only scanner	If on, only tie lines of the given scanner number(s) are drawn. You can define several scanner numbers by using minus and comma, for example, **1-3,5**.
Only mismatch	If on, only tie lines within the given mismatch value range are drawn. Define the minimum and maximum mismatch value for drawing tie lines in the text fields.

SETTING	EFFECT
Only slope	If on, only tie lines with the given slope value range are drawn. Define the minimum and maximum slope value for drawing tie lines in the text fields. 0.0 refers to horizontal, 90.0 to vertical direction. Tie points are not drawn if this option is on.

Settings

Settings command opens the **Tie line Settings** dialog. It is the same dialog as opened by the Define Tie Lines tool.

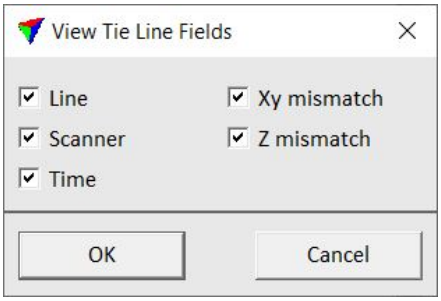
Fields

Fields command lets you select which attributes are displayed in the **Tie Lines** window.

To select visible fields:

1. Select **Fields** command from the **View** pulldown menu.

   This opens the **View Tie Line Fields** dialog:



2. Select fields you want to see in the list of loaded points and click OK.

FIELD NAME	DESCRIPTION
Line	Line number. May refer to the flight line or drive path number in ALS or MLS point clouds.
Scanner	Number of a scanner. This is displayed if scanners are separated for placing tie line observations. An asterisk (*) is displayed if scanners are not separated.
Time	Point of time of a tie line observation. Derived from the time stamps of the point

FIELD NAME	DESCRIPTION
	cloud. Expressed in seconds.
Xy mismatch	Horizontal mismatch at the location of a tie line observation. This may represent the mismatch between a known point and the tie line observation or the mismatch between several tie line observations.
Z mismatch	Vertical mismatch at a tie line observation. This may represent the mismatch between a known point and the tie line observation or the mismatch between several tie line observations.

Match tool box

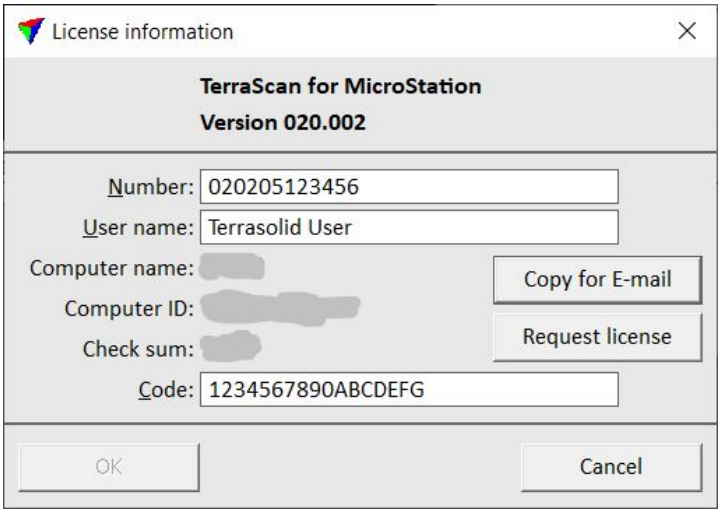
The tools in the **TerraMatch** tool box are used to define user settings, to perform matching of laser data and to access online help.

TO	USE	
Change user settings		Settings
Define coordinate range and resolution		Define Coordinate Setup
Find correction values for laser data		Find Match
Apply known correction values		Apply Correction
Correct fluctuating elevation differences		Find Fluctuations
Match forward/backward measurements of elliptical scans		Match Forward and Backward
Find range corrections caused by high intensity measurements or specific scan angles		Find Range Corrections
Find intensity corrections based on the distance from the scanner		Find Intensity Correction
		Find Mirror Angle Correction
Measure how well strips match		Measure Match
View information about TerraMatch		About TerraMatch
View online help		Help on TerraMatch

About TerraMatch

About TerraMatch tool opens a dialog which shows information about TerraMatch and about the license.

From this dialog, you can open the **License information** dialog which looks the same for all Terra Applications:



Use the **Request license** button to start the online registration for node-locked licenses.

More information about license registration is available on the Terrasolid web pages.

Apply Correction

Apply Correction tool applies known correction values to a data set. You can type in the correction values manually or they can be loaded from a TerraMatch corrections file saved by the following tools:

- Find Match
- Find Fluctuations
- Match Forward and Backward
- Find Range Corrections
- Find Intensity Correction
- Find Tie Line Match
- Find Tie Line Fluctuations

The tool allows to apply corrections to several types of data, such as laser data, tie lines, trajectories, and image lists in TerraPhoto.

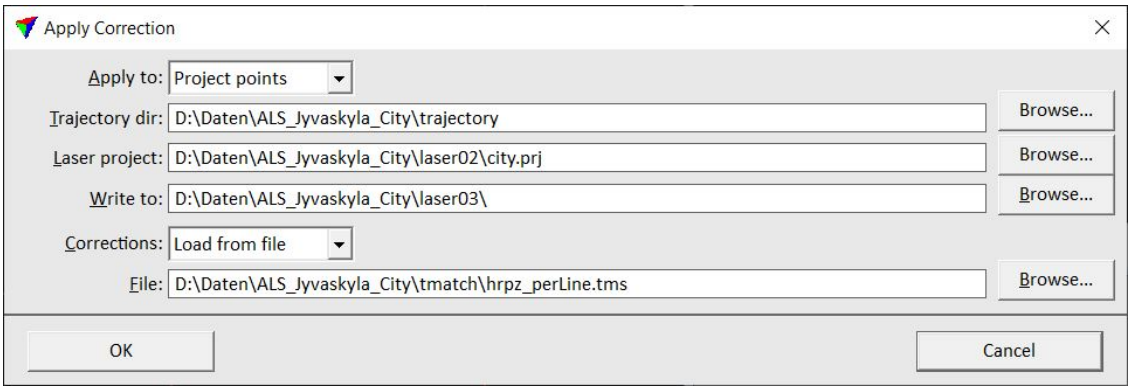
In the process of applying corrections, the software interpolates values between observation locations, such as tie lines, relative to the travel distance. This method is more accurate than

interpolation relative to time, especially for ground-based mobile scanning data sets where stops may occur.

General procedure for applying corrections:

1. Select the **Apply Correction** tool.

   This opens the **Apply corrections** dialog:



2. Define settings and click OK.

   This opens subsequent dialogs where you can enter or verify the correction values to apply.

3. Click OK in order to start the process.

   A report window displays the results of the process. The report is written during the process, if fluctuating corrections are applied to project points.

SETTING	EFFECT
Apply to	Data set to correct: • **Project points** - all blocks referenced by a given project file. *(not UAV)* • **Loaded points** - points loaded into TerraScan. • **Tie line file** - tie lines in a file saved on a hard disk. • **Loaded tie lines** - active tie lines in TerraMatch. • **Loaded image list** - active image list in TerraPhoto. • **Trajectories** - active trajectories in TerraScan.
Laser project	TerraScan project file to apply corrections to. This is only active if **Apply to** is set to **Project points**.
Write to	Directory into which to write the modified block binary files or the modified trajectory

SETTING	EFFECT
	files. This is only active if **Apply to** is set to **Project points** or **Trajectories**.
Trajectory dir	Directory containing TerraScan trajectory files.
Corrections	Source of correction values: • **Enter manually** - corrections values are typed manually. • **Load from file** - reads correction values from a TerraMatch corrections file.
File	File containing correction values. This is only active if **Corrections** is set to **Load from file**.
Correct	Type of correction to apply: • **Whole data set** - one value to apply to the whole data set. • **Individual lines** - separate correction values for each strip. This is only active if **Corrections** is set to **Enter manually**.

Key-in command syntax for **Apply correction**:

apply=points/project/tiefile/tielines/images

trajdir=trajectory_folder

project=project_file

writedir=result_folder

corrections=correction file

run=0/1

Example:

apply=project trajdir=c:\data\trajectory_scan project=c:\data\laser02\tscan.prj writedir=c:\data\laser03 corrections=c:\data\calib\fluct_xyz.tms run=0

Define Coordinate Setup

Define Coordinate Setup tool sets up coordinate system values that a Terra Application uses for laser points and images. It determines the coordinate range inside which all data must be located and the resolution to which coordinate values are rounded. The coordinate setup is stored into the active CAD file and is used by all Terra Applications.

Terra Applications use signed 32 bit integer values for storing coordinates of laser points and images. This has the advantage of using only 12 bytes of memory for the coordinate information of each point. You can control how accurately coordinate values are stored by defining how big each integer step is.

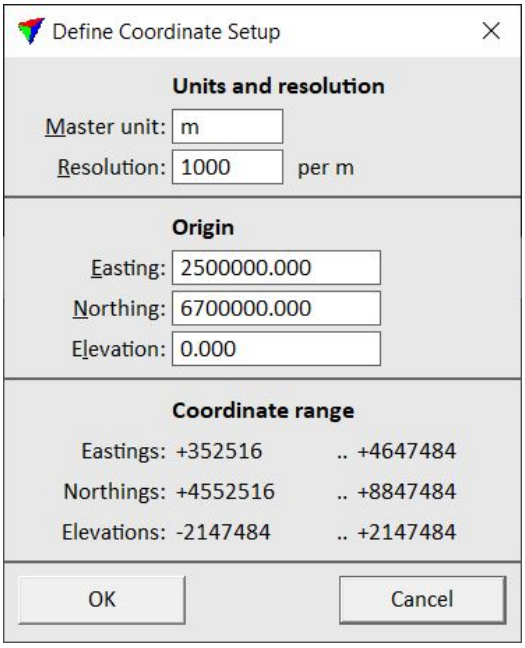
If, for example, one integer step is equal to one millimeter, all coordinate values are rounded to the closest millimeter. At the same time it would impose a limitation on how far apart points can be or how big the coordinate ranges are. Millimeter steps produce a coordinate cube which has a size of 2^{32} millimeters or 4294967.296 meters. If the origin of the coordinate system is at [0.0, 0.0, 0.0], the coordinate ranges are limited to values between -2147483 and +2147483. If necessary, you can fit the coordinate ranges to your data by modifying the Easting and Northing coordinates of the coordinate system origin.

If one integer step is equal to one centimeter, the coordinate values can range from -21 million to +21 million which is large enough for most coordinate systems.

To define the coordinate setup:

1. Select the **Define Coordinate Setup** tool.

   This opens the **Define Coordinate Setup** dialog:



2. Define settings and click OK.

   This modifies the coordinate system values used by all Terra Applications in the active CAD file.

Find Fluctuations

Find Fluctuations tool compares short intervals of each strip against other overlapping strips. It computes elevation corrections for each strip based on a surface-to-surface comparison method. Each short time interval of a strip gets its own correction value. For the final correction file, the correction values can be averaged in order to get a smoother correction curve.

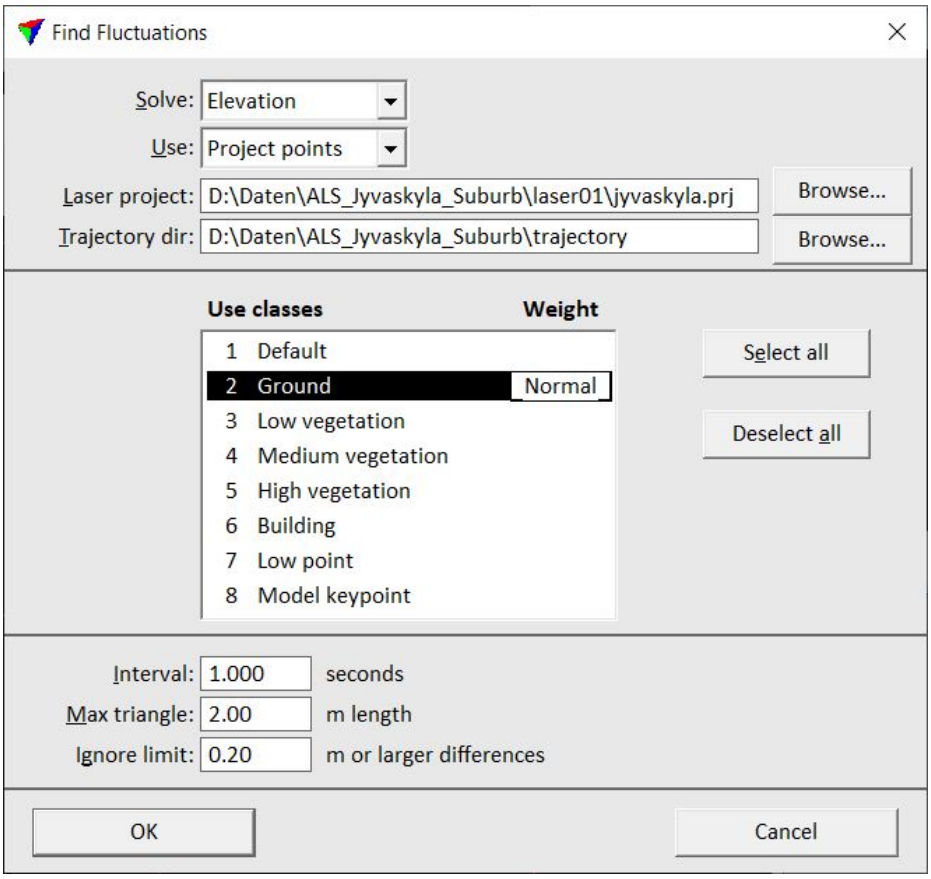
Find Fluctuations tool requires that laser points have time stamps and that the same pre-processing steps have been applied for the laser data as for the Find Match tool. You have to classify ground in each strip separately before this tool can be used. It does not require that trajectories are loaded. It uses trajectory information only to determine the relative accuracies of different strips.

The tool can run on loaded points in TerraScan or on a TerraScan project.

General procedure for finding and applying fluctuating corrections:

1. Select **Find Fluctuations** tool.

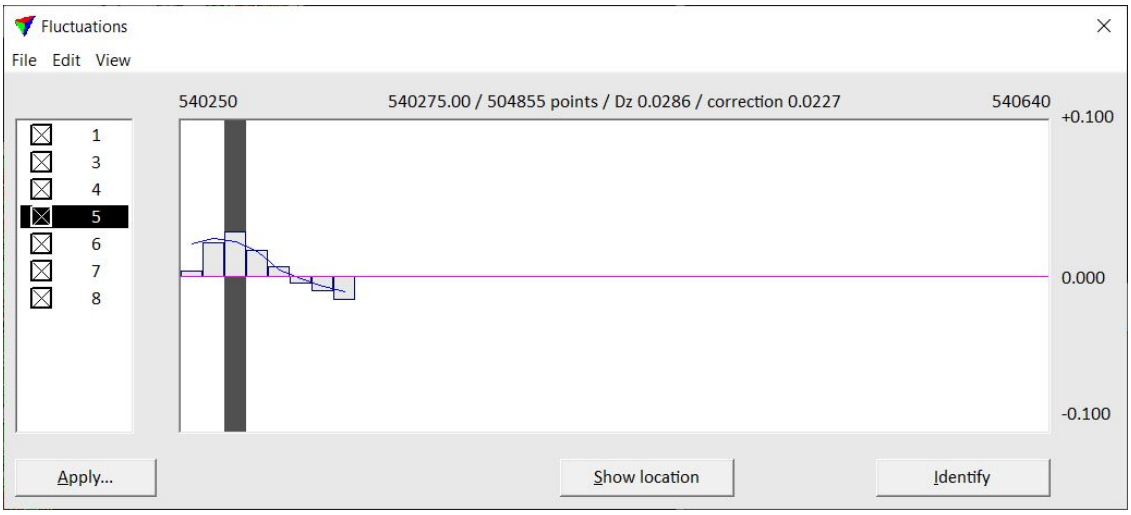
   This opens the **Find Fluctuations** dialog:



2. Select settings and click OK.

SETTING	EFFECT
Solve	Type of solution to find: **Elevation**.
Use	Points to use in find fluctuations: **Loaded points** or **Project points** *(not UAV)*.
Laser project	TerraScan project file which defines the blocks to use in comparison. This is only active if **Use** is set to **Project points**.
Trajectory dir	Directory containing TerraScan trajectory files.
Use classes	Classes to use for comparison and weight factors to apply.
Interval	Time interval used by the software to calculate a correction value.
Max triangle	Maximum length of a triangle created for the surface-to-surface comparison.
Ignore limit	Limit value for differences between strips that the software tries to match. The values should be a bit higher than the largest mismatch between strips. Larger mismatches are treated as gross errors and therefore not included in the calculation.

This opens the **Fluctuations** dialog:



The dialog shows the list of strips on the left and a graph of corrections for the selected strip on the right. The yellow bars in the graph represent the time intervals for which a correction value is calculated. The correction value for a selected time interval is shown on top of the graph.

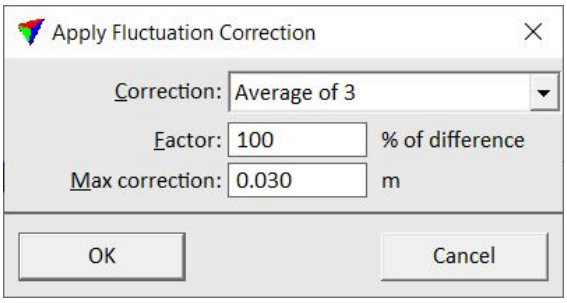
3. Check the fluctuating corrections using the buttons and menu commands from the Fluctuations dialog.

4. Save a corrections file using the **Save** results command from the **File** pulldown menu. The correction file allows to apply corrections later to the laser data with the Apply Correction tool.

   OR

4. Apply corrections directly using the **Apply** button in the **Fluctuations** dialog.

   This opens the **Apply Fluctuation Corrections** dialog:



5. Define settings and click OK.

   This applies the fluctuating corrections to the laser data.

SETTING	EFFECT
Correction	Method of averaging the correction values: • **One step** - no averaging applied. • **Average of 3** - three observations are averaged. • **Average of 5** - five observations are averaged. • **Average of 7** - seven observations are averaged. • **Average of line** - the average value of a strip is used as a correction value.
Factor	Factor multiplied to the calculated correction values. A value of 50% means that the original correction values are multiplied by 0.5.
Max correction	Maximum allowed correction that is applied to the laser data.

Fluctuations dialog for surface matching

The **Fluctuations** dialog provides several buttons and menu commands for visualizing, analyzing and saving the fluctuating correction values.

Show location button is used to highlight the location of a time interval in a CAD file view. Select the time interval in the **Fluctuations** dialog graph. Click the button and move the mouse

pointer inside a CAD file view. The selected time interval is dynamically highlighted. Place a data click inside the view in order to center the view at the location of the time interval.

Identify button is used to select the location of a time interval in the **Fluctuations** dialog graph. Click on the button and place a data click in a CAD file view. This selects the time interval closest to the data click in the **Fluctuations** dialog graph.

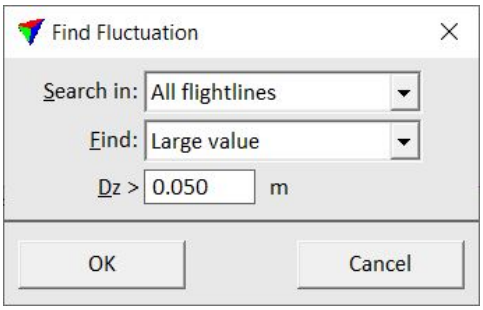
Edit / Find big correction values

Find big correction values command selects locations with big correction values. It can find the largest value or values that are larger than a defined threshold.

To locate big correction values:

1. Select **Find** command from the **Edit** pulldown menu.

   This opens the **Find Fluctuation** dialog:



2. Select settings and click OK.

   The time interval with the maximum correction value or the first value larger than the defined **Dz** threshold is shown in the **Fluctuations** dialog and selected in the graph.

Edit / Find next

Find next command can be used after the Find command has been used with **Find** set to **Large value** and a **Dz** threshold. The command selects the next time interval along the graph with a correction value larger than the defined threshold.

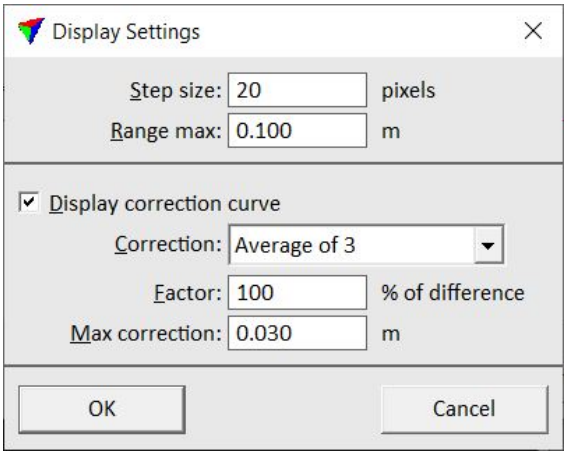
View / Display settings

Display settings command defines settings for the graph display in the **Fluctuations** dialog. This includes settings for the size of the yellow bars representing the time intervals and the maximum range of correction values. In addition, settings for displaying the correction curve and applying some averaging to the correction values are defined.

To define settings for the display of fluctuation corrections:

1. Select **Display settings** command from the **View** pulldown menu.

This opens the **Display Settings** dialog:



2. Define settings and click OK.

   This applies the new settings to the graph display.

SETTING	EFFECT
Step size	Defines the display size of one time interval (width of the yellow bar) in the **Fluctuations** dialog graph.
Range max	Maximum correction value range displayed in the **Fluctuations** dialog graph.
Display correction curve	If on, the correction curve is displayed as blue line in the **Fluctuations** dialog graph.
Correction	Method of averaging the correction values: • **One step** - no averaging applied. • **Average of 3** - three observations are averaged. • **Average of 5** - five observations are averaged. • **Average of 7** - seven observations are averaged. • **Average of line** - the average value of a strip is used as correction value.
Factor	Factor multiplied to the calculated correction values. A value of 50% means that the original correction values are multiplied by 0.5.
Max correction	Maximum allowed correction that is applied to the laser data.

When a correction file is saved from the **Fluctuations** dialog, the settings for a correction curve and for averaging correction values are used as defined in the **Display settings** dialog.

View / Statistics

Statistics command shows a dialog with some statistical values for the fluctuations per strip and for all strips. The statistics includes minimum, maximum, and average correction value, median, average magnitude and standard deviation.

You can save a text file or print the statistics using commands from the **File** pulldown menu in the **Statistics** dialog. The dialog size can be changed with commands from the **View** pulldown menu.

Find Intensity Correction

Find Intensity Correction tool solves intensity corrections based on the range of a point from the scanner. This is useful for mobile laser data if the intensity values of points systematically increase with the point's 3D distance from the scanner.

Finding intensity corrections requires laser data from overlapping strips or scanners and preferable from a hard surface, such as a road surface. The points on the surface must be classified into a separate class. The correction is computed per scanner by comparing intensity values of one scanner with all other points within a given sample radius.

The tool provides correction values for range intervals in a TerraMatch correction file. This correction file can then be used to apply the corrections to the laser data of a project. There is also an option of smoothing the correction values.

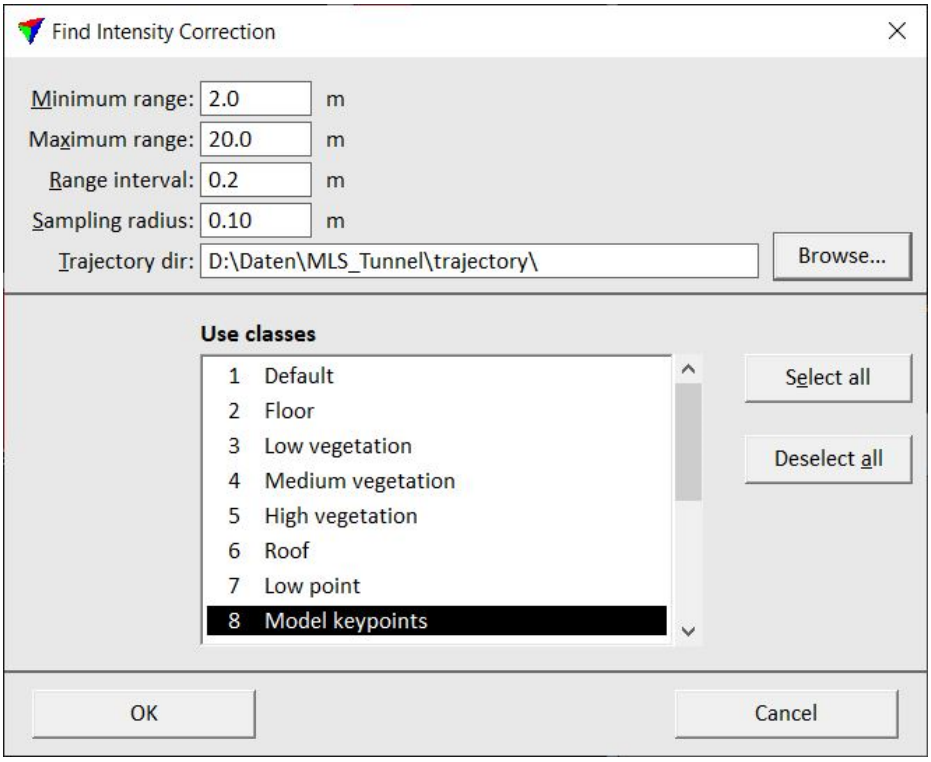
Intensity correction should be done when strips have been matched but the overlap between strips is not yet cut off. It may help to improve the result of extracting vector elements for paint markings automatically or for generating intensity ortho images with TerraScan.

To find intensity correction:

1. Load laser data into TerraScan from an area that is suitable for finding intensity corrections.

2. Select the **Find Intensity Correction** tool.

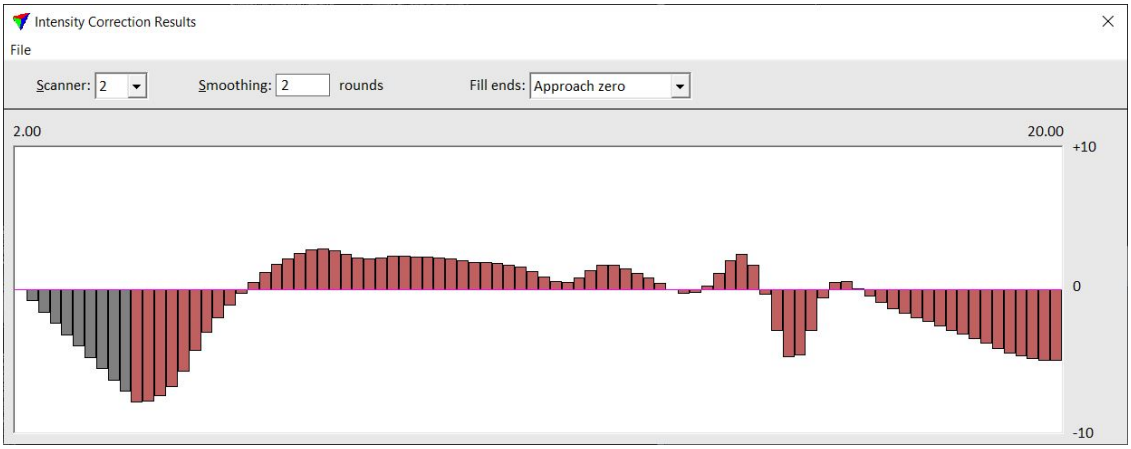
   This opens the **Find Intensity Correction** dialog:



3. Define settings and click OK.

SETTING	EFFECT
Minimum range	Minimum 3D distance from the scanner used for computing the intensity correction values.
Maximum range	Maximum 3D distance from the scanner used for computing the intensity correction values.
Range interval	Distance interval for computing correction values. One correction value is computed for each interval within **Minimum range** and **Maximum range**.
Sampling radius	Distance around each point for comparing the point's intensity value of one scanner with the average intensity values of all other points.
Trajectory dir	Directory containing TerraScan trajectory files.
Use classes	Classes to use for finding intensity corrections.

This opens the **Intensity Correction Results** dialog:



4. Define settings.

SETTING	EFFECT
Scanner	Number of the scanner for which to apply intensity correction values.
Smoothing	Number of smoothing rounds to apply to the correction curve.
Fill ends	How to assign correcion values to points for which there is no observation within the given **Minimum** and **Maximum range**: • **Approach zero** - correction values linearly approach zero. • **Closest observation** - uses correction value of the closest range interval with an observation.
File / Save correction	Saves a TerraMatch correction file for being used in the Apply Correction tool.

5. Save the corrections using the **Save corrections** command from the **File** pulldown menu.

6. Close the **Intensity Correction Results** dialog.

7. Apply the range corrections to laser data using the Apply Correction tool.

Find Match

Find Match tool analyzes the mismatch in laser data and solves for correction parameters. The tool utilizes the surface-to-surface matching method described in Find match vs. Tie Lines.

You can run **Find Match** either on points loaded into TerraScan or on a TerraScan project. When running on a project, TerraMatch automatically scans through all project blocks during one iteration round.

Before you run **Find Match**, you must have performed a number of pre-processing steps which can be outlined as follows:

- Import trajectories into TerraScan.
- Split any trajectories which overlap themselves.
- Import time-stamped laser points into TerraScan.
- Make sure that strip numbering of laser points matches trajectory numbers.
- Classify low points.
- Classify ground separately for each strip.
- (Optional) Classify ground to another class in places which are best suited for comparison.
- (Optional) Classify buildings.
- (Optional) Smoothen ground surface if most of it is asphalt or some other hard surface.

You can select the classes which to use in surface-to-surface comparison and how much weight to apply to each class. This makes it possible to manually classify locations which have sloped surfaces and to apply a higher weight value to those classes.

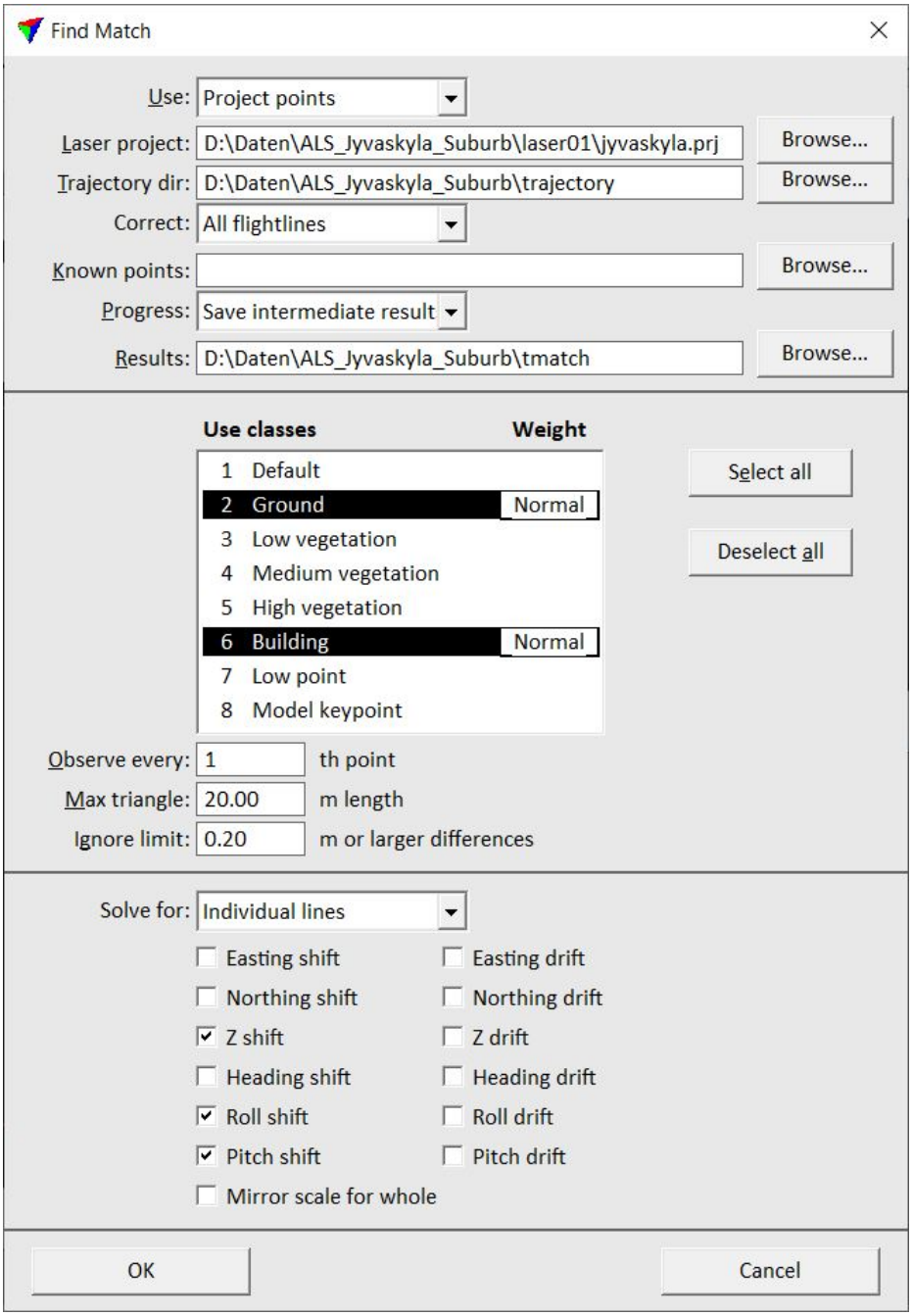
You may choose from the following strategies:

- Use ground points only and use **High weight** value for ground.
- Use good surfaces only. Classify suitable locations manually to **Building class** or **Sloped ground class**. Use **High weight** value for the classes.
- Use both ground points and good surfaces. Classify suitable locations manually. Apply **High weight** value to those classes and **Low** or **Medium weight** to ground class.

General procedure to find correction parameters:

1. Select the **Find Match** tool.

   This opens the **Find Match** dialog:



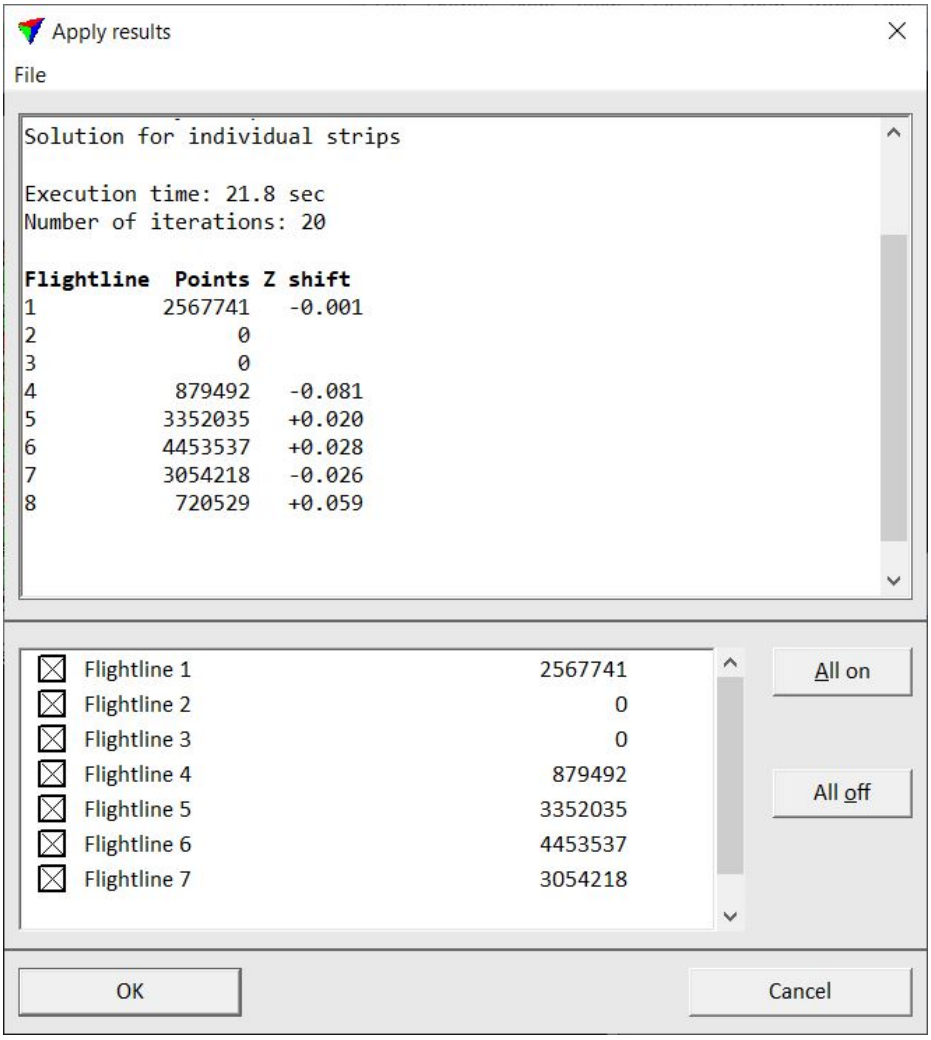
2. Define settings and click OK.

SETTING	EFFECT
Use	Points to use in comparison: **Loaded points** or **Project points** *(not UAV)*.
Laser project	TerraScan project file which defines the blocks to use in comparison. Selectable only when **Use** is set to **Project points**.
Trajectory dir	Directory containing TerraScan trajectory files.

SETTING	EFFECT
Correct	Quality of trajectories to correct. This allows you to keep better quality trajectories as fixed and compute corrections for lower quality trajectories only.
Known points	Optional text file containing known points.
Progress	If set to **Saving intermediate results**, the software saves the solution values after each iteration.
Results	Path to the file for saving intermediate results. This is only active when **Progress** is set to **Save intermediate results**.
Use classes	Classes to use for comparison and weight factors to apply.
Observe every	How many points to make an observation with. Use 1 for small data sets and a bigger value (2-5) for large data sets.
Max triangle	Maximum length of a triangle created for the surface-to-surface comparison.
Ignore limit	Limit value for differences between strips that the software tries to match. The values should be a bit higher than the largest mismatch between strips. Larger mismatches are treated as gross errors and therefore not included in the calculation.
Solve for	Type of solution to find: • **Whole data set** - one value per selected correction to apply to the whole data set. • **Individual lines** - separate correction values for each strip per selected correction.
Easting shift	Solves for a constant easting correction value.
Northing shift	Solves for a constant northing correction value.
Z shift	Solves for a constant elevation correction value.
Heading shift	Solves for a constant heading correction value.
Roll shift	Solves for a constant roll correction value.
Pitch shift	Solves for a constant pitch correction value.
Mirror scale for whole	Solves for a mirror scale factor. Always solved for the whole data set, no matter what type of

SETTING	EFFECT
	solution is selected in the **Solve for** list.
Easting drift	Solves for easting correction which changes linearly by time.
Northing drift	Solves for northing correction which changes linearly by time.
Elevation drift	Solves for elevation correction which changes linearly by time.
Heading drift	Solves for heading correction which changes linearly by time.
Roll drift	Solves for roll correction which changes linearly by time.
Pitch drift	Solves for pitch correction which changes linearly by time.

The application runs through a number of iterations which may last anything from a few seconds to several hours depending on the size of the data set. When the iteration has converged, the **Apply results** dialog opens:



3. View the report and optionally store it as a text file.

4. Save a corrections file by using the **Save corrections** command from the **File** pulldown menu. This enables the application of the corrections later using the Apply Correction tool. This is the recommended workflow.

5. Click **Cancel** to close the dialog without applying the corrections directly.

OR

3. Check all strips to which you want to apply the correction in the lower list box.

4. Click OK to apply the corrections directly.

When using a project, you should set the directory into which the output files are written. When using loaded points, corrections are applied to the loaded points in memory.

Find Mirror Angle Correction

Find Mirror Angle Correction tool solves point cloud corrections dependent on scan angle. The tool can adjust points in a cross section perpendicular to system direction of travel, thus making it useful to fix smiling face error present in point cloud data. Corrections are solved individually per scanner.

Finding mirror angle corrections requires laser data from overlapping strips or scanners and preferably from a hard surface, such as a road surface. The points on the surface must be classified into a separate class. In addition, trajectories with timestamps covering the point cloud are required. The correction is computed per scanner by comparing mismatch to surfaces observed by other scanners and strips.

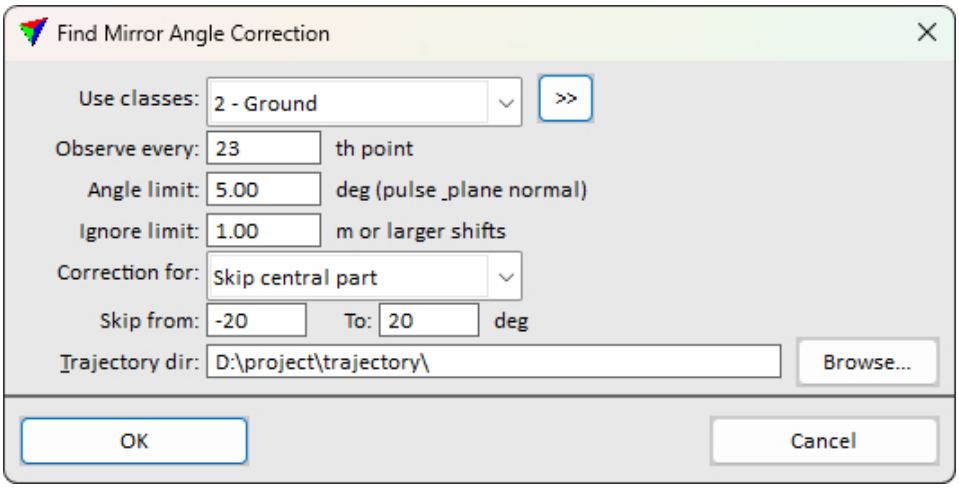
The tool provides correction values for angle intervals in a TerraMatch correction file. This correction file can then be used to apply the corrections to the laser data of a project. There is also an option of smoothing the correction values. Alternatively, corrections can be applied directly from the tool to loaded points.

To find mirror angle correction:

1. Load laser data into TerraScan from an area that is suitable for finding mirror angle corrections.

2. Select the **Find Mirror Angle Correction** tool.

   This opens the **Find Mirror Angle Correction** dialog:

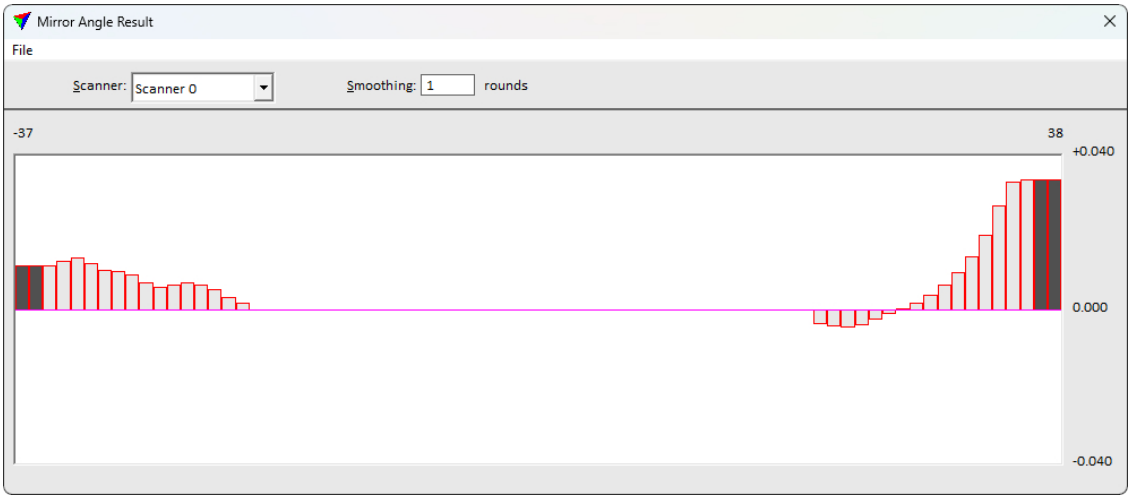


3. Define settings and click OK.

SETTING	EFFECT
Use classes	Classes to use for finding mirror angle corrections.
Observe every	How many points to make an observation with. Use to limit point usage with high

SETTING	EFFECT
	density clouds.
Angle limit	Limit for how much normal vector of the local plane has to differ from vector from the location to the scanner. The purpose of this setting is to eliminate observations where plane normal vector and the vector to the scanner are parallel, which means that mirror angle shift will not result in any change on the surface. Usually > 10 degree value works well to filter ambiguous observations.
Ignore limit	Limit value for differences between strips that the software tries to match. The values should be a bit higher than the largest mismatch between strips. Larger mismatches are treated as gross errors and therefore not included in the calculation.
Correction for	If set to **Skip central part**, any adjustment does not apply to points within specified scan angle range.
Skip from	Lower and upper limit for angle range not adjusted. This is only available if **Correction** for is set to **Skip central part**.
Trajectory dir	Directory containing TerraScan trajectory files.

This opens the **Mirror Angle Result** dialog:



4. Adjust the level of smoothing.

SETTING	EFFECT
Scanner	Number of the scanner for which to apply intensity correction values.
Smoothing	Number of smoothing rounds to apply to the correction curve.
File / Save correction	Saves a TerraMatch correction file for being used in the Apply Correction tool.
File / Apply correction	Apply correction to loaded points.

5. Save the corrections using the **Save corrections** command from the **File** pulldown menu.

6. Close the **Mirror Angle Result** dialog.

7. Apply the range corrections to laser data using the Apply Correction tool.

Find Range Corrections

Find Range Corrections tool solves range corrections for different intensity values, scanners or angles. Very high intensity values may cause a wrong elevation value for the laser points which leads to local inaccuracies at such locations. Usually, points with high intensity values are a bit raised from the surrounding surface and from their correct elevation level. The system manufacturer provides a range correction file specific for the system. The **Find Range Corrections** tool can be used to adjust the values from this initial system-specific correction.

Range corrections per scanner can be used to correct little elevation differences in data from several scanners or scan heads. This results in less noise in data collected with a multiple-scanner system.

Range corrections per angle can be used to correct little elevation differences in data caused by scan angles.

Finding range corrections requires laser data from a smoothly changing hard surface with different intensities or from different scanners. The points on the surface must be classified into a separate class. For airborne scanning, data from the airport runways with strong white paint markings are good locations for collecting suitable data for intensity-based range correction. For mobile scanning data or UAV data, a road or a parking space with a special calibration mat for intensity-based range correction can be used.

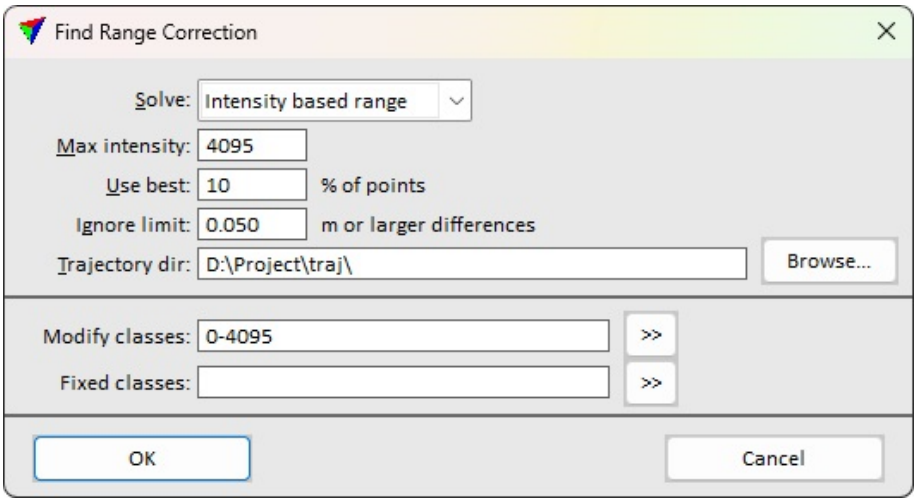
The tool provides adjustment values for different intensities or scanners in a TerraMatch correction file. The correction file can then be used to apply the corrections to the laser data of a project. There is also an option for combining the intensity-based corrections found in TerraMatch with a the range correction values provided by the system manufacturer.

To find range correction:

1. Load the laser data into TerraScan from the area that is suitable for finding range corrections.

2. Select the **Find Range Correction** tool.

   This opens the **Find Range Correction** dialog:



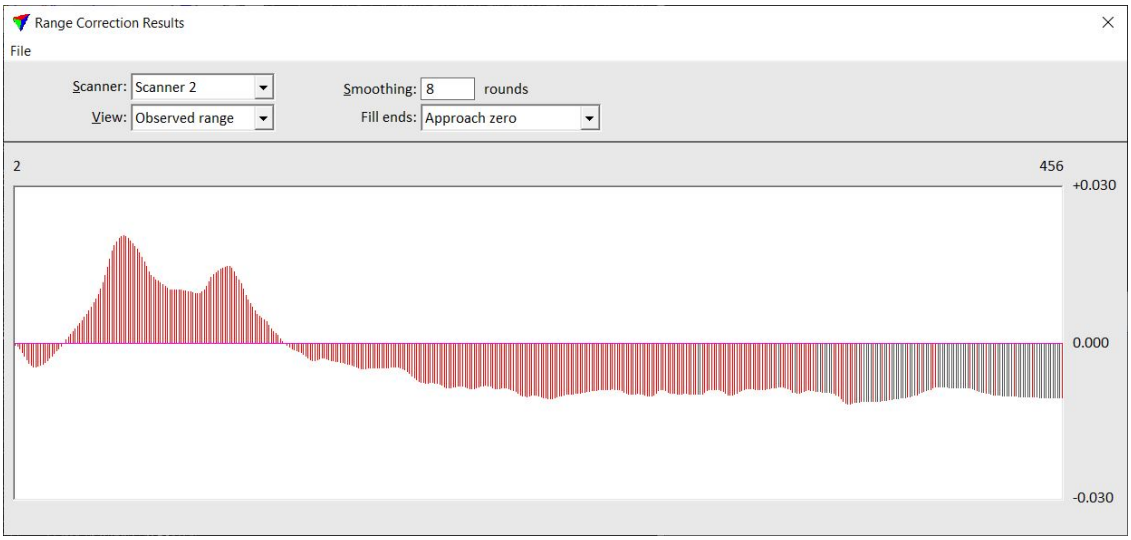
3. Define settings and click OK.

SETTING	EFFECT
Solve	Type of range correction: • **Intensity based range** - corrections for intensity-based range inaccuracies. • **Range per scanner** - corrections for scanner-based range inaccuracies. • **Range per angle** - corrections for angle-dependent range inaccuracies.
Max intensity	Maximum intensity value for which range corrections should be found. Common values are 255 for 8 bit intensity, 4095 for 12 bit intensity and 65535 for 16 bit intensity data. This is only active if **Solve** is set to **Intensity based range**.
Max angle	Maximum scan angle value for which range corrections should be found. This is only active if **Solve** is set to **Range per angle**.
Use best	Defines what points the software uses for finding range corrections. The software uses the given percentage of points with the highest local intensity variation. This is only active if **Solve** is set to **Intensity based range**.
Ignore limit	Helps to avoid bad observations. The software ignores observations with a elevation difference bigger than this value.
Trajectory dir	Directory containing TerraScan trajectory files.

SETTING	EFFECT
Modify classes	Classes to use for finding range corrections. Applying the correction adjusts points in these classes.
Fixed classes	Classes to use for finding range corrections. Applying the adjustment does not modify points in these classes.

This opens the **Range Correction Results** dialog.

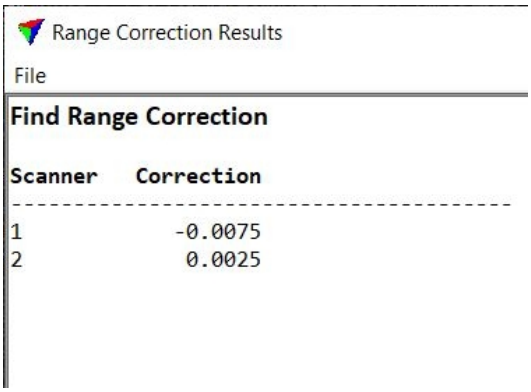
The dialog for **Intensity based range** or **Range per angle** corrections is shown below:



SETTING / COMMAND	EFFECT
Scanner	Number of the scanner for which to apply range corrections.
View	Intensity value range for display: • **Whole range** - whole range from 0 to **Max intensity**. • **Observed range** - intensity range avaiable in the used points.
Smoothing	Number of smoothing rounds to apply to the correction curve.
Fill ends	How to assign correcion values to very small or very large intensity values for which there are no observations: • **Approach zero** - correction values linearly approach zero. • **Closest observation** - uses correction value of the closest intensity value with an observation.

SETTING / COMMAND	EFFECT
File / Save correction	Saves a TerraMatch correction file for being used in the Apply Correction tool.
File / Merge with system file	Adds the corrections to another correction file provided by the system manufacturer and saves a TerraMatch correction file for being used in the Apply Correction tool.

The dialog for **Range per scanner** corrections just shows the correction value for each scanner:



4. Define settings for **Intensity based range** or **Range per Angle** corrections.

5. Save the TerraMatch range corrections using the **Save corrections** command from the **File** pulldown menu.

   For **Intensity based range** or **Range per angle** corrections, you can also use the **Merge with system file** command from the **File** pulldown menu in order to create a correction file that includes system-specific corrections.

6. Close the **Range Correction Results** dialog.

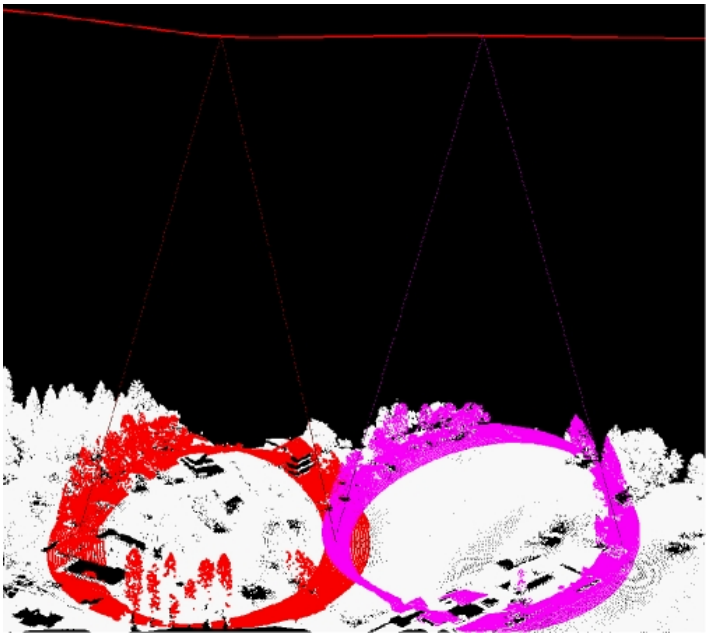
7. Apply the range corrections to laser data using the Apply Correction tool.

Help on TerraMatch

Help on TerraMatch tool opens the online help in the standard web browser.

Match Forward and Backward

Match Forward and Backward tool can be used for matching flightlines from scanner systems which measure the same location twice in a single flight pass, e.g. by elliptical scan pattern.



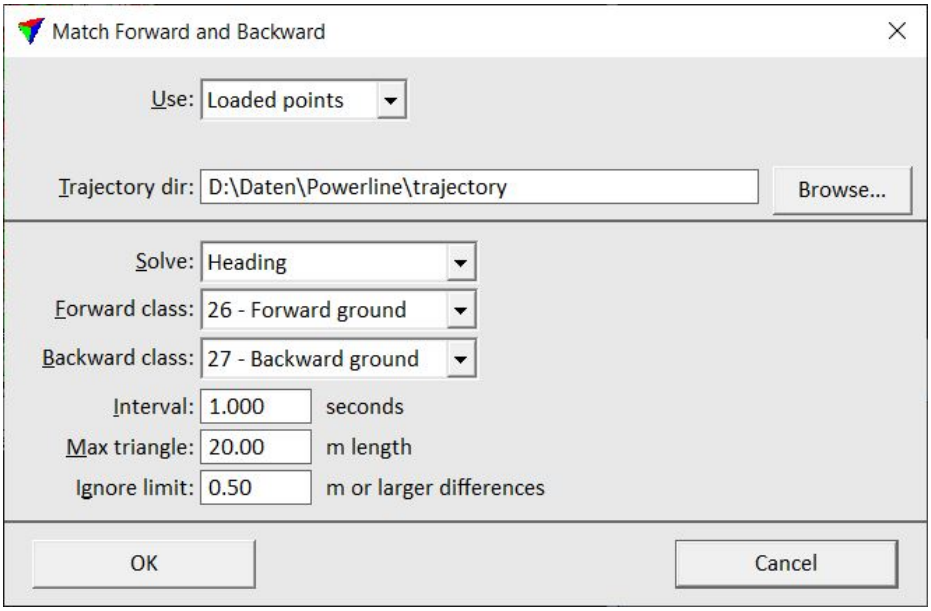
The tool requires that surfaces are classified per flightline with forward and backward measurements in separate classes. It translates the differences between the forward and backward points into corrections of heading, pitch and/or fluctuating elevation corrections using a surface-to-surface matching method.

The **Match Forward and Backward** tool can use loaded points in TerraScan as well as point files referenced by a TerraScan project. It needs TerraScan trajectories for finding a solution. It can solve for one misalignment angle or the elevation correction at a time.

Find Forward and Backward matching corrections:

1. Select the **Match Forward and Backward** tool.

   This opens the **Match Forward and Backward** dialog:



2. Enter settings and click OK.

   This opens the **Fluctuations** dialog. Proceed with applying corrections as described above for Find Fluctuations tool.

SETTING	EFFECT
Use	Data to use for comparison: • **Project points** - all blocks referenced by a given project file. *(not UAV)* • **Loaded points** - points loaded into TerraScan.
Laser project	TerraScan project file to apply corrections to. This is only active if **Use** is set to **Project points**.
Trajectory dir	Directory containing TerraScan trajectory files.
Solve	Parameter for which a correction is solved: **Elevation**, **Heading** or **Pitch**.
Match across flightlines	If on, an elevation correction is solved in a way the matches individual flightlines to each other as well. This is only active if **Solve** is set to **Elevation**.
Forward class	Class that contains points on surfaces from forward scans per flightline.
Backward class	Class that contains points on surfaces from backward scans per flightline.
Interval	Time interval used by the software to calculate a correction value.

SETTING	EFFECT
Max triangle	Maximum length of a triangle created for the surface-to-surface comparison.
Ignore limit	Limit value for differences between forward and backward surfaces that the software tries to match. The values should be a bit higher than the largest mismatch between forward and backward points. Larger mismatches are treated as gross errors and therefore not included in the calculation.

Measure Match

Measure Match tool measures how well different strips match each other. It computes the elevation difference between surfaces from individual strips and a mean surface.

The report value can be used to determine if laser strips are matching each other better or worse compared to an earlier measurement. You can use this tool:

- Determine if strips match each other at normal level (comparing to earlier projects).
- Determine if a modification applied to laser data was an improvement (comparing before and after modification).

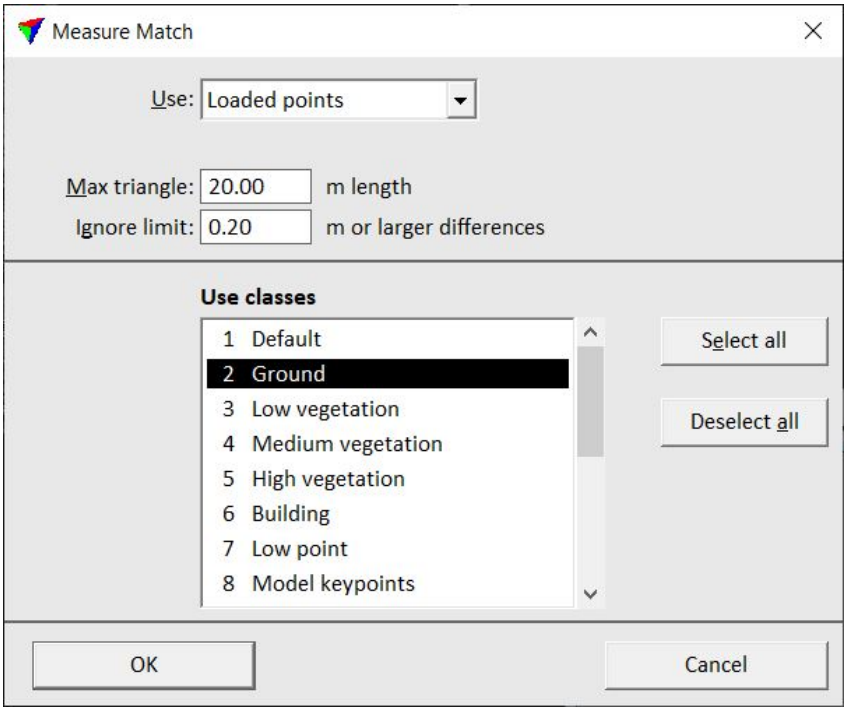
As the comparison is based on surfaces, you should normally perform ground classification on each strip individually before running this tool. You may also classify some other suitable surfaces such as building roofs from each strip.

Measure Match tool can use all the points from laser data files in a TerraScan project or loaded points.

To measure how well strips match:

1. Select the **Measure Match** tool.

   This opens the **Measure Match** dialog:



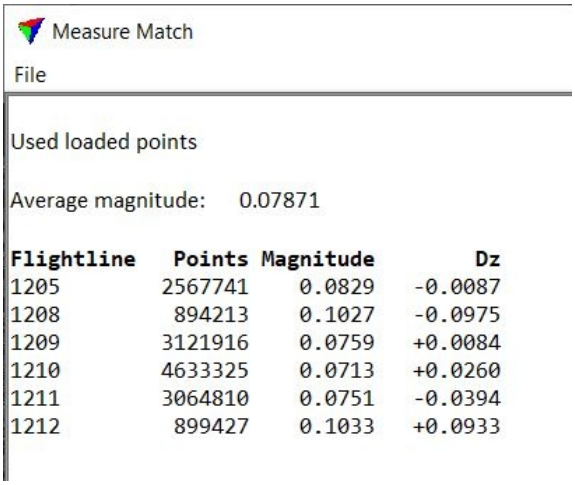
2. Select rows in the list box for the classes to use in the comparison.

3. Define the other settings and click OK.

   The application computes the average elevation differences between each strip and a mean surface.

SETTING	EFFECT
Use	Data to use for comparison: • **Project points** - all blocks referenced by a given project file. *(not UAV)* • **Loaded points** - points loaded into TerraScan.
Laser project	TerraScan project file to apply corrections to. This is only active if **Apply to** is set to **Project points**.
Max Triangle	Maximum length of a triangle created for the surface-to-surface comparison.
Ignore limit	Limit value for differences between strips that the software uses for computing elevation differences. Larger mismatches are treated as gross errors and therefore not included in the calculation.
Use classes	Classes to use for computing elevation differences between individual strips and the mean surface.

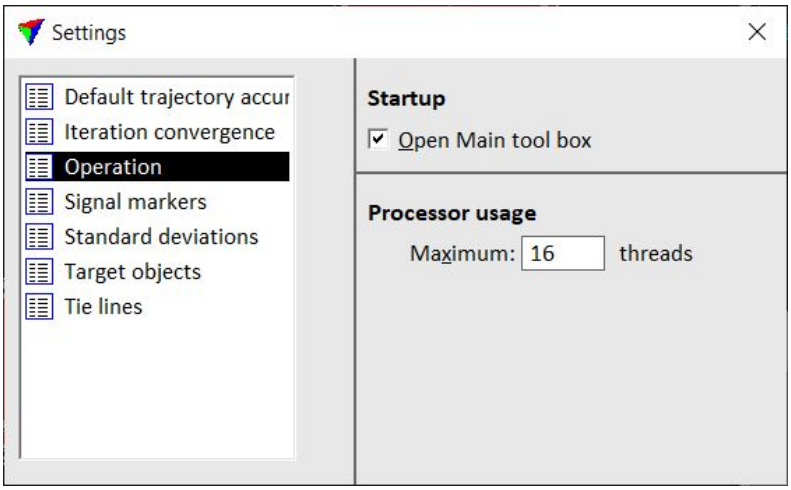
The results are shown in the **Measure Match** report:



ATTRIBUTE	MEANING
Average magnitude	Mean value of absolute elevation difference values.
Flightline	Number of the line.
Points	Amount of points included in the computation for each line.
Magnitude	Absolute value of the elevation difference between a line and the mean surface.
Dz	Mean value of the elevation difference between a line and the mean surface.

Match Settings

Match Settings tool lets you change a number of settings controlling the way how TerraMatch works. Selecting this tool opens the TerraMatch **Settings** dialog:



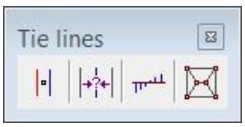
Settings are grouped into logical categories. If a category in the list is selected the appropriate controls are displayed to the right of the category list.

The settings are saved into the TerraMatch settings file in the installation directory when the **Settings** dialog is closed.

The different categories and related settings are described in detail in Section TerraMatch Settings.

Tie line tool box

The tools in the **Tie lines** tool box are used to define tie line settings, to find a match solution and fluctuating corrections based on tie lines.



TO	USE	
Define tie lines for matching		Define Tie Lines
Find correction values using tie lines		Find Tie Line Match
Find fluctuating corrections using tie lines		Find Tie Line Fluctuations
Find rubbersheet correction matching data to control points		Find Rubbersheet Fit

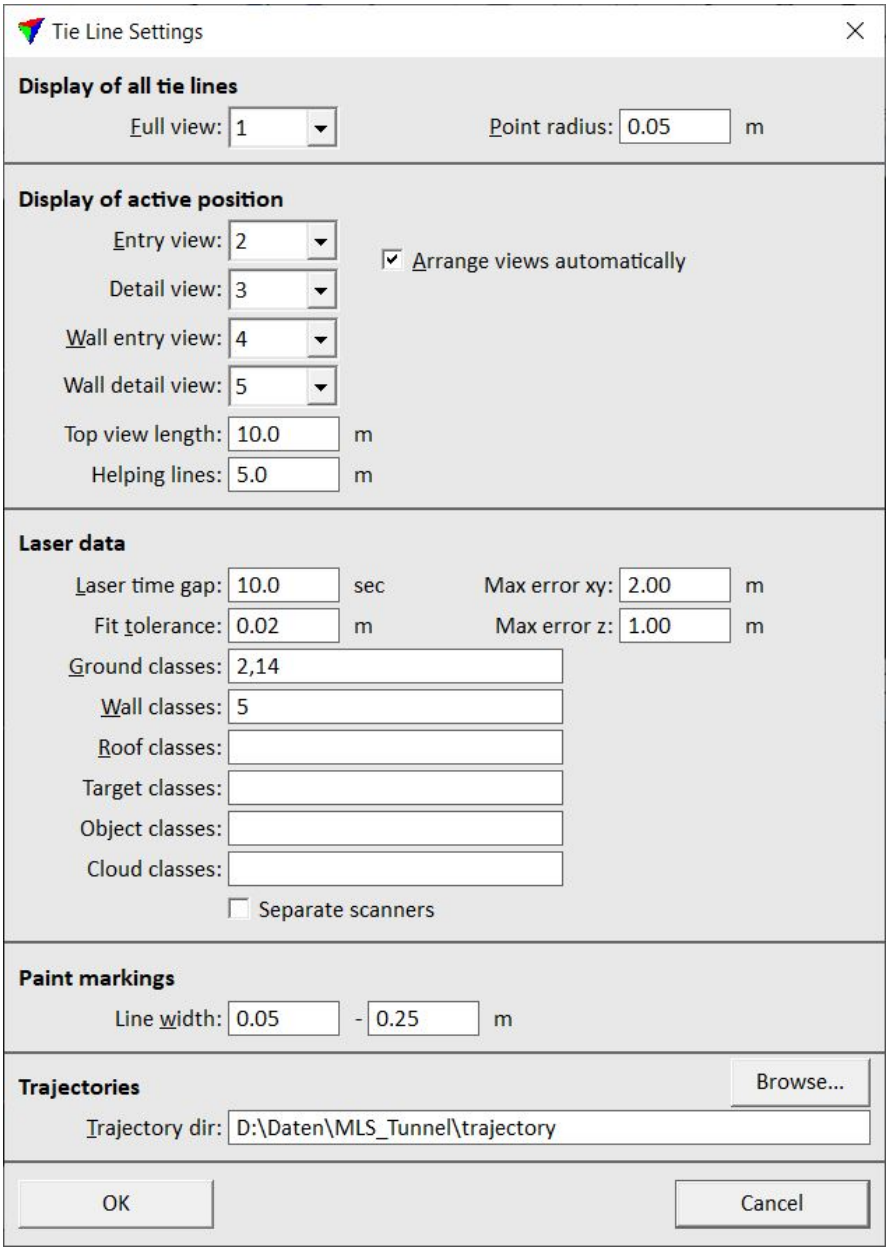
Define Tie Lines

Define Tie Lines tool opens the dialog for tie line settings. It is the starting point for working with tie lines in TerraMatch.

To start the tie line mode in TerraMatch:

1. Select **Define Tie Lines** tool.

   This opens the **Tie Line Settings** dialog:



2. Define settings and click OK.

   This opens the **Tie line** window and arranges the views for tie line work. See chapter Working with Tie Lines for more information about how to work with tie lines.

SETTING	EFFECT
Full view	Number of the CAD file view for displaying a full top view of the data when the tie point mode is active.
Point radius	Radius of a circle that is displayed in the **Full view** at the location of a tie line.
Entry view	Number of the CAD file view for displaying laser data from all strips at a location of a

SETTING	EFFECT
	horizontally-oriented tie line. The view is updated whenever a tie line position is selected in the **Tie lines** window.
Detail view	Number of the CAD file view for displaying laser data from one strip at a location of a horizontally-oriented tie line. The view is updated whenever a tie line position is selected in the **Tie lines** window. In this view, tie lines can be placed manually.
Wall entry view	Number of the CAD file view for displaying laser data from all strips at a location of a vertically-oriented tie line. The view is updated whenever a tie line position is selected in the **Tie lines** window.
Wall detail view	Number of the CAD file view for displaying laser data from one strip at a location of a vertically-oriented tie line. The view is updated whenever a tie line position is selected in the **Tie lines** window. In this view, tie lines can be placed manually.
Top view length	Length of top view to create for ground line and known line tie lines.
Helping lines	Length of helping lines that are displayed in detail views when placing a tie line manually.
Arrange views automatically	If on, the CAD file views are arranged on the screen according to the settings for entry and detail views.
Laser time gap	Time difference between different lines at the same location.
Max error xy	Estimation of the maximum difference between lines in horizontal positioning. Only tie lines up to this distance are accepted in automatic tie line search.
Max error z	Estimation of the maximum difference between lines in elevation positioning. Only tie lines up to this distance are accepted in automatic tie line search.
Fit tolerance	Estimation of the noise level in the data. It determines how tie lines are fitted to the data of one line.
Ground classes	Laser point classes for the automatic search of Section lines on flat ground and on

SETTING	EFFECT
	surfaces.
Wall classes	Laser point classes for the automatic search of **Section lines** on vertical walls.
Roof classes	Laser point classes for the automatic search of **Roof intersection lines**.
Target classes	Laser point classes for the automatic search of targets. Targets can be defined in Target objects category of the TerraMatch **Settings**.
Object classes	Laser point classes for the automatic search of group objects. Objects are defined by classified and grouped points in TerraScan. Each object must be assigned to one group and groups of one object type must be classified into a separate class. See MLS to ALS matching workflows for more information.
Cloud classes	Laser point classes for the automatic search of cloud-to-cloud tie lines. See MLS to ALS matching workflows for more information.
Separate scanners	Of on, tie lines are placed for each scanner separately. This is used for scanner system calibration.
Line width	Estimation of the width range of paint markings. This is used for the automatic search of paint lines and for placing **Ground** tie lines automatically.
Trajectory dir	Directory where the TerraScan trajectory files are stored.

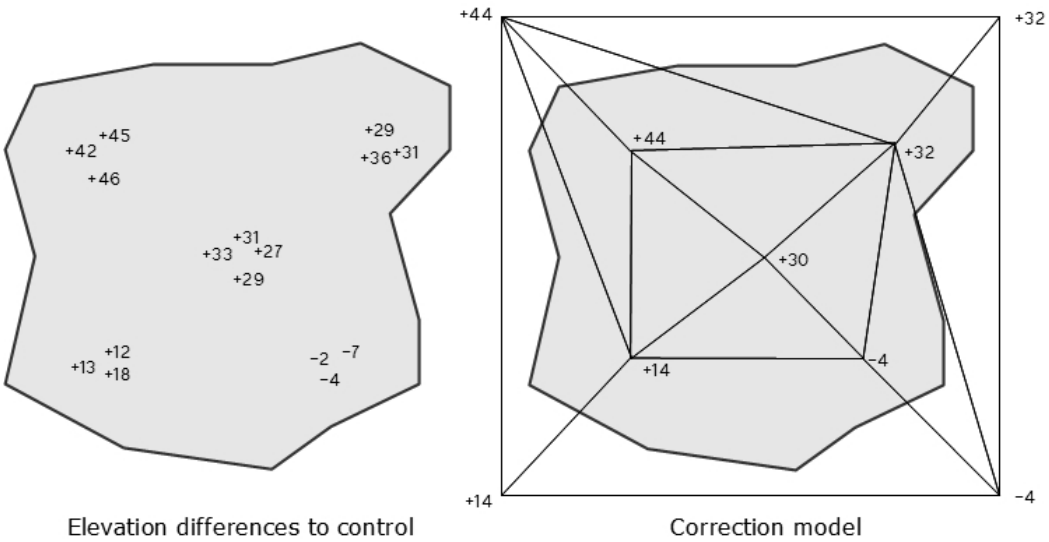
The settings for tie lines can be changed when the tie line mode is active using the Settings command from the **View** pulldown menu in the Tie line window.

Find Rubbersheet Fit

Find Rubbersheet fit tool can be used to match data to control points. The matching is done based on a triangulated correction model for XYZ, XY, or Z.

The tool requires tie lines that are suitable for computing the correction model. The tie lines are collected using commands from the TerraMatch Tie line window. Suitable tie line types are **Known xyz**, **Known xy**, or **Known z**.

In the tool settings you can define how averaging is applied between closeby observations. Further, the values for the outer corners of the correction model can be either derived from the closest correction value or set to zero. The following figure illustrates the computation of a rubbersheet correction model.

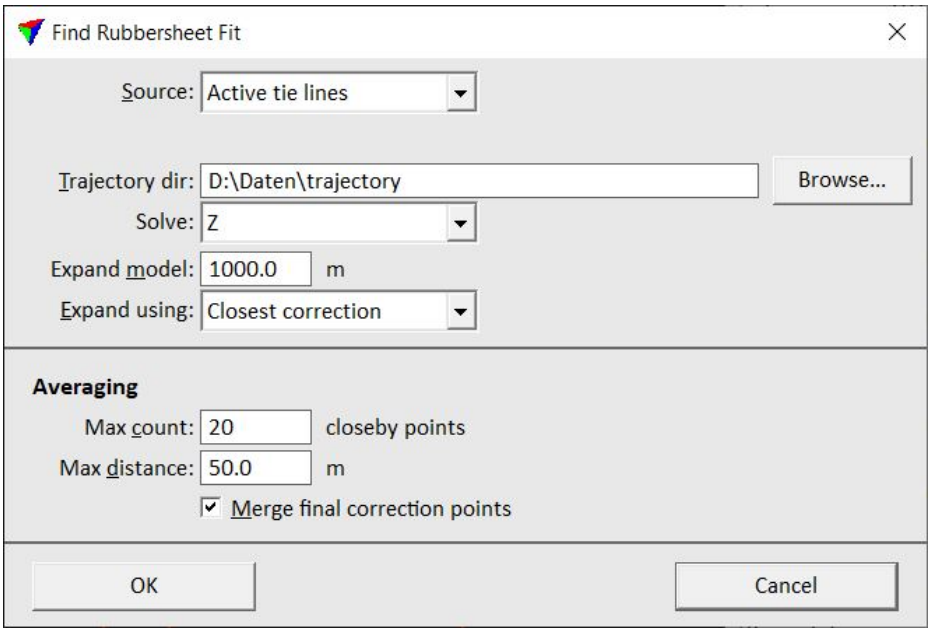


The tool can be used, for example, as a last adjustment step for aerial airborne laser data. After matching the data internally, the data set is matched to control points using the rubbersheet correction.

General procedure for finding and applying fluctuating corrections:

1. Select **Find Rubbersheet Fit** tool.

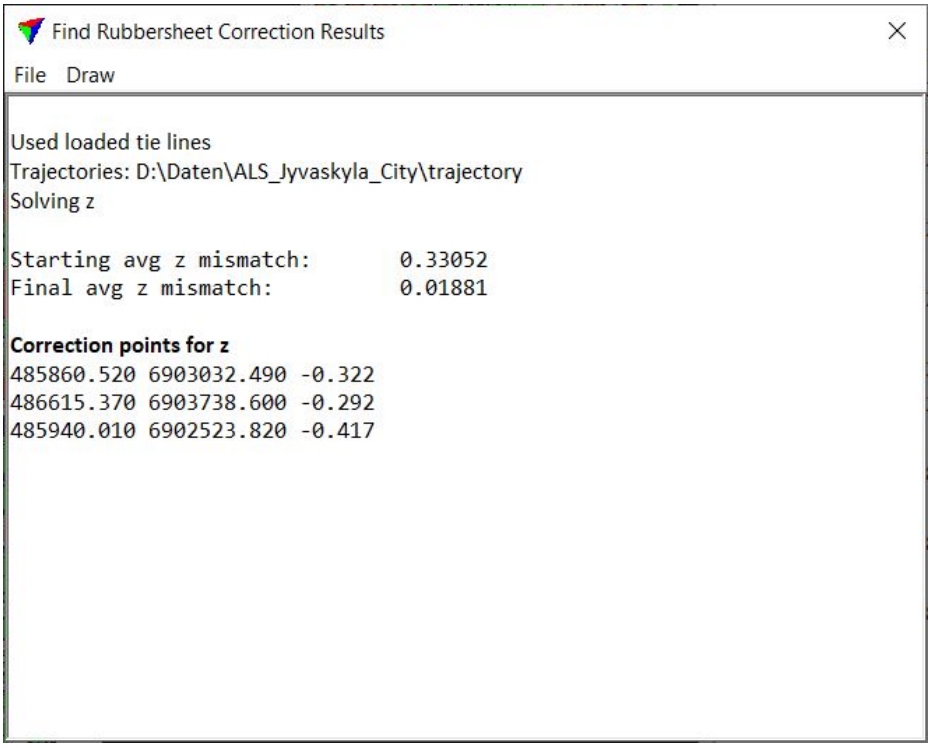
   This opens the **Find Rubbersheet Fit** dialog:



2. Define settings and click OK.

SETTING	EFFECT
Source	Source file for calculating the fluctuating corrections: • **Active tie lines** - tie lines in an open Tie line window are used. • **Tie line file** - tie lines stored in a tie line file are used.
Tie lines	Path to the tie line file that is used for calculating the corrections. This is only active when **Source** is set to **Tie line file**.
Trajectory dir	Directory where the TerraScan trajectory files are stored.
Solve	Defines what correction values are computed: **Xyz**, **Xy**, or **Z**.
Expand model	Distance by which the correction model is expanded from the observation location closest to the data set boundary to the outside.
Expand using	Determines how the values for the outside corners of the correction model are derived: • **Zero correction** - the correction value is set to 0.0. • **Closest correction** - the correction value is equal to the closest computed correction value.
Max count	Maximum amount of observations that are averaged if they are located closeby.
Max distance	Maximum distance between observations that are averaged.
Merge final correction points	If on, the final correction points are merged into one correction value according to the averaging settings.

This opens the **Find Rubbersheet Correction Results** dialog:



The dialog shows the report of the correction model computation. Starting and final average mismatch values indicate the level of improvement that can be achieved by applying the correction model. Further, list of all correction points of the model is shown.

3. (Optional) You may draw the correction vectors into the CAD file by using the command from the **Draw** pulldown menu. The commands open the **Draw Correction Vectors** dialog which lets you define a scale factor for drawing the correction vectors.

4. Save a corrections file using the **Save corrections** command from the **File** pulldown menu.

   You may also save the report as a text file or print it directly by using the corresponding commands from the **File** pulldown menu.

5. Apply the corrections to the laser data using the Apply Correction tool.

Find Tie Line Fluctuations

Find Tie Line Fluctuations tool compares short intervals of each strip against other overlapping strips. It computes corrections for different parameters based on tie lines. Each short distance interval of each strip gets its own correction value. For the final correction file, the correction curve can be smoothed.

Find Tie Line Fluctuations tool requires tie lines that are suitable for calculating fluctuating correction values for the different parameters. The tie lines are collected using commands from the TerraMatch Tie line window. Additionally, tie points collected in TerraPhoto based on images can be included in the calculation. The tie points in TerraPhoto must be of types **Known depth** or **Depth** tie points.

The smoothing of the correction curve can be done using two alternative methods:

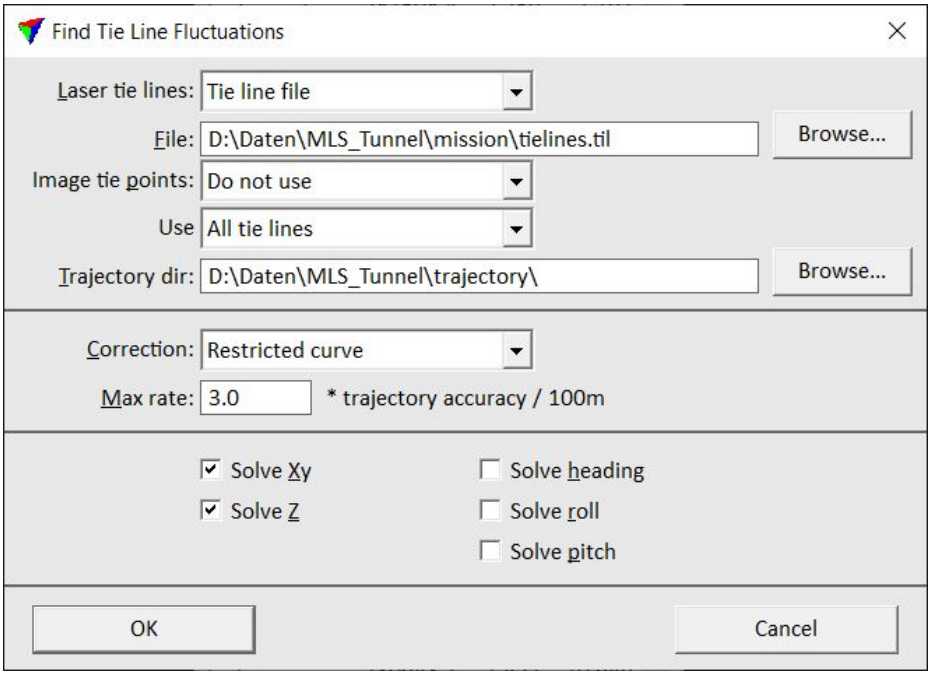
- **Restricted curve**: The smoothing of the correction curve involves the accuracy estimates for trajectory positions. Bigger corrections values are applied for positions where the accuracy estimate is worse. If trajectories are estimated to be very accurate, no rapid drift is modeled even though tie line observations may indicate that. The **Max rate** factor determines, how fast the corrections curve changes can be. A small factor results in a smoother curve. This should be used if the tie lines are not so good and may contain outliers. A bigger factor results in a less smooth curve and the single tie line observations get more influence in the final solution. This should be used for good tie lines.
- **Smooth curve**: A 1D Gaussian filter is implemented to handle filtering of any kind of observations. It should reduce the impact of noise but still model the drift if there are good observations. It was developed based on MMS data with drift in XY and Z. The smoothing may allow rapid changes in the correction curve if the tie line observations are accordingly. The method is suited for data sets where there are many stops or slow-downs during the drive along the same trajectory, and when travel distance is not changing so much (up to 4 * sigma). The averaging is performed along the neighborhood of one trajectory, where each tie line observation gets in the end one time stamp.

If accuracy estimates for trajectory positions are not available, the software uses values defined in Default trajectory accuracy category of TerraMatch **Settings**.

General procedure for finding and applying fluctuating corrections:

1. Select **Find Tie Lines Fluctuations** tool.

   This opens the **Find Tie Line Fluctuations** dialog:



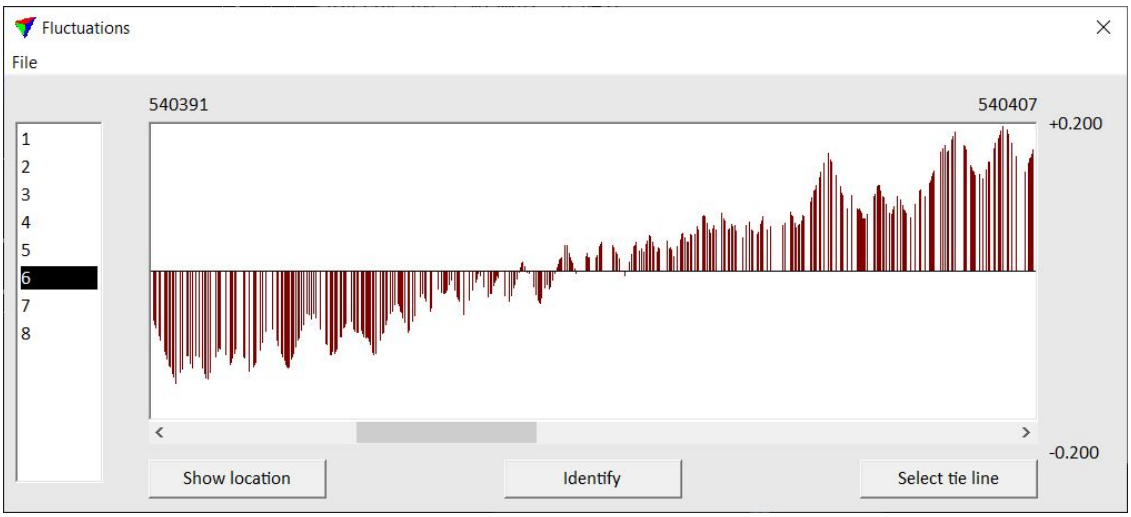
2. Define settings and click OK.

SETTING	EFFECT
Source	Source file for calculating the fluctuating corrections: • **Active tie lines** - tie lines in an open Tie line window are used.

SETTING	EFFECT
	• **Tie line file** - tie lines stored in a tie line file are used.
Tie lines	Path to the tie line file that is used for calculating the corrections. This is only active when **Source** is set to **Tie line file**.
Image tie points	Determines whether tie points from TerraPhoto are included in the calculation: • **Do not use** - no tie points from TerraPhoto are used. • **Active tie points** - known depth tie points are used if a tie point file is loaded in TerraPhoto.
Use	Defines what tie lines to use for calculating the corrections: • **All tie lines** - use all tie lines. • **Known points only** - use only tie lines of type **Known xyz**, **Known xy**, **Known z** and **Known line**.
Trajectory dir	Directory where the TerraScan trajectory files are stored.
Correction	Determines the method for smoothing the correction curve: • **Free curve** - no smoothing is applied. Each tie line observation fully effects the solution. • **Restricted curve** - smoothing based on trajectory accuracy estimates is applied. The amount of smoothing is determined by the **Max rate** factor and effected by the accuracy of trajectory positions. • **Smooth curve** - smoothing based on a 1D Gaussian filter is applied.
Max rate	Determines how fast the corrections curve changes can be. A smaller factor results in a smoother curve. Values can range between 0.1 and 100.0, the default value is 2.0. This is only available if **Correction** is set to **Restricted curve**.
Range	Distance forward and backward from a tie line observation within which correction values are averaged. Values can range between 0.1 and 100.0, the default value is 50. This is only active if **Correction** is set to **Smooth curve**.

SETTING	EFFECT
Solve Xy	Solves for a fluctuating xy correction.
Solve Z	Solves for a fluctuating z correction.
Solve heading	Solves for a fluctuating heading correction.
Solve roll	Solves for a fluctuating roll correction.
Solve pitch	Solves for a fluctuating pitch correction.

This opens the **Fluctuations** dialog:



The dialog shows the list of strips on the left and a graph of corrections for the selected strip on the right. The red bars in the graph represent the tie line observations from which a correction value is calculated. The correction value for a selected observation is shown on top of the graph.

3. Check the fluctuating corrections using the buttons and commands from the **Fluctuations** dialog. The options are described in Section Fluctuations dialog for tie lines.

4. Save a corrections file using the **Save corrections** command from the **File** pulldown menu.

5. Apply the corrections to the laser data, tie lines, and other data types using the Apply Correction tool.

Fluctuations dialog for tie lines

The **Fluctuations** dialog provides several buttons and menu commands for visualizing, analyzing and saving the fluctuating correction values.

Show location button is used to highlight the location of a time interval in a CAD file view. Select the time interval in the **Fluctuations** dialog graph. Click the button and move the mouse pointer inside a CAD file view. The selected time interval is dynamically highlighted. Place a data click inside the view in order to center the view at the location of the time interval.

Identify button is used to select the location of a time interval in the **Fluctuations** dialog graph. Click on the button and place a data click in a CAD file view. This selects the time interval closest to the data click in the **Fluctuations** dialog graph.

Select tie line button is used to select a tie line observation in the **Tie lines** window. Select a tie line observation in the **Fluctuations** dialog graph and click the button. This selects the tie line observation in the **Tie line** window.

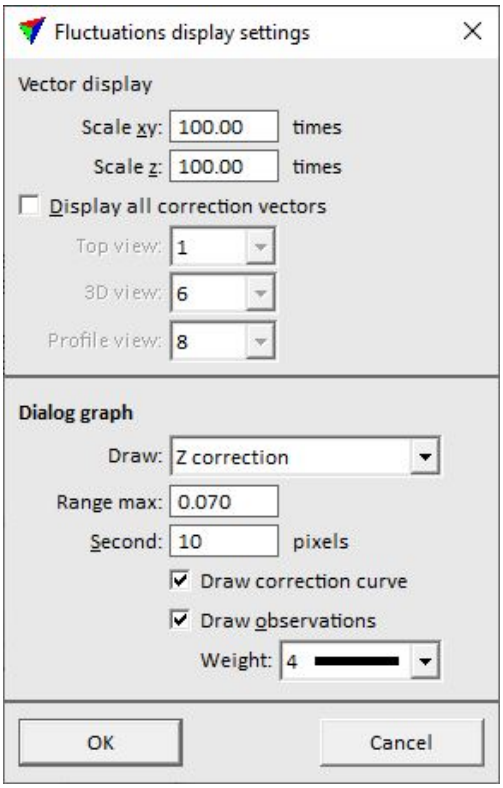
File / Display settings

Display settings command defines settings for the graph display in the Fluctuations dialog. This includes settings for displaying correction vectors in CAD file views and for the content shown in the graph display.

To define settings for the display of fluctuation corrections:

1. Select **Display settings** command from the **File** pulldown menu.

   This opens the **Fluctuations display settings** dialog:



2. Define settings and click OK.

   This applies the new settings to the graph display and the vectors shown in CAD file views.

SETTING	EFFECT
Scale xy	Scale factor for the display of correction vectors in xy direction.

SETTING	EFFECT
Scale z	Scale factor for the display of correction vectors in z direction.
Display all correction vectors	If on, correction vectors are displayed as lines in CAD file views. The length of the line is the correction value at this location scaled by the value set for **Scale xy** and **Scale z**.
Level	Level number in the CAD file on which the correction vectors are displayed.
Top view	Number of the CAD file view for displaying the correction vectors in a top view.
3D view	Number of the CAD file view for displaying the correction vectors in a 3D view.
Profile view	Number of the CAD file view for displaying the correction vectors in a profile view.
Draw	Correction that is displayed in the **Fluctuations** dialog graph.
Range max	Maximum correction value range displayed in the **Fluctuations** dialog graph.
Second	Defines the display size of one second time interval in the **Fluctuations** dialog graph.
Draw correction curve	If on, a line element represents the correction curve in the graph display in addition to the correction vectors.
Draw observations	If on, the tie line observations are shown in the graph display as red dots in addition to the correction vectors. The size of the dots is determined by the **Weight** selection.

Find Tie Line Match

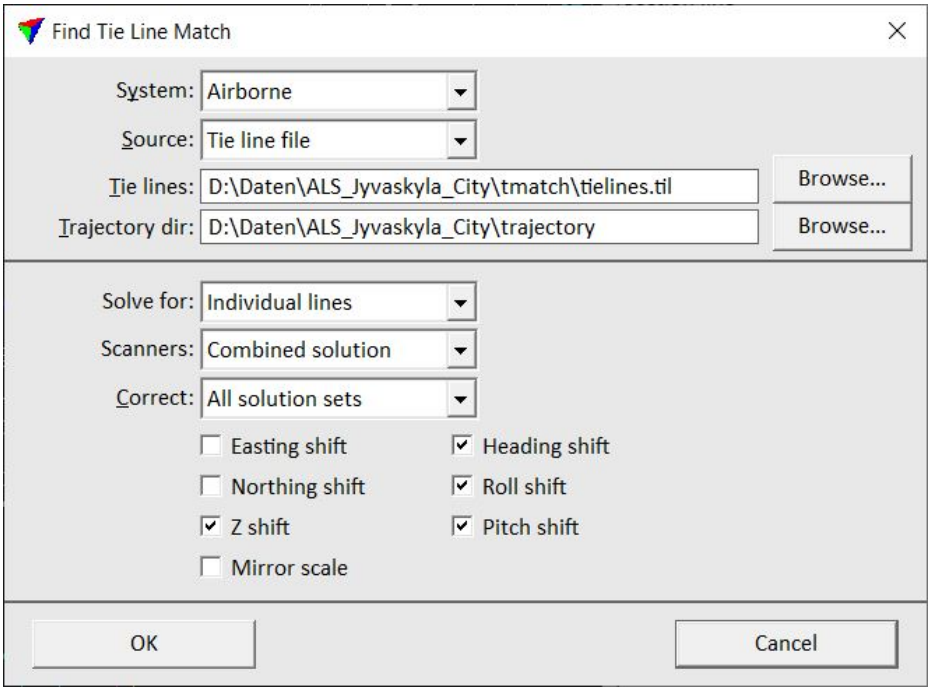
Find Tie Line Match tool analyzes the mismatch in the tie lines and searches correction values. The tool utilizes the feature-to-feature matching method described in Find match vs. Tie Lines.

In preparation of using this tool, you have to import trajectories into TerraScan and collect tie lines that are suited for solving the required parameters.

General procedure for solving and applying correction parameters:

1. Select the **Find Tie Line Match** tool.

   This opens the **Find Tie Line Match** dialog:



2. Define settings and click OK.

SETTING	EFFECT
System	Scanner system used for collecting the laser data: • **Airborne** - scanner with a line or zig-zag scan pattern. For scanners with any other scan pattern, **Generic** is the better choice, even if it is an airborne system scanner. • **Generic** - mobile system scanner, airborne system scanner with any other than line or zig-zag scan pattern.
Source	Source file for calculating the correction values: • **Active tie lines** - tie lines in an open **Tie line** window are used. • **Tie line file** - tie lines stored in a tie line file are used.
Tie lines	Path to the tie line file that is used for calculating the correction values. This is only active when **Source** is set to **Tie line file**.
Trajectory dir	Directory where the TerraScan trajectory files are stored.
Solve for	Type of solution to find: • **Whole data set** - a solution for the whole data set is calculated.

SETTING	EFFECT
	• **Line groups** - a solution for strips of different groups is calculated. This requires that groups are defined for the TerraScan trajectories. • **Individual lines** - a solution for each strip is calculated.
Scanners	Defines how data from different scanners is used: • **Combined solution** - a solution for all scanners is calculated. • **Solution per scanner** - a solution for each individual scanner is calculated.
Correct	Defines how line groups or individual lines are corrected: • **All solution sets** - a solution is calculated for being applied to all strips or groups. • **Selected sets** - a solution only for selected strips or groups is calculated. This is only active when **Solve for** is set to **Line groups** or **Individual lines**.
Easting shift	Solves for a constant easting correction value. This is only active if **System** is set to **Airborne**.
Northing shift	Solves for a constant northing correction value. This is only active if **System** is set to **Airborne**.
Z shift	Solves for a constant elevation correction value. This is only active if **System** is set to **Airborne**.
Mirror scale	Solves for a mirror scale factor. This is only active if **System** is set to **Airborne**.
Heading shift	Solves for a constant heading correction value.
Roll shift	Solves for a constant roll correction value.
Pitch shift	Solves for a constant pitch correction value.
Lever X	Solves for a constant lever arm correction in X (left - right) direction. This is only active if **System** is set to **Generic**.
Lever Y	Solves for a constant lever arm correction in Y (forward - backward) direction. This is only active if **System** is set to **Generic**.
Lever Z	Solves for a constant lever arm correction in Z (up - down) direction. This is only active if

SETTING	EFFECT
	System is set to **Generic**.

3. If **Correct** is set to **Selected sets**, the **Select sets to correct** dialog opens. Select the group(s) or line(s) for which to calculate correction values and click OK.

   The software calculates correction values for the selected parameters. It opens the **Find Tie Line Match Results** dialog. The dialog shows information about the correction values and the number of usable observations for each parameter.

4. Save a corrections file using the **Save corrections** command from the **File** pulldown menu in the **Find Tie Line Match Results** dialog. You can also save a text file and print the report by utilizing the corresponding commands from the **File** pulldown menu in the dialog.

5. Use the Apply Correction tool from the **Match** tool box to apply the corrections to the laser data, tie lines, or other files.

Lever arm corrections should actually not be solved by using tie lines. However, the functionality can be used to remove remaining mismatch in the data due to lever arm inaccuracies. Mainly, the options to solve lever arms with tie lines has been implemented in the software in order to calibrate data from several laser heads of one scanner.

Combine rotation angle

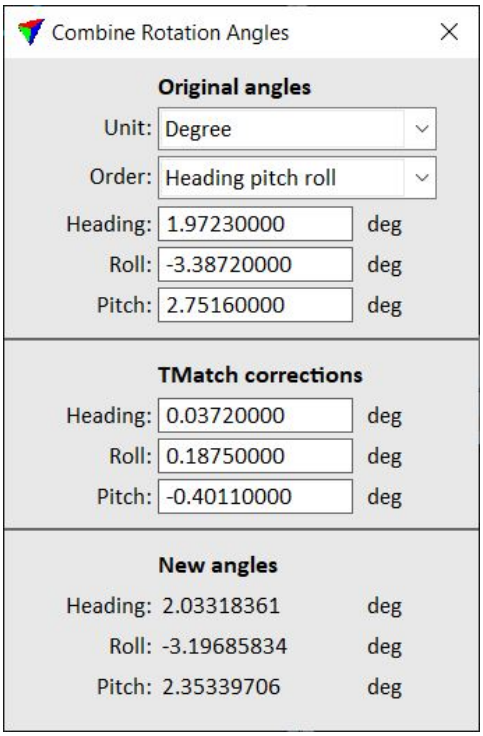
Key-in command only, under development

Combine rotation angles key-in command opens a dialog in which system misalignment angles and TerraMatch corrections for heading, roll and pitch can be combined. The software computes new system misalignment angles from the input and shows them in the lower part of the dialog.

To combine rotation angles:

1. Type *combine rotation angles* command in the **Spaccels** window of Spatix or the **Key-in** line of Bentley CAD and press <Enter>.

   This opens the **Combine Rotation Angles** dialog:



2. Select settings for **Unit** and **Order**, and type the values for **Heading**, **Roll**, **Pitch** into the corresponding fields.

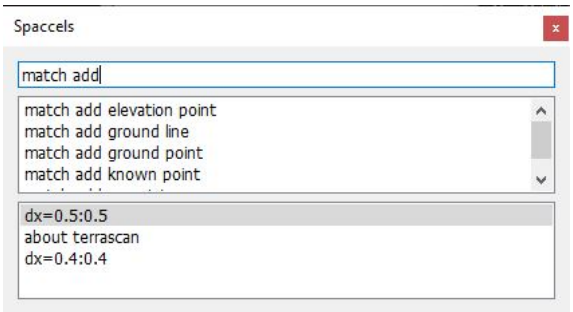
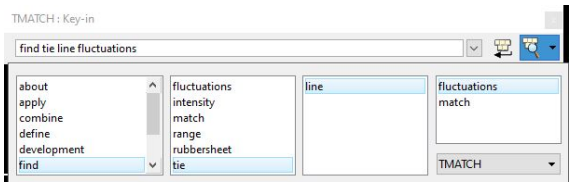
   The new system misalignment angles are shown in the lower part of the dialog.

SETTING	EFFECT
Unit	Unit of the misalignment angles: **Degree** or **Radian**.
Order	Order of misalignment angles for computing the correct system misalignment. The list provides all possible combinations of the three angles heading, roll and pitch. The

SETTING	EFFECT
	probably most common order is **Heading pitch roll**.
Heading | Roll | Pitch	Original system misalignment angles. They are normally provided by the system manufacturer as a result of a system calibration process.
Heading | Roll | Pitch	Misalignment angle corrections computed by TerraMatch. They are normally a result of a TerraMatch calibration process and refine the manufacturer's system calibration.

Key-in commands/Spaccels

Key-in commands (Bentley CAD) or **Spaccels** (**Sp**atix **accel**erate**s**) are a way to speed up the call of tools and menu commands. The CAD platforms offer command lines where you can type and execute the commands. In addition, commands can be assigned to keys (function keys in Bentley CAD). This speeds up some manual tasks significantly as you can call tools by pressing a key instead of mouse clicks. Especially tools with optional parameters in their call commands are well suited for speeding up manual work with keys.

SPATIX	BENTLEY CAD
Tools in TerraMatch can be started by entering a spaccel in the Spatix **Spaccels** window. The window contains a command line and two lists that help to find the correct syntax of a command.	Most of the tools in TerraMatch can be started by entering a key-in command in the Bentley CAD **Key-in** line. The **Browse Key-in** option of the **Key-in** line can be used to find out the syntax of a key-in command.
	
The upper list in the **Spaccels** window lists all available spaccels. This includes commands for calling tools of Spatix and any loaded IxApp, such as Terra applications. If you know approximately the beginning of the command syntax, start typing the first word. The list of spaccels is reduced to those that start with the typed letters. This helps to find the correct command syntax. You can select a spaccel from the list with a double-click. This writes the spaccel in the command line on the top of the window. Press <Enter> in order to execute the command. This starts the corresponding tool. The lower list in the **Spaccels** window lists spaccels that have been executed. To repeat a command, you may select it from this list with a double-click and press <Enter>.	If you select TMATCH in the list at the lower right corner of the **Browse Key-in** dialog, the selection of commands is limited to TerraMatch commands only. There are four list fields that show available commands. Select the first word of a command in the left list. This adds the word to the command line and displays matching second words in the second-left list field. Select the second word of a command. This adds the word to the command line and displays any matching third words in the next list field. Continue until a command is complete. If you know approximately, how a command looks like, you may start typing the command in the **Key-in** line. The software automatically completes words of the command, so you just type the first letter(s) and then, confirm the suggested word with <Space>. Press <Enter> in order to execute a key-in command. This starts the corresponding tool or performs another action called by the command.

SPATIX	BENTLEY CAD
In Spatix, you can assign commands to any key or combination of keys. Key assignments are defined in the **Shortcuts** window. The window lists all tools/function calls of the software and lets you define a key (combination) for selected ones. In addition, **Spaccels** for commands with optional parameters can be defined and assigned to a key (combination) as well.	In Bentley CAD, you can assign commands to function keys. This is done in the **Function keys** category of **User Settings**. You first need to select the function key and then, type the correct command in the command line. Set the command with <Enter>.

This Chapter lists a selection of commands and their optional parameters. Some of them you may consider assigning to keys. For each command, a link to the corresponding tool or menu command is given. Use this link to jump to a more detailed description of the tool/command.

The syntax of commands/spaccels is the same in all CAD platforms. Also optional parameters for function calls are defined in the same way.

KEY-IN COMMAND	KEY-IN COMMAND
apply correction	match add elevation point
define tie lines	match add ground line
find rubbersheet fit	match add ground point
find tie line fluctuations	match add known point
find tie line match	match add xy point
	match app maintool

Apply Correction

Apply Correction starts the Apply correction tool.

Syntax:

apply correction

Define Tie Lines

Define Tie Lines starts the Define Tie Lines tool.

Syntax:

define tie lines

Find Rubbersheet Fit

Find Rubbersheet Fit starts the Find Rubbersheet Fit tool.

Syntax:

find rubbersheet fit

Find Tie Line Fluctuations

Find Tie Line Fluctuations starts the Find Tie Line Fluctuations tool.

Syntax:

find tie line fluctuations

Find Tie Line Match

Find Tie Line Match starts the Find Tie Line Match tool.

Syntax:

find tie line match

Match App Maintool

Match App Maintool opens the **TerraMatch** main tool box. By default, the tool box is opened when TerraMatch is loaded. The command can be used to re-open the tool box after it was accidentally closed.

Syntax:

match app maintool

Match Add Elevation Point

Match Add Elevation Point starts the tool for placing elevation point type of tie lines.

Syntax:

match add elevation point

Match Add Ground Line

Match Add Ground Line starts the tool for placing ground line type of tie lines.

Syntax:

match add ground line

Match Add Ground Point

Match Add Ground Point starts the tool for placing ground point type of tie lines.

Syntax:

match add ground point

Match Add Known Point

Match Add Known Point starts the tool for placing known point type of tie lines.

Syntax:

match add known point

Match Add Xy Point

Match Add Xy Point starts the tool for placing xy point type of tie lines.

Syntax:

match add xy point

Configuration Variables for Bentley CAD platforms

Bentley CAD applications are able to locate TerraMatch with the help of configuration variables. When you install TerraMatch, the installation program will create a configuration file TERRA.CFG which defines the required environment variables. This file is placed in Bentley CAD tool's CONFIG\APPL sub-directory.

For example, C:\USTATION\CONFIG\APPL\TERRA.CFG may contain:

```
#-------------------------------------------------
#  TERRA.CFG - Configuration for Terra Applications
#-------------------------------------------------
TERRADIR=c:/terra/
TERRACFG=$(TERRADIR)config/
TERRADOCS=$(TERRADIR)docs/
MS_MDLAPPS < $(TERRADIR)ma/
%if exists ($(TERRACFG)*.cfg)
%   include $(TERRACFG)*.cfg
%endif
```

This configuration file will include all the configuration files in C:\TERRA\CONFIG directory. TerraMatch's configuration file TMATCH.CFG contains:

```
#--------------------------------------------
#  TMATCH.CFG - TerraMatch Configuration File
#--------------------------------------------
# Directory for storing the user license file (TMATCH.LIC)
TMATCH_LICENSE=$(TERRADIR)license/
# Directory for user preferences (TMATCH.UPF)
TMATCH_PREF=$(TERRADIR)tmatch/
# Directory for application settings (TMATCH.INF)
TMATCH_SET=$(TERRADIR)tmatch/
```

In a default configuration, Bentley CAD automatically includes these settings as configuration variables. You can check the values for these variables in the **Configuration Variables** dialog of Bentley CAD. In case these variables have not been defined correctly, you should define them manually.

Installation Directories

TerraMatch shares the same directory structure with all Terra Applications. It is recommended that you install all Terra Applications in the same directory.

The list below shows a typical directory structure when TerraMatch has been installed in path C:\TERRA64.

C:\TERRA64	installation directory for Terrasolid applications
🗀app	application files for Spatix
🗐tmatch.ix	application
🗐tmatchsb.dll	library
🗀config	application configuration files
🗐tmatch.cfg	defines environment variables for Bentley CAD
🗐tmatch.ini	defines environment variables for Spatix
🗀license	user license files
🗐 tmatch.lic	user license
🗀ma	application files for Bentley CAD
🗐 tmatch.ma	application
🗐 tmatch.dll	library
🗐 tmatchsb.dll	library
🗀tmatch	user settings and configuration files

Scripting interface

TerraMatch implements a scripting interface which you can use to send key-in commands to the CAD system. Any programming method provided by the CAD system is applicable, such as MDL, Bentley CAD Visual Basic or simply function key definition. In your own code, you may launch any action available in TerraMatch as toolbox icon, pulldown menu command or dialog push button, and set values of any dialog variable. Actions and dialog variables are only available when the corresponding dialog is created. This ensures that the application state is ready for the action or for setting a variable.

Scripting key-in commands

TerraScan, TerraPhoto, TerraMatch and TerraModeler implement the same scripting interface and thus, work with the same key-in command logic. The key-in commands below show the syntax for TerraMatch commands while examples are given from TerraScan. The syntax for the other applications follow logical rules:

APPLICATION	SET LOGGING	LAUNCH ACTION	SET VARIABLE
TerraScan	scan log	scan action	scan set
TerraPhoto	photo log	photo action	photo set
TerraMatch	match log	match action	match set
TerraModeler	model log	model action	model set

Match Log Dialogs *logfile*

Match Log Dialogs *logfile* starts to write actions and dialog variables to a text file at a given location on the hard disc. E.g., "scan log dialogs d:\logs\dialogs.txt" writes the logfile "dialogs.txt" in directory d:\logs\ on the hard disc. If the file does not exist, it is created when the first action to log is performed.

The command is most useful to find out action, dialog and variable names. Start the logfile creation by using the key-in command in the Key-in line[Bentley CAD] or Spaccels window[Spatix]. Call the tool or command in the software and define settings in the dialog. Close the dialog with OK or Cancel. The application writes the dialog name, variable names and setting values into the logfile.

Use the key-in command without the *logfile* variable in order to stop writing actions to the logfile.

Match Action *action*

Match action *action* starts the given action. E.g. "scan action trajectviewfields" launches the command **View fields** in the **Trajectory** window which means it opens the **View Trajectory Fields** dialog. Actions are linked to dialog push buttons or dialog pulldown menus in the software. An action can be started only when the dialog is open.

Match Action HideDialog

Match action hidedialog instructs the software to keep the next modal dialog hidden and close it with OK.

Match Set *variable* = *value*

Match set *variable* = *value* assigns the given value to the given variable. E.g. "scan set VtfNumber=1" sets the **Number** attribute to be visible in the **View Trajectory Fields** dialog. If there is no matching variable in an open dialog, the application stores the variable-value-assignment in a buffer. When the next dialog is created, it will apply the assignment and clear the buffer.

Match Close Dialog *dialog*

Match close dialog *dialog* closes a modeless dialog with the given name. E.g. "scan close dialog ManageTrajectories" closes the Trajectories window.

Scripting examples (Bentley CAD VBA)

TerraMatch setup provides an example script that includes Bentley CAD VBA modules. The script is stored in the \EXAMPLE folder of the Terra installation directory, e.g. C:/TERRA64/EXAMPLE/SCRIPTING_EXAMPLE.MVBA. The example script can be loaded in the VBA Manager of Bentley CAD and used, for example, as starting point for own scripts.

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