System 1200 Newsletter – No. 43
Mixing GPS and TPS Data (3)

Continuing From The Last Newsletter…

This is the final newsletter in the series of 3 newsletters discussing the mixing of GPS and TPS data.

The first of these 3 newsletters discussed the general problem of moving between grid and ground coordinates.

The last newsletter discussed how to apply **Geometric Corrections** when using a total station in order to make the TPS measurements fit existing control.

This newsletter explains the same problem from a GPS perspective, how to make GPS measurements fit existing control and how to make GPS and TPS measurements fit together.

The Big Question

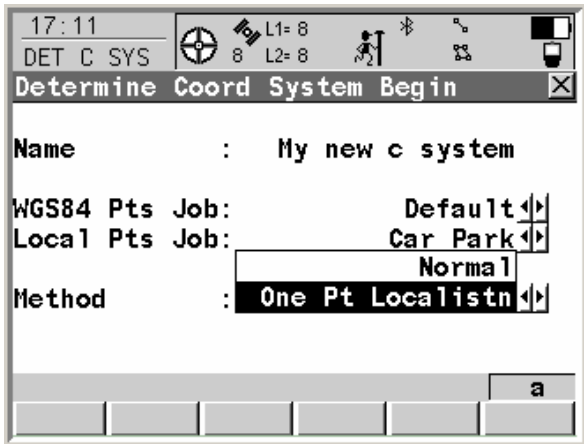
Remember that points measured with a GPS1200 instrument are stored in WGS84 geodetic coordinates and are converted to the required easting and northing coordinates using a coordinate system (read newsletter 09_2004 for more details on the coordinate conversion process).

It should be clear that it is necessary to use the correct coordinate system in order to make GPS coordinates fit to the local control (the required Easting and Northing) and/or TPS measurements. How do we know which coordinate system is the right one? This is a big question!

The answer is, it depends. We will explain in the following sections typical examples.

In the examples below it is assumed that the reader understands the basic idea that it is necessary to measure control points (that have known easting and northing coordinates) with the GPS rover. These measured GPS points are then "matched" with the known control points in order to compute a coordinate system.

It is well known that the System1200 Determine Coordinate System application is generally used to compute the coordinate system in the field. What is perhaps not so well known is that two different methods can be used to compute the coordinate system. **Normal** and **1 Pt Localization** are the options, select the appropriate **Method** in the **Det C SYS Determine Coordinate System Begin** panel.



The main difference between the two methods is that the **Normal** method will allow for any number of control points to be measured and used in computing the coordinate system. All matched pairs of points are used to determine all the "individual parts" of the coordinate system.

When using the **1 Pt Localization** method, only one point needs to be measured to compute the coordinate system. Additionally, for the OneStep and TwoStep coordinate systems, the rotation and scale elements of the coordinate system can be separately computed using a variety of different methods. This allows many more "special cases" to be handled.

Simple Cases

The ideal situation when wishing to make GPS measurements fit to the existing local control is that the area in which you wish to work is surrounded by control points with known local coordinates.

It is then a simple matter to measure all the known control points with the GPS rover and compute a coordinate system based on these control points.

Subsequently measured GPS points using this coordinate system will then fit this existing control.

In this case, the **Normal** method within the Determine Coordinate System application would be used.

Newsletters 09_2004, 10_2004 and 11_2004 provide more information about which coordinate system should be used for different circumstances.

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Special Cases

It is likely that there are more “special” cases that need to be supported.

For example, what if the coordinates of only one control point are known, but it is required that the subsequent measured GPS points are scaled to fit the TPS measured ground distances?

What if the coordinates of only one control point are known, but it is required that each subsequent measured GPS point remains on the grid?

There are also many other special cases, but this newsletter would become a thick book if all possible cases were examined. The 2 cases above are the most common and should provide enough information to be able to handle other cases.

As mentioned above, for these special cases a **OneStep** or **TwoStep** coordinate system would normally be computed using the **1 Pt Localization** method. This allows shifts, rotations and scales to be computed using a variety of methods.

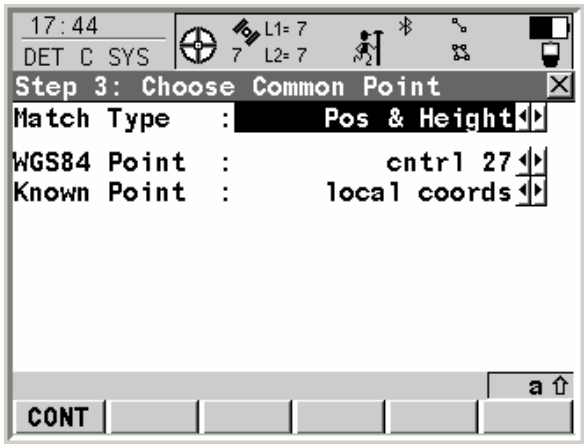
Scaling To The Ground

A very common example is where it is necessary to conduct a GPS survey in an area where only one known control point exists, (or only one control point be measured) but you must ensure that all subsequent GPS measurements are scaled to the ground. This can be thought of as squeezing the GPS measurements.

Scaling the GPS measurements to the ground would mean that if a total station user was going to work in this area later and did not use any **Geometric Corrections** (therefore measuring ground distances – refer to previous newsletter) then the total station measurements would fit the GPS measured points.

In this case a OneStep coordinate system would be computed. Since we must separately compute the shift, rotational and scaling parts of the OneStep, then the **1 Pt Localization** method within the Determine Coordinate System application should be used.

Start the **Determine Coordinate System** application. Select the **1 Pt Localization** method and compute a **OneStep** coordinate system. Continue to the **DET C SYS Step 3: Choose Common Point** panel. Here, select the GPS measured point (Tip - you can measure the control point here if you have not yet done so – press **F5(SURVY)**) and the control point where the local coordinates are known (For example, coordinates are 5000 N, 100 E).

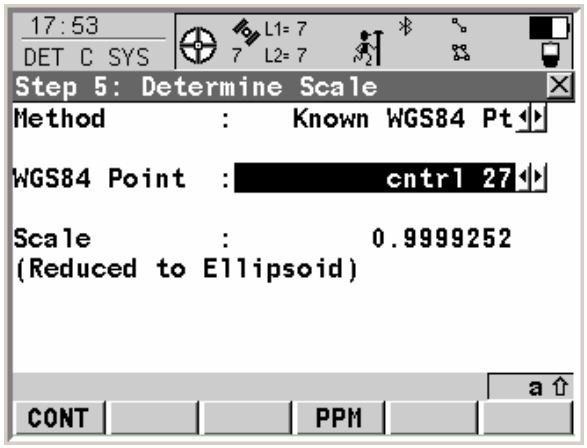


You have now computed the “shift” part of the OneStep coordinate system.

If we were to end the computation of the coordinate system here, then all subsequent measured GPS points close to this control point would have coordinates similar to 5000, 100, but as we move away from the known point the GPS measured points would not be correct. They would not be scaled to the ground. We still need to compute the scale factor for this coordinate system.

Press **F1(CONT)** to access the **Step 4: Determine Rotation** panel. In this example we do not need to compute a rotation so leave the **Method** set to **Use WGS84 North**.

Press **F1(CONT)** to access the **Step 5: Determine Scale** panel.



Here you need to select the method **Known WGS84 Pt** and select the same point that was used to match to the local control point. The **Scale** that is shown is based on the height of the point above the WGS84 ellipsoid.

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This is basically the same as the **Height Scale Factor** mentioned in the first newsletter, but that newsletter was discussing TPS measurements. The scale factor computed here has the same effect, but in this case the scale factor scales the GPS measurements between the grid and ground - previously the TPS measured distances were being scaled).

The more alert reader may note that for TPS measurements, a **Map Projection Scale Factor** is also needed to fully convert between ground and grid measurements. Why is this not necessary for GPS measurements when computing a OneStep coordinate system? Remember that the origin of the "temporary" Transverse Mercator projection which is used within a OneStep coordinate system is based on the matched common point. This means that the **Map Projection Scale Factor** is 1.0000 – hence only the **Height Scale Factor** is required in this case to convert between grid and ground coordinates for the GPS measured points.

Continue through the determine coordinate system program, the coordinate system will then be stored to the instrument and attached to the active job.

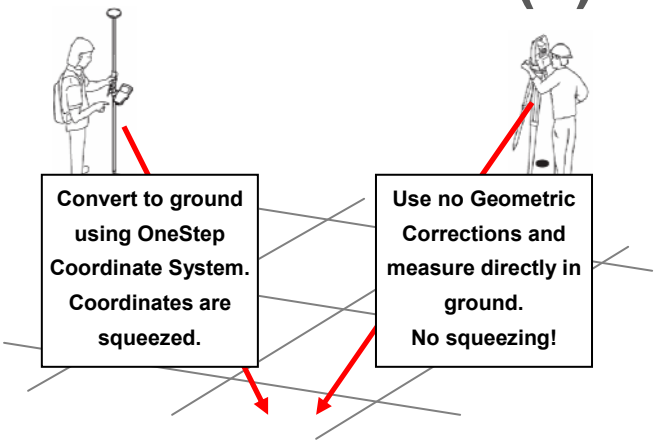
All subsequent measured GPS points will then be converted using this coordinate system and "squeezed" to fit the ground measurements.

Summary

It is easy to mix GPS and TPS data, ensuring that both fit the existing points which are based on ground coordinates, even when only one control point is known.

On the GPS instrument, the GPS measurements are "squeezed" to fit to the ground by determining a coordinate system which takes into account the height of a GPS measured point and allows the necessary scale factor to be computed. Ground coordinates are computed.

On the total station, the TPS measurements are not squeezed (no Geometric Corrections are used) and the ground distances are measured and ground coordinates are computed.



Shifting To The Grid

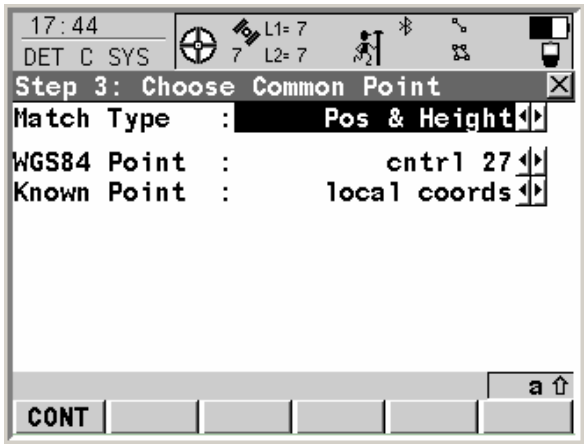
Another very common example is when it is necessary to conduct a GPS survey in an area where only one known control point exists. You must ensure that all subsequent GPS measurements tie into "true grid" coordinates, for example, this could be the national coordinate system or State Plane Zone.

It is unlikely that the reference station is set up over a known point, but more likely that the reference station is set up "anywhere" with a "HERE" position. This is accurate to only 5-10m.

As in the previous example, the **1 Pt Localization** method within the Determine Coordinate System application can be used to determine this coordinate system. (The **Normal** method could also be used for this case, but the **1 Pt Localization** method is much easier to use).

Start the **Determine Coordinate System** application. Select the **1 Pt Localization** method and compute a **Classic 3D** coordinate system. Remember to select the correct ellipsoid and projection or State Plane Zone.

Then continue to the **DET C SYS Step 3: Choose Common Point** panel.



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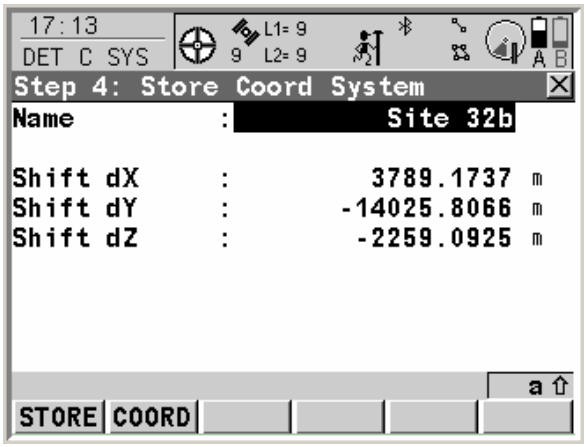
This panel is identical to the one for the previous example and again allows the common point to be selected.



What has been computed is a Classic 3D coordinate system, but only 3 parameters have been computed – the dX, dY and dZ shift (the rotations and scale for this case are not computed).

Continue through the determine coordinate system application. The coordinate system is stored on the instrument and attached to the active job.

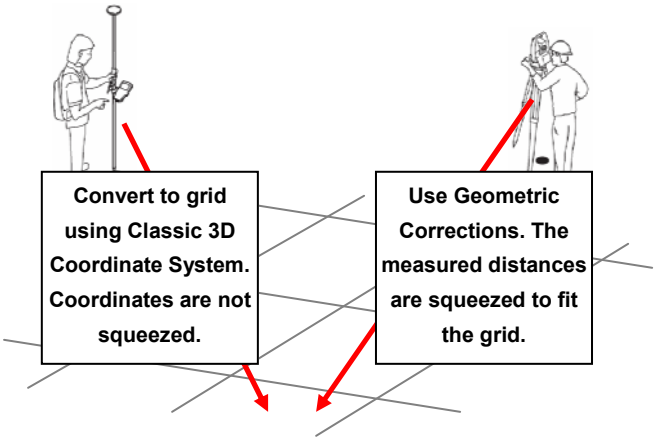
All subsequent measured GPS points will then be converted using this coordinate system and will fit the "grid".

Summary

It is easy to mix GPS and TPS data ensuring that both fit existing control points which are based on grid coordinates – even when only one control point is known.

On the GPS instrument, the GPS measurements are not "squeezed" – the appropriate projection is used when determining the coordinate system and therefore grid coordinates are computed, converting the GPS measured points to northing and easting coordinates.

As described in the last newsletter however, TPS measurements are squeezed to fit the grid. The "squeezing" is done by using geometric corrections to convert the measured "ground" slope distances to "grid" horizontal distances.



Overall Summary

This series of 3 newsletters has covered the topic of mixing GPS and TPS data and ensuring that GPS and TPS measured points fit the existing control.

System1200 has the functionality and flexibility to handle most cases when it is necessary to mix GPS and TPS data.

It is however, very important to understand the basic theory of **Geometric Corrections** (map projection scale factors and height scale factors) and the difference between measuring **grid** and **ground distances**. It is also important to know the basic theory of **coordinate systems** and how to **determine the correct coordinate system** for the particular circumstances.

Please contact your local Leica representative if there are specific topics you would like covered in these newsletters.

We welcome all suggestions for TPS1200, GPS1200, specific applications or LGO. We look forward to receiving your ideas.

BA Surveying & GIS
Geosystems Division

- when it has to be **right**
Leica Geosystems