

## SfM\_Georef v.1.0

Sfm\_georef is a gui-based Matlab tool for scaling and orienting SfM point clouds to real-world coordinates, using observations made directly in the SfM image set. A valid SfM project (in the Bundler format) is required. Folder structures as produced by SFMToolbox (<http://www.visual-experiments.com/demos/sfmtoolkit/>) and Bundler Photogrammetry Package (<http://blog.neonascend.net/archives/bundler-photogrammetry-package/>) are directly supported. For scaling a project, at least one distance (a control length) between positions that can be directly observed in two or more images is needed. For scaling and orienting a project, the real 3d positions of three or more points (control points) that can be observed in two or more images, is necessary. Once the transform is determined, this can be applied to dense point cloud (.ply) files generated by PMVS2, with provision given for merging multiple files into one.

Tested on Win.7 64bit, Matlab 2010b. Should work on other operating systems, although visual layout of the controls on the main window will not be optimal.

Use of sfm\_georef can be divided into three stages:

- 1) Assembling the control measurements and reading the SfM project
- 2) Identifying the control points in the image set, calculating the equivalent 3d positions in the SfM coordinate system and calculating the transform that relates the SfM and the control coordinate systems
- 3) Transforming and merging dense point clouds associated with the SfM project.

### Getting started: Typical use of SfM\_Georef

#### 1) *Prepare the control data*

Control data can be supplied to sfm\_georef in different formats, but the easiest is as a  $[n \ 3]$  matrix providing the x, y, z coordinates for  $n$  control points. For 3 control points:

```
ctrl_pts = [x1, y1, z1; x2, y2, z2; x3, y3, z3];
```

If control distances have been measured rather than point coordinates, these are provided as a  $[2n \ 1]$  vector for  $n$  control distances. The format of the vector is:

```
ctrl_dists = [NaN; dist1; NaN; dist2; ... NaN; distn];
```

#### 2) *Start sfm\_georef, importing SfM project data and identify points in the SfM image set*

When starting sfm\_georef for the first time on a project, use the following syntax:

```
[transform, obs, ctrl_pts, R3_images] = sfm_georef(sfm_image_dir, ctrl_pts);
```

substituting ctrl\_pts for ctrl\_dists as required, and where *sfm\_image\_dir* is a string that describes the path to the SfM project directory. If *sfm\_image\_dir* is empty, a dialog box will be produced. If the Matlab current working directory is the SfM directory, use *sfm\_image\_dir* = `'.'`.

On exit from `sfm_georef`, `R3_images` will contain a cell array of `R3_image` objects with all the camera information (camera models and orientations) and the image paths of the SfM project. To call `sfm_georef` again for the same project, substitute `R3_images` for the `sfm_image_dir`.

After loading the project data three windows will be generated:

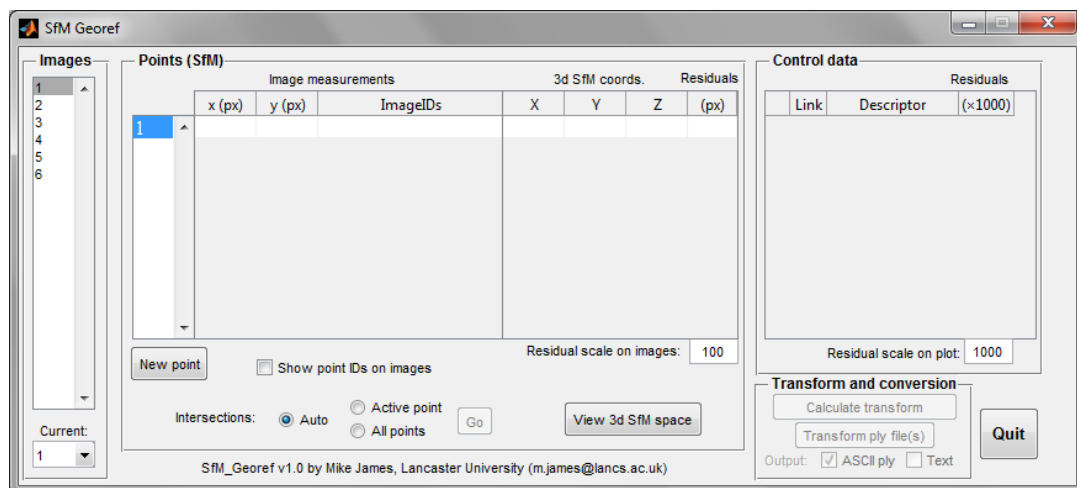
1) Image window, showing image 1

Image windows are where observations in the images can be made. Use the standard Matlab buttons to navigate and zoom in to the image. To define an observation of a point, locate the point in the image, ensure that none of the Matlab image navigation tools are active and that you have a cross-hairs cursor, and click. A red cross will mark the location. Note – if the SfM project did not contain any orientation information for the image, observations are not allowed.

2) SfM object space 3d plot

This window can be brought up at any time from the control window via the ‘View 3d SfM space’ button in the ‘Points (SfM)’ panel. The plot gives the 3d positions of cameras in the SfM project. Camera positions are marked as red dots and any intersected point locations are given as blue circles. The coordinate system is that of the SfM project. Use the standard Matlab buttons to navigate around the plot.

3) Main SfM Georef control window



The control window is divided into four panels:

*Images* – control which images are visible and which one is active

*Points (SfM)* – records image observations, controls intersection strategy and gives 3d point coordinates in SfM coordinate system

*Control Data* – Lists the control data imported, allows point selection for transform and shows the resulting residuals

*Transform and conversion* – Allows the transform between SfM and control coordinate systems to be calculated and applied to ply files.

Additionally, there is a ‘Quit’ button. Use this to exit `sfm_georef`. *Do not* use the standard windows close button in the top right – data changes will be lost.

### *Making point observations:*

- 1) Find a control point that will be visible in multiple images.
- 2) Show the appropriate images by selecting their image numbers in the Images list box, using control-click or shift-click as appropriate for multiple selection.
- 3) Bring the first image to use to the front by either clicking on the window frame or by changing the 'Current' drop down box to the required image number.
- 4) Locate the feature in the image and click. The image coordinates will be stored as observations of Point 1, and listed in the 'Image measurements' table.
- 5) Locate the feature in another image and mouse-click to make the observation. The second observation will be added to the table. With two observations, an intersection will be calculated; if successful, the 3d coordinates will be provided in the '3d SfM coords' column.

### Note:

Image residuals are calculated by projecting the 3d position of the determined point onto the image plane. Image residuals are shown by green lines on the images, and their scale can be changed by changing the number in the 'Residual scale on images:' box. The default of 100 draws residual vectors that are 100x as long as the real image residuals.

The residuals column in the table gives the RMS residual value for all observations of each point.

You can show the point IDs on the image windows by selecting the tick box – useful if you have many points.

### *To add more points:*

To add another point, click the 'New point' button. Another point will be added to the point list box, and will be highlighted. Any observations in image windows will now be attributed to this point. To make further observations of a different point, make sure that the point number is selected in the point list box.

### *To delete an observation:*

Make the image in which you want to delete the observation the current image, select the point number in the point number list box, and press the 'delete' key. Note – the point number list box must be the active control (i.e. the last control clicked on) for the delete to be successful.

### *Intersections:*

By default, intersection calculations are automatically updated for each change in the image observations. If intersections want to be carried out manually, select the appropriate strategy from the intersection buttons. A manual intersection can then be carried out by clicking on 'Go'.

### *Current image:*

Use this list box to change the image number that is currently active (i.e. the image in which measurements are expected). Useful when you have many windows open and the one you want is buried.

### *Organising control data:*

Control data are listed in the order supplied in the input. Descriptors (very helpful) can be added to each control point by typing in the Descriptor column.

The first column in the table is the 'active' column. If ticked, the control point is active and, if it has a valid link to a point in the SfM project, will be used in the calculation of the transform.

Unselect any control points that you do not want to be included in the calculation.

The Link column indicates which point in the SfM project (i.e. in the Points SfM panel) represents the same feature as the control point defined by that row. The transform will be calculated to minimise the square of the distance (i.e. least squares) between the transformed SfM points and their linked, active control points.

Residuals are given when a transform has been calculated, and represent the 'mismatch' distances between the control points and the transformed SfM points, in the control coordinate system. In the table, the residual units are given as a thousandth of the units used for the control coordinates. For example, if control data are provided in metres, residuals are quoted in millimetres.

### *Transform and conversion:*

If sufficient SfM points and active control exist for a scale or 3d transform to be calculated the 'Calculate scale/transform' button will become active. Scale can be determined from one or more distance measurement or two 3d points, a transform requires three or more 3d points.

If the transform is successful, residuals will be calculated and a 3d plot given, showing the control points and the residuals

### **3) Rerunning *sfm\_georef*, and importing previous data**

To rerun *sfm\_georef* on the same data, importing the observations previously made, *obs*, and using the SfM project information originally read and subsequently stored in *R3\_images*, use the following syntax.

```
[trans, obs, ctrl_pts] = sfm_georef(R3_images, ctrl_pts, obs);
```

Note – *R3\_images* stores absolute paths to the image files. If you have changed the image path since the *R3\_image* variable was produced, then change Matlab's working directory to the image directory, then start *sfm\_georef*. If *Sfm\_georef* doesn't find the images on the original path, then it looks in the current working directory and will find the image files.

## **Feedback and bug reports**

All feedback and bug reports are welcome; please send to [m.james@lancaster.ac.uk](mailto:m.james@lancaster.ac.uk)  
I will endeavour to do my best, but I cannot guarantee answering all emails. Apologies in advance.

Mike James, Lancaster University 30/11/11