

SfM_Georef v.3.0 [Beta]

http://www.lancs.ac.uk/staff/jamesm/software/sfm_georef.htm

Introduction

Sfm_georef is a gui-based tool for scaling and orienting SfM point clouds to real-world coordinates, using observations made directly in the SfM image set. Sfm_georef does not carry out any SfM reconstruction, but uses the camera data output by other software to enable point clouds (as .ply files) to be scaled or geo-referenced. Output from the following SfM software or reconstruction pipelines are supported:

- Photoscan (<http://www.agisoft.ru/products>)
- Bundler Photogrammetry Package (<http://blog.neonascent.net/archives/bundler-photogrammetry-package/>)
- SFMToolbox (<http://www.visual-experiments.com/demos/sfmtoolkit/>)
- VisualSFM (<http://www.cs.washington.edu/homes/ccwu/vsfm/index.html>)
- OSM-Bundler or Python Photogrammetry Toolbox (<http://code.google.com/p/osm-bundler/>)

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 (full geo-referencing), the real 3D coordinates of three or more points (control points) that can be observed in two or more images, is necessary, or coordinates for the camera positions. 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 (as produced by CMVS) into one.

SfM_Georef v3.0 is written in Matlab (release 2013b, Win.7 64-bit) and has been compiled as a stand-alone executable. To run the executable, you will need to download and install Matlab runtime libraries (see instructions below). NOTE: This is a newer version than previous versions of sfm_georef, you will need to get the newer runtime libraries.

Installation (stand-alone executable)

- 1) Uncompress sfm_georef_3.0_beta.zip to a folder. The executable itself (sfm_georef_3.0.exe) needs no further installation.
- 2) Download and install the Matlab Compiler Runtime. For sfm_georef v3.0 the version required is 8.2 (64 bit) and can be downloaded from:

<http://www.mathworks.co.uk/products/compiler/mcr/>

The runtime version appropriate to the compiler version used is required. If you already have Matlab Compiler Runtimes installed, multiple versions can co-exist without difficulty.

Use of sfm_georef can be divided into three stages:

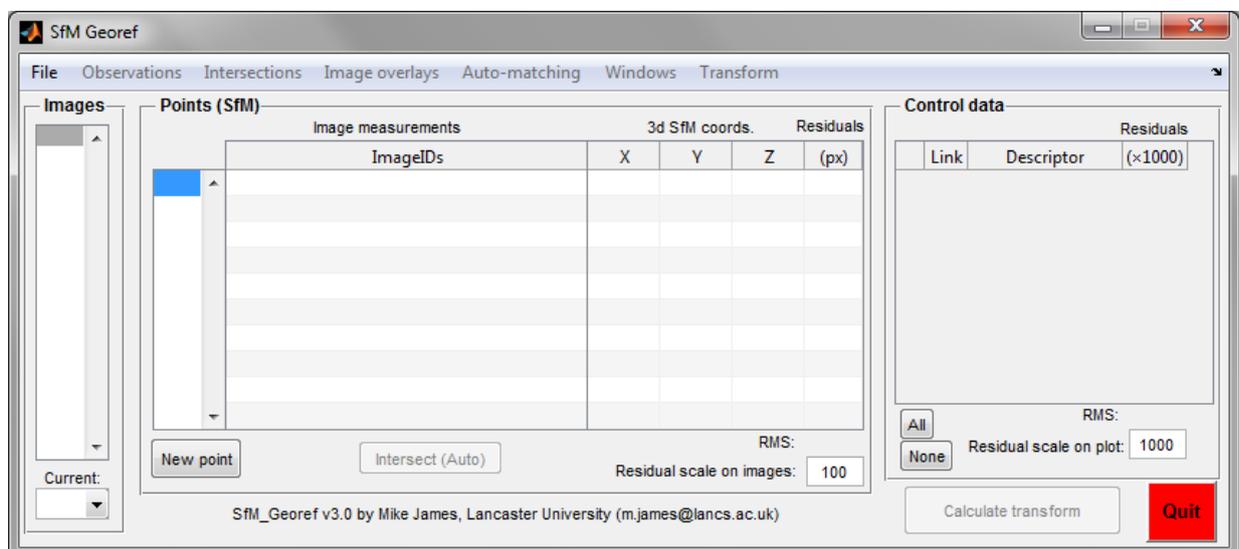
- 1) Reading the SfM project and importing control measurements
- 2) Identifying the control points in the image set, calculating the equivalent 3d positions in the SfM coordinate system and calculating the transform that relates the SfM and the control coordinate systems
- 3) Transforming and merging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

Getting started: Typical use of SfM_Georef

1) Start sfm_georef, import SfM project data and control measurements

Start sfm_georef by double clicking on the .exe file (Windows); the main control window will appear as well as a console window (black). The console window will display any error or other information, as you use sfm_georef.

The main SfM_Georef control window:



The control window is divided into a menu bar and three main panels:

Images – controls which images are visible and which image is ready to make measurements in

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

Additionally, there are buttons for:

Transform and conversion – Determines the transform between SfM and control coordinate systems.

Quit – Use this to exit sfm_georef. Warning – this does not yet prompt you to save any data... unsaved data *will* be lost

To geo-reference a new SfM reconstruction, the appropriate files need to be loaded using the File menu command. For:

SFMToolkit or Bundler Photogrammetry Package projects:

File → Import project folder; select the folder that contains your images. For Bundler Photogrammetry Package projects this will also have a subfolder 'bundler' with the file 'bundle.out'. For SFMToolkit projects, bundle.out will be in a 'bundler' subfolder. The import also reads the file list.txt in the image directory. If any these files are not present, the import will fail.

VisualSFM or Photoscan:

File → Import project file; select the .nvm or .psz file from your project

If all the appropriate data are found, then you will see no error messages, the main sfm_georef window will become populated with the image numbers found in the project, the first image will be displayed as well as a 3D plot of the relative camera positions in the project.

1) Image window, showing image 1

Image windows are where observations (mouse clicks) in the images can be made. Use the

standard Matlab buttons  to navigate around and zoom in to the image – click the button once to activate a navigation tool, click again to deactivate. [Note: Use of the other buttons and menus is not directly supported and may produce undesired behaviour]. 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 main menu (Windows → 3D SfM space). The plot gives the 3D positions of cameras in the SfM project coordinate system. Camera positions are marked as red dots and any intersected point locations are given as blue circles. Use the standard Matlab buttons to navigate around the plot.

Importing control data:

Control data can be imported via the File → Import Control menu item. Control data can be supplied to sfm_georef in different formats, but you can start with a text file containing the data in three tab or space separated columns, described by a header line. For example, for 3 control points with (optional) descriptors:

x	y	z	descriptor
1.122	2.335	0.363	target_1
0.204	34.24	8.929	target_2
9.324	5.252	3.443	target_4

Note: Descriptors cannot contain characters that could be determined as delimiters (e.g. spaces or tabs – ‘target_1’ is OK, ‘target 1’ would produce an error).

If control distances have been measured rather than point coordinates, these are provided with the header ‘distances’

```
distances      descriptor
6.993   tar_1_to_tar_2
3.442   tar_1_to_tar_3
9.322   tar_2_to_tar_3
```

If camera positions are being supplied, then you need the same number of lines as there are cameras (i.e. a position for each camera). The order of the lines must match the order of the cameras read in sfm_georef. The syntax is:

```
cam_x   cam_y   cam_z   descriptor
1.122   2.335   0.363   photo_1
0.204   34.24   8.929   photo_2
9.324   5.252   3.443   photo_3..
```

Control data can also be directly imported from previously saved sfm_georef projects by importing the project file via the File → Import Control menu item. In this case, only the control information is imported from the read project, all other data are neglected.

Saving your sfm_georef project

All measurements, transformations, control and the image set can be saved as a sfm_georef project file via the File → Save SfM_Georef project as menu item. The file produced is a binary Matlab data file, that can be read by Matlab or by sfm_georef. Note that images themselves are not stored, but their locations are recorded as full paths. If images or SfM folders are moved, the images will have to be relinked. Once the current project is saved, File → Save SfM_Georef project can be used to update the project file.

Loading a pre-existing sfm_georef project

A previous project can be loaded via the File → Import Control menu item

2) Identifying points in the SfM image set and making point observations

To scale or geo-reference the SfM project, the control points need to be identified in the images so their coordinates in the SfM coordinate system can be determined. (Note this is not required if you provide camera positions as control data).

- 1) Identify 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. Usually, residual values are around 1 pixel or smaller. Significantly larger residuals indicate that either the image has not been incorporated well in the SfM project (i.e. the imported camera model or the camera orientations are inaccurate) or – more usually – that one of the image measurements is actually of the wrong feature.

The residuals column in the table gives the RMS residual value for all points.

You can show the point IDs on the image windows from the main menu (Image overlays → Point IDs – 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 Intersections menu. For either Intersections → Active point or Intersections → All points, intersections are only carried out when the Intersect button below the Image measurements table is clicked.

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 or edited 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.

3) Transform and conversion

The Control data table comprises four columns:

Tick box – indicates whether or not this control measurement is to be used in calculations of scale or geo-reference transform

Link – gives the ID number of the SfM point that represents this control point. If using control distances, each distance measurement is represented by two lines in the Control data table, giving the IDs of the two points between which the distance measurement has been made

Descriptor – a text description of the control point.

Residuals – gives the mismatch between the control data and the transformed SfM points, once a transform has been determined.

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, full geo-referencing 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. The File → Export menu item will become active allowing conversion of:

SfM points – The transformed coordinates of the points identified and intersected in the SfM project are exported to a text file

SfM project – The transform can be applied to a bundler file, with the output written as a new Bundler-format (.out) file. Select the Bundler SfM file to read, then a new filename for the output. NOTE: The read Bundler file should be the same one used for the sfm_georef project – only the SIFT points are extracted and are then combined with the camera data in the current sfm_georef project. The SfM project transform is not implemented for VisualSFM projects.

Ply files – Points in .ply files can be imported, transformed and then written back to a .ply file. If multiple .ply files are selected then they are merged and the output written as one file. This feature enables the dense point clouds output by CMVS/PMVS to be transformed to the geo-referenced coordinate system. Note only the ASCII ply files written by Bundler or PMVS are explicitly supported.

Auto-matching

From v.3.0, `sfm_georef` offers an auto-matching facility to aid collection of control (or other) point observations. Auto-matching searches other images for a point indicated in one image.

Auto-matching is enabled by selecting one of the following options in the Auto-matching menu:

Open images only – only other currently open images are searched

Images with existing observations – any image with an existing observation of the active point are searched, and their observations refined.

All potential images – SfM-georef calculates which other images could view the point and searches them. Note, this may involve loading many images (slow), and occlusions are not accounted for.

The auto-matching process uses a square region of pixels located around a point observation in a base image. These pixels are reprojected onto an oriented 3D patch in image space to form the texture to match in other images. 3D patch normals are initially determined by the normal of the best-fit plane to the local sparse 3D points. The size of the image patch used in the base image can be set by Auto-matching → Set match patch size.

Target searching.

In applications where control points are natural features, auto-matching can be used to accelerate and improve the precision of point identification in images. However, if symmetric and identical control targets have been deployed, auto-matching can be used in a fully automated target search. First, identify a minimum number of targets to derive a transform linking the SfM and Control coordinate systems (e.g. three). For example, enable auto-matching by selecting Auto-matching → All potential images. In one image with three targets, make observations of each and calculate the transform. Make sure that the patch size is suitable for the target size (i.e. sufficiently large to capture the target texture, but not too large so that variable background texture will also be included). Define a typical target view by Auto-matching → Target-based matching → Set target template. This will define the pixels which represent a template target for matching throughout the project. To initialise the full search, use Auto-matching → Target-based matching → Auto target search.

Feedback and bug reports

Feedback and bug reports are welcome; please send to `m.james__at__lancaster.ac.uk` (removing the underscores and using the 'at' symbol).

I will endeavour to do my best, but I cannot guarantee answering all emails. Apologies in advance.

If you use `sfm_georef`, please cite the following work:

James, M. R. and Robson, S. (2012) Automated image-based 3D surface reconstruction for the geosciences: Accuracy and application, *J. Geophys. Res.*, 117, F03017, doi:10.1029/2011JF002289.

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