

Rectification, MissStereo: user's guide

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1 Introduction

This document is a short user's guide to software programs `Rectification` and `MissStereo` that compute a disparity map with high accuracy from a stereo image pair. `MissStereo` is the complete pipeline, adding only a final step of disparity computation while `Rectification` puts the image pair in rectified epipolar geometry.

Remark: The name *MissStereo* comes from the origin of the software in the framework of the workshop MISS (Mathématiques pour l'Imagerie Stéréoscopique Spatiale) codirected by CNES (the French national space agency) and Ecole Normale Supérieure of Cachan.

2 Installation

2.1 Requirements

Dependencies of the software are the following:

- `libpng` and `zlib` for reading/writing images in PNG format (<http://libpng.sourceforge.net/index.html> and <http://www.zlib.net/>)
- `libtiff` for reading/writing images in TIFF format (<http://www.remotesensing.org/libtiff/>)
- `CMake` for building the software (<http://www.cmake.org/>)
- C++ compiler (GNU `g++`)

Most linux distributions propose easy to install packages for these (if not already installed by default). If you need to install them, be sure to use the developer's versions (package with extension `-dev`), so that you get header files and not only the libraries.

2.2 Build

The build process has three steps:

1. Decompress the archive.
2. Launch `cmake` to generate `Makefile`.
3. Launch `make` pour compilation and link.

To decompress, you can input in a shell the command

```
tar xzf MissStereo.tgz
```

Create a folder of your choice where to install the software, for example `build`, and go to that folder:

```
cd MissStereo
mkdir build
cd build
```

Launch `cmake` with argument the base folder containing the source codes (there is a file `CMakeLists.txt`) in that folder):

```
cmake ../src
```

This checks the availability of the dependencies and outputs `Makefile` in case of success. To build optimized version of programs, the variable `CMAKE_BUILD_TYPE` must be modified using

```
cmake -D CMAKE_BUILD_TYPE:string=Release ../src
```

or with utility `ccmake`.

To build, simply type

```
make
```

You can also use the option `'-j2'` to launch two parallel compilations (or more if you have additional cores). The executable files are then in folder `bin` and libraries in `lib`. For example, you get `lib/libNumerics.a` and `bin/rectify`.

By default, static libraries are produced. If you prefer dynamic ones, you can set to `ON` the variable `BUILD_SHARED_LIBS`, either by adding the option when launching `cmake`

```
cmake -D BUILD_SHARED_LIBS:BOOL=ON ../src
```

or by using the utility `ccmake` (notice the double c).

3 Usage

3.1 Installation

The software is composed of independent executable modules that need to be launched in a certain order. For this purpose a script, `MissStereo.sh`, is provided. You can launch it from whichever folder, or for example copy it in your folder `${HOME}/bin`. Make sure it has the executable bit set:

```
chmod +x MissStereo.sh
```

and you can launch it as follows:

```
MissStereo.sh [arguments]
```

You need to inform the script of where to find the executable files it needs. You can do it with the environment variable `MISS_STEREO_PATH`. To initialize it from a Bourne shell, use

```
export MISS_STEREO_PATH=${HOME}/MissStereo/build/bin
```

You need to do that from each shell session from which you call `MissStereo.sh`. To make it automatic, you can add this line to the `.bashrc` file in your home folder.

Another possibility is to include said path to your default paths (variable `PATH`), as follows:

```
export PATH=${HOME}/MissStereo/build/bin:${PATH}
```

However, notice that doing so “pollutes” your executable namespace. In particular, one of the programs is named `size` but it has nothing to do with its homonym from `bin-utils`. With a line as above, you call the program of `MissStereo` by default, to use the one from `bin-utils` you have to input its full path.

This software produces intermediate images and files that are useful but are not erased by the script upon completion. To avoid mixing results from different experiments, it is advised to create a new folder for each image pair and to launch the script from such a folder.

For the script `Rectify.sh` the procedure is quite similar.

3.2 Program workflow

The workflow is illustrated in Figure 1. The input is `im1.png` and `im2.png`. The same images in TIFF `float` format, thus without quantization, are produced by `MissStereo.sh`.

Additional step specific to `Rectify.sh` is displayed in Figure 2. This is for better visualisation of the results.

The specific part computing disparity maps of `MissStereo.sh` is displayed in Figure 3.

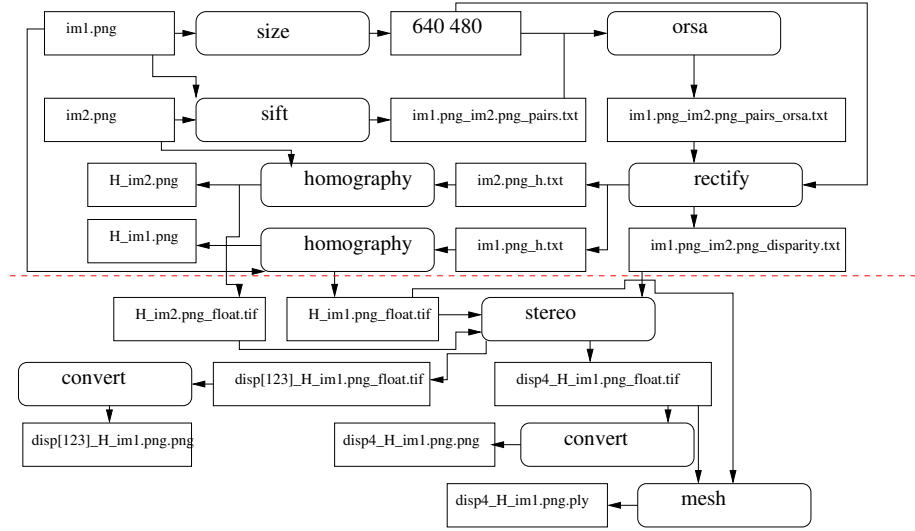


Figure 1: Workflow of `Rectify.sh`. The part below the dashed line is specific to `MissStereo.sh`.

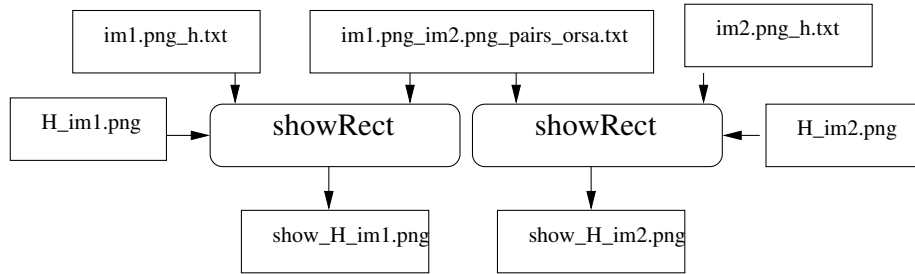


Figure 2: Workflow of end of `Rectify.sh`.

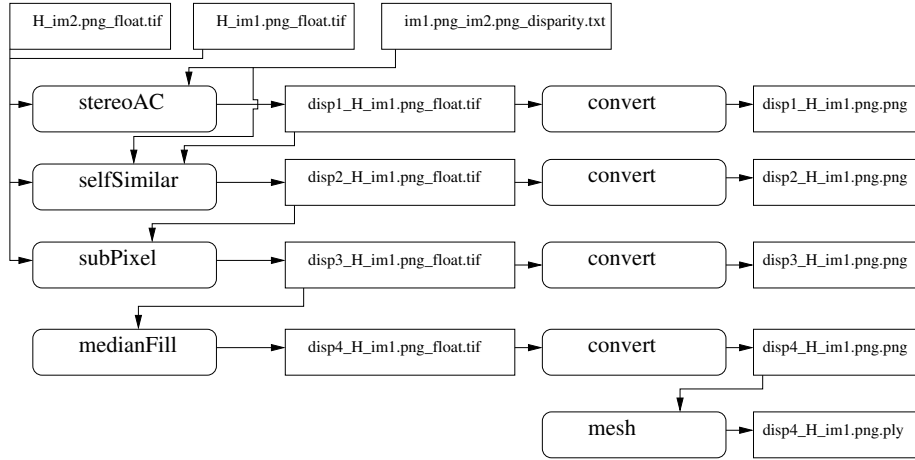


Figure 3: Workflow of MissStereo.sh.

Files ending in `_float.tif` are TIFF images coded in `float` (warning: few software programs are able to read them). Here is the description of the different files:

- `im[12].png`: input image pair. They must be in PNG format, color or gray level. However color information is not used during the computation.
- `im1.png_img2.png_pairs.txt`: text file with each line of the form

$$x1 \ y1 \ x2 \ y2$$

indicating correspondences between found SIFT points. y -axis is oriented downward starting from the top of the image.

- `im1.png_img2.png_pairs_orca.txt`: same as the previous one but only with inliers found by ORSA algorithm (a RANSAC variant).
- `im1.png_img2.png_disparity.txt`: two whole numbers of minimal and maximal disparity in correspondences. This limits the search area in correlation computation.
- `H_im[12].png`: rectified image files, 8 bits per sample. These are the final images of Rectify.sh. They are not used in the following but are easier to visualize than the next ones:
- `H_im[12].png_float.tif`: rectified images in TIFF `float`. These are used in algorithm MARC2 (program `stereo`).
- `show_H_im[12].png`: same images as `H_im[12].png` but with superimposed data visualization. Some corresponding horizontal lines are displayed and SIFT points selected by ORSA algorithm are shown.

- `disp1_H_im1.png_float.tif`: disparity map in integer value and mask.
- `disp2_H_im1.png_float.tif`: the same with self-similar pixels masked.
- `disp3_H_im1.png_float.tif`: subpixel disparity map and mask.
- `disp4_H_im1.png_float.tif`: subpixel disparity map densified by median filter and mask.
- `disp1_H_im1.png.png`: color PNG 8 bit version of `disp1_H_im1.png_float.tif` with cyan color for invalid pixels.
- `disp2_H_im1.png.png`: color PNG 8 bit version of `disp2_H_im1.png_float.tif` with cyan color for invalid pixels.
- `disp3_H_im1.png.png`: color PNG 8 bit version of `disp3_H_im1.png_float.tif` with cyan color for invalid pixels.
- `disp4_H_im1.png.png`: color PNG 8 bit version of `disp4_H_im1.png_float.tif` with cyan color for invalid pixels.
- `disp4_H_im1.png.ply`: PLY binary file representing the 3D point cloud.

The mask is encoded in the images themselves: pixels outside the mask of trust take the value “Not a Number” (NaN), a code authorized by the IEEE 754 norm concerned with floating point real numbers. In a C or C++ code, this can be detected in the following manner:

```
if(val != val) printf("Not a Number");
if(val == val) printf("A number");
```

Notice that the second test is also true for values $\pm\infty$, also legal in IEEE norm. However these values are not used by **stereo**.

The 3D points file, with format PLY (Stanford Triangle Format), can be visualized with open source softwares MeshLab (<http://meshlab.sourceforge.net/>) or ParaView (<http://paraview.org/>) for example. Notice that without calibration data, the coefficient of proportionality between height and inverse of disparity is unknown. Therefore, the z axis has a different scale than x and y axes.

3.3 Example

```
$ mkdir exp_cporta
$ cd exp_cporta
$ ../scripts/Rectify.sh ../data/cporta/cporta[01].png
sift:: 1st image: 138 keypoints
sift:: 2nd image: 166 keypoints
sift:: matches: 79
seed: 1282568730
Remove 11/79 duplicate matches
```

```

Optimized stochastic mode (ORSA).
nfa=-53.9227 size=66 (niter=1)
nfa=-82.9632 size=58 (niter=1)
nfa=-84.5837 size=67 (niter=2)
nfa=-108.783 size=59 (niter=2)
nfa=-129.833 size=67 (niter=3)
nfa=-134.921 size=66 (niter=17)
best matching found: 66 points log(nfa)=-134.921 (500 iterations)
F= [ -2.21475e-09 -7.68203e-08 4.56218e-05;
      3.91179e-08 4.06368e-08 0.00108488;
      -5.29503e-05 -0.00108256 0.00754136 ]
Geometric error threshold: 0.563054
LM iterations: 7 f=462.259
Initial rectification error: 3.25344 pix
Final rectification error: 0.0981728 pix
Disparity: -15 31
$

```

Remark: min and max disparity can vary from one execution to the next due to the stochastic nature of ORSA.

4 Troubleshooting

Please send an email to the maintainer Pascal Monasse (monasse@imagine.enpc.fr) describing your problem. If it happens when launching the software on certain images, please join the log file (by default `${HOME}/.missStereo.log` unless you have modified this in the script `MissStereo.sh`). It is likely you would also need to send your images for problem analysis.

List of files

MissStereo:

data doc scripts src

MissStereo/data:

cporta stmichel

MissStereo/data/cporta:

cporta0.png cporta1.png

MissStereo/data/stmichel:

u1_uchar.png u2_uchar.png

MissStereo/doc:

manuel.pdf userguide.pdf

MissStereo/scripts:

MissStereo.sh Rectify.sh

MissStereo/src:

CMakeLists.txt	libLWImage	mesh	size
convert	libMatch	orsa	stereoAC
dataStereo	libNumerics	rectify	subPixel
density	libStereo	selfSimilar	
homography	libTransform	showRect	
libIO	medianFill	sift	

MissStereo/src/convert:

CMakeLists.txt convert.cpp

MissStereo/src/dataStereo:

CMakeLists.txt pca_basis.dat prolate.dat

MissStereo/src/density:

CMakeLists.txt density.cpp

MissStereo/src/homography:

CMakeLists.txt homography.cpp

MissStereo/src/libIO:

CMakeLists.txt	draw.h	io_png.h	io_tiff.h
draw.c	io_png.c	io_tiff.c	nan.h

MissStereo/src/libLWImage:

CMakeLists.txt LWImage.cpp LWImage.h


```

MissStereo/src/libMatch:
CMakeLists.txt  match.cpp  match.h

MissStereo/src/libNumerics:
CMakeLists.txt  homography.h  numerics.cpp  rodrigues.h
computeH.cpp    matrix.cpp    numerics.h    vector.cpp
homography.cpp  matrix.h      rodrigues.cpp

MissStereo/src/libStereo:
CMakeLists.txt  patch.cpp  patch.h

MissStereo/src/libTransform:
CMakeLists.txt  map_image.cpp  spline.h
gauss_convol.cpp  map_image.h    TransformSize.cpp
gauss_convol.h    spline.cpp     TransformSize.h

MissStereo/src/medianFill:
CMakeLists.txt  median_disparity.cpp
main.cpp        median_disparity.h

MissStereo/src/mesh:
CMakeLists.txt  mesh.cpp

MissStereo/src/orsa:
CMakeLists.txt  main.cpp  orsa.cpp  orsa.h

MissStereo/src/rectify:
CMakeLists.txt  rectify.cpp

MissStereo/src/selfSimilar:
CMakeLists.txt  main.cpp  selfSimilar.cpp  selfSimilar.h

MissStereo/src/showRect:
CMakeLists.txt  showRect.cpp

MissStereo/src/sift:
CMakeLists.txt  domain.cpp  library.cpp  splines.cpp
demo_lib_sift.cpp  domain.h    library.h    splines.h
demo_lib_sift.h    filter.cpp  numerics.cpp
demo_sift.cpp      filter.h    numerics.h

MissStereo/src/size:
CMakeLists.txt  size.cpp

MissStereo/src/stereoAC:

```

CMakeLists.txt main.cpp stereoAC.cpp stereoAC.h

MissStereo/src/subPixel:

CMakeLists.txt fft.h subpixel.cpp
fft.c main.cpp subpixel.h

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