

*i.fusion.hpf, implementation of the High Pass Filter
Additive (HPFA) Image Fusion Technique
Python script add-on for GRASS-GIS*

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`i.fusion.hpf` is a GRASS-GIS module to combine high-resolution panchromatic data with lower resolution multispectral data, resulting in an output with both excellent detail and a realistic representation of original multispectral scene colors.

The process involves a convolution using a High Pass Filter (HPF) on the high resolution data, then combining this with the lower resolution multispectral data.

Optionally, a linear histogram matching technique is performed in a way that matches the resulting Pan-Sharpened image to their statistical mean and standard deviation of the original multi-spectral image.

Source: [Gangkofner et al. \(2008\)](#)

Thanks to Moritz Lennert on implementing the linear histogram matching technique

Algorithm description

1. Computing ratio of low (Multi-Spectral, hereafter noted as MSx) to high (Panchromatic) resolutions
2. High Pass Filtering the Panchromatic Image
3. Resampling MSx image to the higher resolution
4. Adding weighted High-Pass-Filtered image to the upsampled MSx image
5. Optionally, matching histogram of Pan-sharpened image to the one of the original MSx image

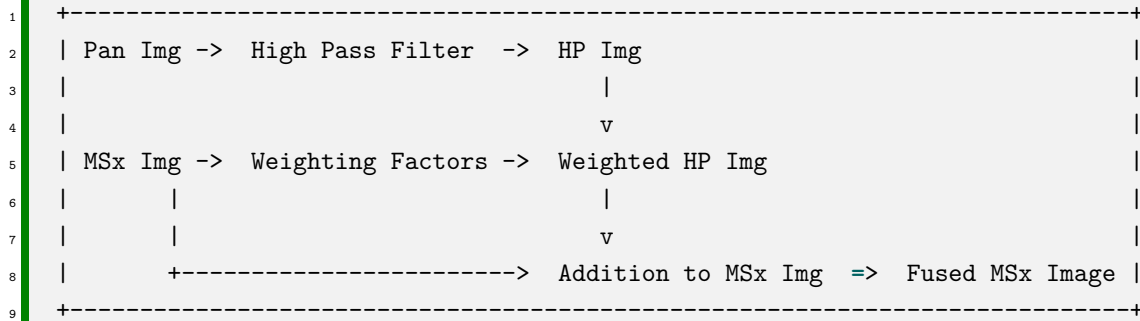
From the original paper

Step 1: HP Filtering of the High-resolution Image to Extract the Structural Detail

Step 2: Adding the HP Filtered Image to Each Band of the Multispectral Image Using a Standard Deviation-based Injection Model

Step 3: Linear Histogram Match to Adapt SD and Mean of the Merged Image Bands to Those of the Original MS Image Bands

Figure 1:



Installation

Requirements

see [GRASS Addons SVN repository](#), [README file](#), [Installation - Code Compilation](#)

Steps

Making the script `i.fusion.hpf` available from within any GRASS-GIS ver. 7.x session, may be done via the following steps:

1. launch a GRASS-GIS' ver. 7.x session
2. navigate into the script's source directory
3. execute `make MODULE_TOPDIR=$GISBASE`

Usage

After installation, from within a GRASS-GIS session, see help details via `i.fusion.hpf --help` — also provided here:

```

1  Description:
2  Fusing high resolution Panchromatic and low resolution \
   Multi-Spectral data based on the High-Pass Filter Addition \
   technique (Gangkofner, 2008)
3
4  Keywords:
5  imagery, fusion, HPF, HPFA
6

```

```

7 Usage:
8 i.fusion.hpf [-l2] pan=string msx=string[,string,...]
9   outputprefix=string [ratio=value] [center=string] [center2=\
   string]
10   [modulation=string] [modulation2=string] [--help] [--verbose]
11   [--quiet]
12
13 Flags:
14 -l Linearly match histogram of Pan-sharpened output to \
   Multi-Spectral input
15 -2 2-Pass Processing (recommended) for large resolution ratio\
   (>=5.5)
16 --h Print usage summary
17 --v Verbose module output
18 --q Quiet module output
19
20 Parameters:
21     pan    High resolution panchromatic image
22     msx    Low resolution multi-spectral image(s)
23 outputprefix Prefix for the Pan-Sharpended Multi-Spectral \
   image(s)
24             default: hpf
25     ratio  Custom ratio overriding standard calculation
26             options: 1.0-10.0
27     center Center cell value of the High-Pass-Filter
28             options: low,mid,high
29             default: low
30     center2 Center cell value for the second \
   High-Pass-Filter (use -2 flag)
31             options: low,mid,high
32             default: low
33     modulation Level of modulating factor weighting the HPF \
   image to determine crispness
34             options: min,mid,max
35             default: mid
36     modulation2 Level of modulating factor weighting the second \
   HPF image to determine crispness (use -2 flag)
37             options: min,mid,max
38             default: mid
39             min: Minimum: 0.25
40             mid: Mid: 0.35
41             max: Maximum: 0.5

```

Remarks

- requires (currently) manual color rebalancing (e.g. by using `i.colors.enhance`)
- easy to use, i.e.:

- for one band `i.fusion.hpf pan=Panchromatic msx=MS_BandName`
- for multiple bands `i.fusion.hpf pan=Panchromatic msx=Red,Green,Blue,NIR`

- easy to test various parameters that define the High-Pass filter's kernel size and center value
- should work with any kind of imagery (think of bitness)

Examples

Landsat

```
1 i.fusion.hpf -l -c --o pan=lsat7_2000_80 msx=lsat7_2000_10,\
  lsat7_2000_20,lsat7_2000_30 center=high modulation=max
```

The above command calls `i.fusion.hpf` to pan-sharpen the multispectral images `lsat7_2000_10`, `lsat7_2000_20`, `lsat7_2000_30` based on the panchromatic `lsat7_2000_80` with the parameters

- `center=high` to increase the impact of the high pass filter
- `modulation=max` to increase the crispness of the output images
- `-l` and `-c` to respectively match the histogram and color table of the sharpened output images to their corresponding original multi-spectral
- `--o` to overwrite raster maps with the same name as the to-be-produced output, which are essentially left-overs from previous sharpening attempts

IKONOS

QuickBird2

WorldView(2, 3)

To add

GeoEye

Implementation notes

- First commit on Sat Oct 25 12:26:54 2014 +0300
- Working state reached on Tue Nov 4 09:28:25 2014 +0200

some samples already published in [GRASS-Wiki](#), [QuickBird](#), [HPFA based sharpening](#)

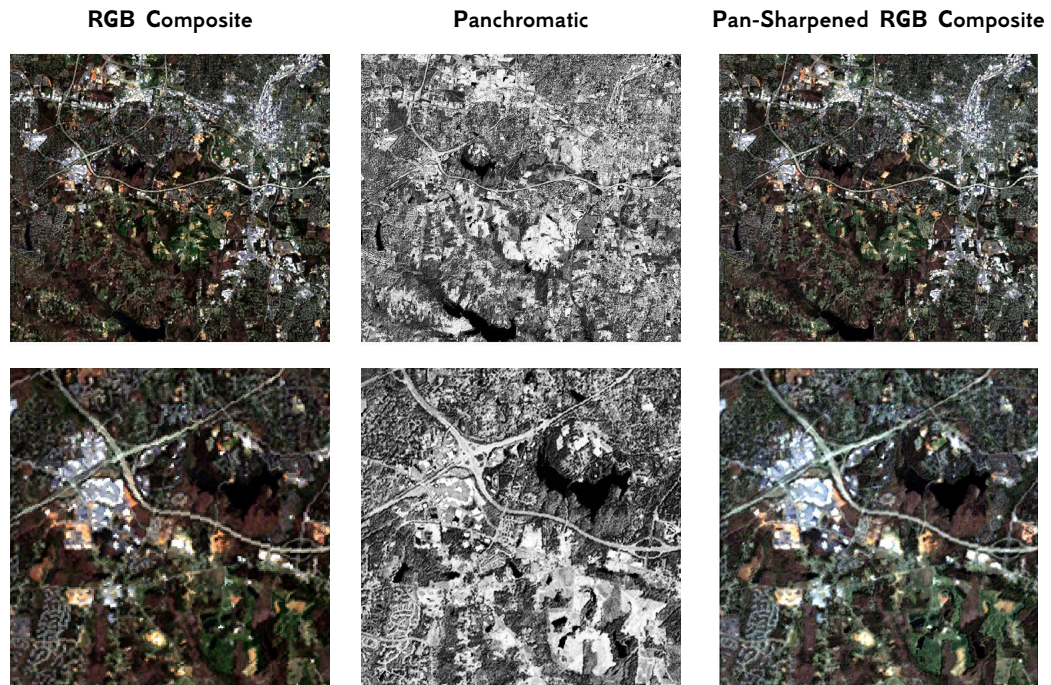


Figure 1: Fragment from a
Landsat7 ETM acquisition

(p016r035_7p20000331_z17_nc_spm_wake.tif

over New Delhi, India (available at

[62166-6181-6-1-5 website](#)

for details)

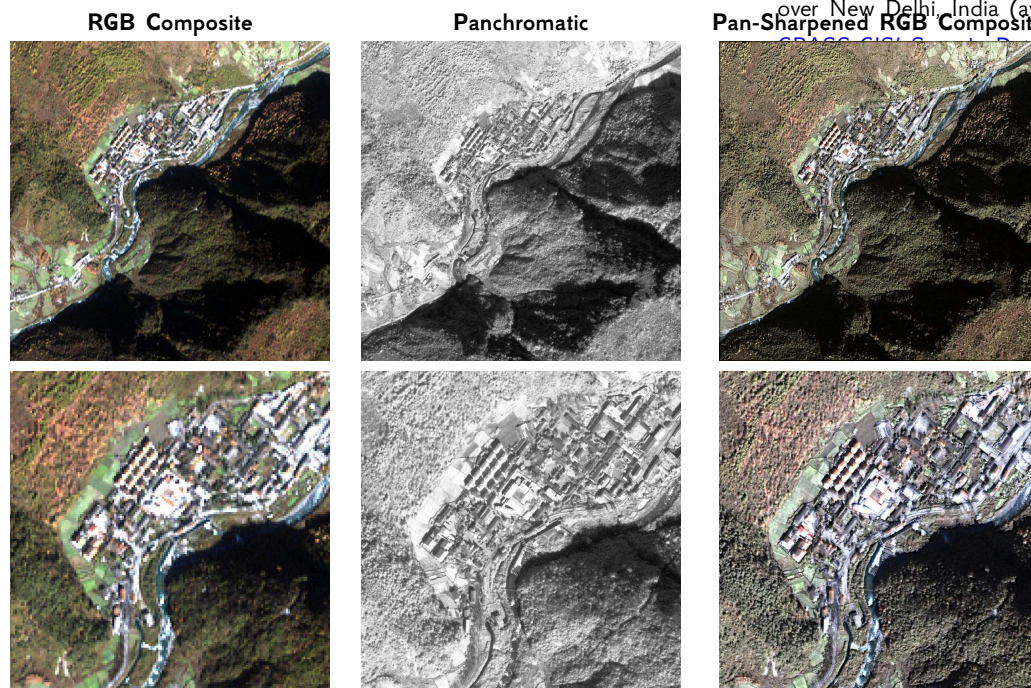


Figure 2: Fragment from an
IKONOS acquisition (po_XXXXXX)
over Sichuan, China (available ...)

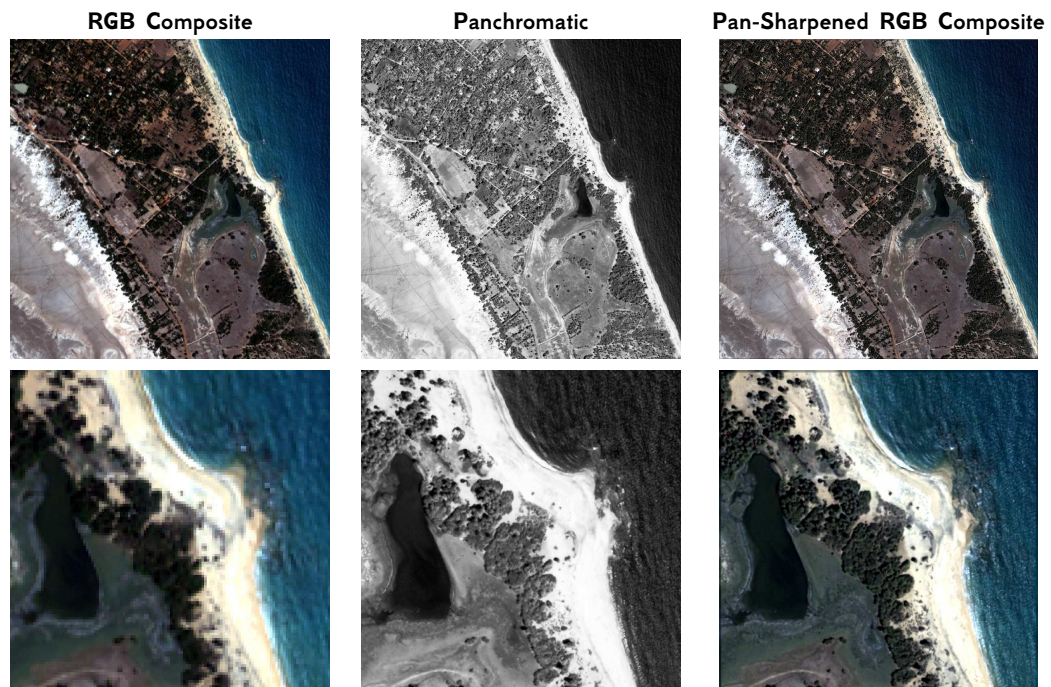


Figure 3: Fragment from a Quick-Bird2 acquisition (04APR05050541) near Kokilai Lagoon, Sri Lanka

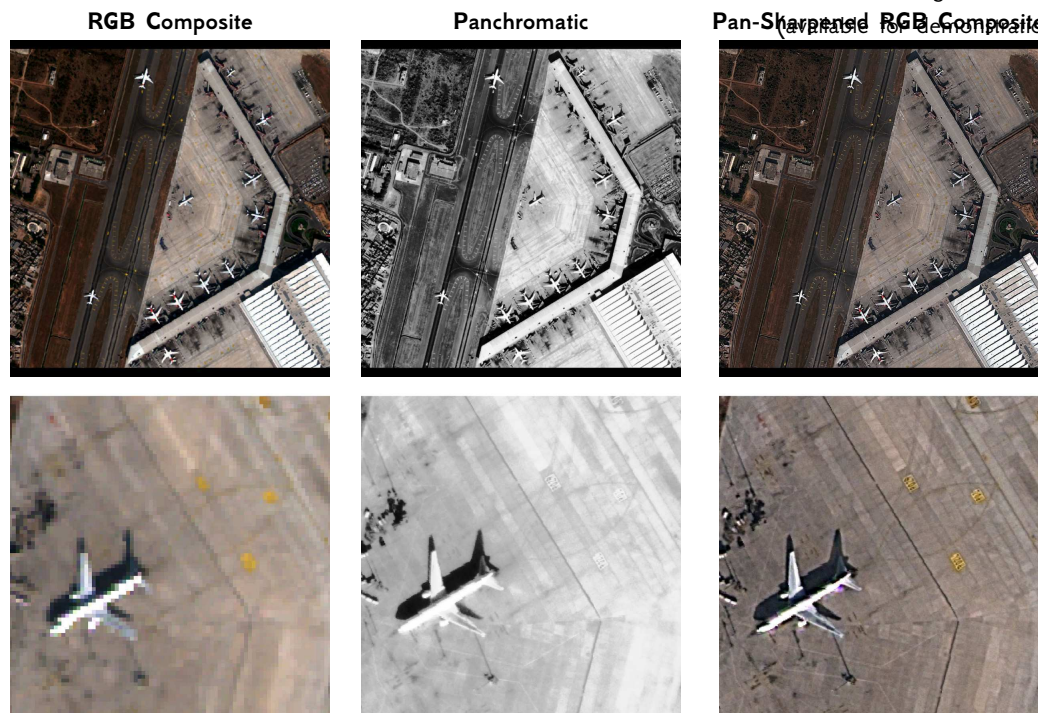


Figure 4: Fragment from a Geo-Eye acquisition (12DEC02053124) over New Delhi, India (available for demonstration purposes, see sections §?? and §?? for license details)

Remarks

- currently requires manual color rebalancing (e.g. by using `i.landsat.rgb`)
- easy to use, i.e.:
 - for one band `i.fusion.hpf pan=Panchromatic msx=${Band}`
 - for multiple bands `i.fusion.hpf pan=Panchromatic msx=Red,Green,Blue,NIR`
- easy to test various parameters that define the High-Pass filter's *kernel size* and *center value*
- should work with any kind of imagery (think of bitness)

To Do

- Go through <http://trac.osgeo.org/grass/wiki/Submitting/Python>
- Use `format()` instead of the `%` operator (?)
 - Sources:
 - * http://chimera.labs.oreilly.com/books/1230000000393/ch02.html#_solution_33
 - * <https://docs.python.org/3/library/string.html#formatspec>
- Proper command history tracking. Not all "r" modules do it... ?
- Add timestamps (`r.timestamp`)
- Deduplicate code where applicable
- Make `-v` messages shorter, yet more informative (i.e. report center cell value)

Questions

- Will it compile in other systems?
- Checking options to integrate in `i.pansharpen`. Think of FFM methods vs. Others?
- Utilise the existing histogram matching code in `i.pansharpen`? It performs histogram matching using the Standard Deviation and Mean of the reference image.

See discussion(s) in mailing list and trac.

References

Gangkofner, U. G., Pradhan, P. S., and Holcomb, D. W. (2008). Optimizing the high-pass filter addition technique for image fusion. *PHOTOGRAMMETRIC ENGINEERING & REMOTE SENSING*, 74(9):1107–1118. ([document](#))

- **To Add:** replication of ERDAS Imagine's parameters.

Ευχαριστώ

- Nikos Ves
- Ranjith, https://class.coursera.org/interactivepython-005/forum/profile?user_id=9361576
- Anonymous on coursera's discussion forums
- Pietro Zambelli
- StackExchange contributors
 - <http://stackoverflow.com/a/1140966/1172302>
 - <http://stackoverflow.com/a/275025/1172302>
- Yann Chemin
- Participants in grass-user, grass-dev mailing lists

Code

Listing 1: i.fusion.hpf.py

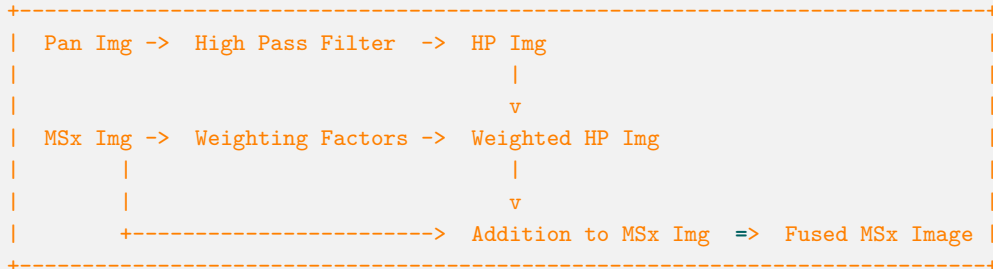
```

1  #!/usr/bin/env python
2  # -*- coding: utf-8 -*-
3
4  """
5  MODULE:      i.fusion.hpf
6
7  AUTHOR(S):   Nikos Alexandris <nik@nikosalexandris.net>
8               Converted from a bash shell script | Trikala, Nov. 2014
9
10
11  PURPOSE:     HPF Resolution Merge -- Algorithm Replication in GRASS GIS
12
13               Module to combine high-resolution panchromatic data with
14               lower resolution multispectral data, resulting in an output
15               with both excellent detail and a realistic representation of
16               original multispectral scene colors.
17
18               The process involves a convolution using a High Pass Filter
19               (HPF) on the high resolution data, then combining this with
20               the lower resolution multispectral data.
21
22               Optionally, a linear histogram matching technique is performed
23               in a way that matches the resulting Pan-Sharpended image to
24               them statistical mean and standard deviation of the original
25               multi-spectral image. Credits for how to implement this
26               technique go to GRASS-GIS developer Moritz Lennert.
27
28

```


Source: "Optimizing the High-Pass Filter Addition Technique for
Image Fusion", Ute G. Gangkofner, Pushkar S. Pradhan,
and Derrold W. Holcomb (2008)

Figure 1:



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License (>=v2). Read the file COPYING that comes with GRASS
for details.

"""

```

#!/Module
#% description: Fusing high resolution Panchromatic and low resolution Multi-Spectral data based on\
the High-Pass Filter Addition technique (Gangkofner, 2008)
#% keywords: imagery, fusion, HPF, HPFA
#%End

#%flag
#% key: l
#% description: Linearly match histogram of Pan-sharpened output to Multi-Spectral input
#%end

#%flag
#% key: 2
#% description: 2-Pass Processing (recommended) for large resolution ratio (>=5.5)
#%end

#%flag
#% key: c
#% description: Match color table of Pan-Sharpended output to Multi-Spectral input
#%end

#%option G_OPT_R_INPUT
#% key: pan
#% key_desc: filename
#% description: High resolution Panchromatic image
#% required : yes
#%end

```

```

79  %%option G_OPT_R_INPUTS
80  %% key: msx
81  %% key_desc: filename(s)
82  %% description: Low resolution Multi-Spectral image(s)
83  %% required: yes
84  %% multiple: yes
85  %%end
86
87  %%option G_OPT_R_BASENAME_OUTPUT
88  %% key: outputsuffix
89  %% key_desc: suffix string
90  %% type: string
91  %% label: Suffix for output image(s)
92  %% description: Names of Pan-Sharpned image(s) will end with this suffix
93  %% required: yes
94  %% answer: hpf
95  %%end
96
97  %%option
98  %% key: ratio
99  %% key_desc: rational number
100 %% type: double
101 %% label: Custom ratio
102 %% description: Custom ratio overriding standard calculation
103 %% options: 1.0-10.0
104 %% guisection: High Pass Filter
105 %% required: no
106 %%end
107
108 %%option
109 %% key: center
110 %% key_desc: string
111 %% type: string
112 %% label: Center cell value
113 %% description: Center cell value of the High-Pass-Filter
114 %% descriptions: Level of center value (low, mid, high)
115 %% options: low,mid,high
116 %% required: no
117 %% answer: low
118 %% guisection: High Pass Filter
119 %% multiple : no
120 %%end
121
122 %%option
123 %% key: center2
124 %% key_desc: string
125 %% type: string
126 %% label: 2nd Pass center cell value
127 %% description: Center cell value for the second High-Pass-Filter (use -2 flag)
128 %% descriptions: Level of center value for second pass
129 %% options: low,mid,high

```

```
130  %% required: no
131  %% answer: low
132  %% guisection: High Pass Filter
133  %% multiple : no
134  %%end
135
136  %%option
137  %% key: modulation
138  %% key_desc: string
139  %% type: string
140  %% label: Modulation level
141  %% description: Modulation level weighting the HPF image determining crispness
142  %% descriptions: Levels of modulating factors
143  %% options: min,mid,max
144  %% required: no
145  %% answer: mid
146  %% guisection: Crispness
147  %% multiple : no
148  %%end
149
150  %%option
151  %% key: modulation2
152  %% key_desc: string
153  %% type: string
154  %% label: 2nd Pass modulation level (use -2 flag)
155  %% description: Modulation level weighting the second HPF image determining crispness (use -2 flag)
156  %% descriptions: mid;Mid: 0.35;min;Minimum: 0.25;max;Maximum: 0.5;
157  %% options: min,mid,max
158  %% required: no
159  %% answer: mid
160  %% guisection: Crispness
161  %% multiple : no
162  %%end
163
164
165  # required librairies -----
166
167  import os
168  import sys
169  sys.path.insert(1, os.path.join(os.path.dirname(sys.path[0]),
170                                  'etc', 'i.fusion.hpfa'))
171  import atexit
172
173  import grass.script as grass
174  from grass.pygrass.modules.shortcuts import general as g
175  from grass.pygrass.raster.abstract import Info
176
177  from high_pass_filter import High_Pass_Filter
178
179  if "GISBASE" not in os.environ:
180      print "You must be in GRASS GIS to run this program."
```

```

181     sys.exit(1)
182
183
184 # globals -----
185 ratio = float()
186 tmp = ''
187 tmp_hpf_matrix = ''
188 modulator = float()
189 modulator_2 = float()
190
191
192 # helper functions -----
193 def cleanup():
194     """Clean up temporary maps"""
195     grass.run_command('g.remove', flags='f', type="rast",
196                      pattern='tmp.%s*' % os.getpid(), quiet=True)
197
198
199 def run(cmd, **kwargs):
200     """Pass quiet flag to grass commands"""
201     grass.run_command(cmd, quiet=True, **kwargs)
202
203
204 def avg(img):
205     """Retrieving Average (or name it: Mean) of input image"""
206     uni = grass.parse_command("r.univar", map=img, flags='g')
207     avg = float(uni['mean'])
208     return avg
209
210
211 def stddev(img):
212     """Retrieving Standard Deviation of input image"""
213     uni = grass.parse_command("r.univar", map=img, flags='g')
214     sd = float(uni['stddev'])
215     return sd
216
217
218 def hpf_weight(lo_sd, hpf_sd, mod, pss):
219     """Returning an appropriate weighting value for the
220     High Pass Filtered image. The required inputs are:
221     - StdDev of Low resolution image
222     - StdDev of High Pass Filtered image
223     - Appropriate Modulating Factor determining image crispness
224     - Number of Pass (1st or 2nd)"""
225     if pss == 1:
226         wgt = lo_sd / hpf_sd * mod # mod: modulator
227         msg = "    >> Weighting = %.2f / %.2f * %.2f = %.2f" % \
228              (lo_sd, hpf_sd, mod, wgt)
229         g.message(msg, flags='v')
230
231     if pss == 2:

```



```
232     wgt = lo_sd / hpf_sd * mod # mod: modulator
233     msg = "    >> 2nd Pass Weighting = %.3f / %.3f * %.3f = %.3f" % \
234           (lo_sd, hpf_sd, mod, wgt)
235     g.message(msg, flags='v')
236
237     return wgt
238
239
240 def hpf_ascii(center, filter, tmpfile, pss):
241     """Exporting a High Pass Filter in a temporary ASCII file"""
242     if pss == 1:
243         global modulator
244         modulator = filter.modulator
245         msg_ps2 = ''
246
247     elif pss == 2:
248         global modulator_2
249         modulator_2 = filter.modulator_2
250         msg_ps2 = '2nd Pass '
251
252     # structure informative message
253     msg = "    > %sFilter Properties: size: %s, center: %s" % \
254           (msg_ps2, filter.size, center)
255     g.message(msg, flags='v')
256
257     # open, write and close file
258     asciif = open(tmpfile, 'w')
259     asciif.write(filter.filter)
260     asciif.close()
261
262
263 # main program
264
265 def main():
266
267     global tmp_hpf_matrix
268
269     pan = options['pan']
270     msxlst = options['msx'].split(',')
271     outputsuffix = options['outputsuffix']
272     custom_ratio = options['ratio']
273     center = options['center']
274     center2 = options['center2']
275     modulation = options['modulation']
276     modulation2 = options['modulation2']
277     histogram_match = flags['1']
278     second_pass = flags['2']
279     color_match = flags['c']
280
281     # # Check & warn user about "ns == ew" resolution of current region =====
282     # region = grass.region()
```

```

283 # nsr = region['nsres']
284 # ewr = region['ewres']
285 #
286 # if nsr != ewr:
287 #     g.message(">>> Region's North:South (%s) and East:West (%s)"
288 #             "resolutions do not match!" % (nsr, ewr), flags='w')
289 # # =====
290
291 # -----
292 # List images and their properties
293 # -----
294
295
296 mapset = grass.gisenv()['MAPSET'] # Current Mapset?
297
298 imglst = [pan]
299 imglst.extend(msxlst) # List of input imagery
300
301 images = {}
302 for img in imglst: # Retrieving Image Info
303     images[img] = Info(img, mapset)
304     images[img].read()
305
306 panres = images[pan].nsres # Panchromatic resolution
307
308 grass.use_temp_region() # to safely modify the region
309 run('g.region', res=panres) # Respect extent, change resolution
310 g.message("!! Region's resolution matched to Pan's (%f)" % panres)
311
312 # -----
313 # Loop Algorithm over Multi-Spectral images //////////////////////////////////
314 # -----
315
316 for msx in msxlst:
317
318     global tmp
319
320     # Inform
321     g.message("\nProcessing image: %s" % msx)
322
323     # Tracking command history -- Why don't do this all r.* modules?
324     cmd_history = ''
325
326     # -----
327     # 1. Compute Ratio
328     # -----
329
330     g.message("\n1 Determining ratio of low to high resolution")
331
332     # Custom Ratio? Skip standard computation method.
333     if custom_ratio:

```

```
334     global ratio
335     ratio = float(custom_ratio)
336     g.message('Using custom ratio, overriding standard method!',
337              flags='w')
338
339     # Multi-Spectral resolution(s), multiple
340     else:
341         # Image resolutions
342         g.message("    > Retrieving image resolutions")
343
344         msxres = images[msx].nsres
345         if panres == msxres:
346             grass.fatal(_("The Panchromatic's image resolution (%s) "
347                          "equals to the Multi-Spectral's one (%s). "
348                          "Obviously, something isn't right! "
349                          "Please check your input images."
350                          % (panres, msxres)))
351         ratio = msxres / panres
352         msg_ratio = '    >> Low (%.3f) to high resolution (%.3f) ratio: %.1f\'\'
353                     % (msxres, panres, ratio)
354         g.message(msg_ratio)
355
356     # 2nd Pass requested, yet Ratio < 5.5
357     if second_pass and ratio < 5.5:
358         g.message("    >>> Ratio < 5.5 -- WON'T perform 2nd pass! "
359                  "Use <ratio> option to override.",
360                  flags='i')
361         second_pass = bool(0)
362
363     # -----
364     # 2. High Pass Filtering
365     # -----
366
367     g.message('\n|2 High Pass Filtering the Panchromatic Image')
368
369     # ===== Temporary files =====
370     tmpfile = grass.tempfile() # Temporary file - replace with os.getpid?
371     tmp = "tmp." + grass.basename(tmpfile) # use its basenam
372     tmp_pan_hpf = "%s_pan_hpf" % tmp # HPF image
373     tmp_msx_blnr = "%s_msx_blnr" % tmp # Upsampled MSx
374     tmp_msx_hpf = "%s_msx_hpf" % tmp # Fused image
375
376     tmp_hpf_matrix = grass.tempfile() # ASCII filter
377
378     if second_pass and ratio > 5.5: # 2nd Pass?
379         tmp_pan_hpf_2 = "%s_pan_hpf_2" % tmp # 2nd Pass HPF image
380         tmp_hpf_matrix_2 = grass.tempfile() # 2nd Pass ASCII filter
381
382     # Temporary files =====
383
384     # Construct Filter
```

```

385 hpf = High_Pass_Filter(ratio, center, modulation, False, None)
386 hpf_ascii(center, hpf, tmp_hpf_matrix, 1)
387
388 # Construct 2nd Filter
389 if second_pass and ratio > 5.5:
390     hpf_2 = High_Pass_Filter(ratio, center2, None, True, modulation2)
391     hpf_ascii(center2, hpf_2, tmp_hpf_matrix_2, 2)
392
393 # Filtering
394 run('r.mfilter', input=pan, filter=tmp_hpf_matrix,
395     output=tmp_pan_hpf,
396     title="High Pass Filtered Panchromatic image",
397     overwrite=True)
398
399 # 2nd Filtering
400 if second_pass and ratio > 5.5:
401     run('r.mfilter', input=pan, filter=tmp_hpf_matrix_2,
402         output=tmp_pan_hpf_2,
403         title="2-High-Pass Filtered Panchromatic Image",
404         overwrite=True)
405
406 # -----
407 # 3. Upsampling low resolution image
408 # -----
409
410 g.message("\n3 Upsampling (bilinearly) low resolution image")
411
412 run('r.resamp.interp',
413     method='bilinear', input=msx, output=tmp_msx_blnr, overwrite=True)
414
415 # -----
416 # 4. Weighting the High Pass Filtered image(s)
417 # -----
418
419 g.message("\n4 Weighting the High-Pass-Filtered image (HPFi)")
420
421 # Compute (1st Pass) Weighting
422 msg_w = "    > Weighting = StdDev(MSx) / StdDev(HPFi) * " \
423     "Modulating Factor"
424 g.message(msg_w)
425
426 # StdDev of Multi-Spectral Image(s)
427 msx_avg = avg(msx)
428 msx_sd = stddev(msx)
429 g.message("    >> StdDev of <%s>: %.3f" % (msx, msx_sd))
430
431 # StdDev of HPF Image
432 hpf_sd = stddev(tmp_pan_hpf)
433 g.message("    >> StdDev of HPFi: %.3f" % hpf_sd)
434
435 # Modulating factor

```



```
436 g.message("    >> Modulating Factor: %.2f" % modulator)
437
438 # weighting HPF_i
439 weighting = hpfi_weight(msx_sd, hpfi_sd, modulator, 1)
440
441 # -----
442 # 5. Adding weighted HPF image to upsampled Multi-Spectral band
443 # -----
444
445 g.message("\n|5 Adding weighted HPF_i to upsampled image")
446
447 fusion = "%s = %s + %s * %f" \
448         % (tmp_msx_hpfi, tmp_msx_blnr, tmp_pan_hpfi, weighting)
449 grass.mapcalc(fusion)
450
451 # history *****
452 cmd_history += "Weighting applied: %.3f / %.3f * %.3f | " \
453              % (msx_sd, hpfi_sd, modulator)
454
455 if second_pass and ratio > 5.5:
456     # -----
457     # 4+ 2nd Pass Weighting the High Pass Filtered image
458     # -----
459     g.message("\n|4+ 2nd Pass Weighting the HPF_i")
460
461     # Compute 2nd Pass Weighting
462     # Formula? Don't inform again...
463
464     # StdDev of HPF Image #2
465     hpfi_2_sd = stddev(tmp_pan_hpfi_2)
466     g.message("    >> StdDev of 2nd HPF_i: %.3f" % hpfi_2_sd)
467
468     # Modulating factor #2
469     g.message("    >> 2nd Pass Modulating Factor: %.2f" % modulator_2)
470
471     # 2nd Pass weighting
472     weighting_2 = hpfi_weight(msx_sd, hpfi_2_sd, modulator_2, 2)
473
474     # -----
475     # 5+ Adding weighted HPF image to upsampled Multi-Spectral band
476     # -----
477
478     g.message("\n|5+ Adding small-kernel-based weighted 2nd HPF_i "
479             "back to fused image")
480
481     add_back = "%s = %s + %s * %f" \
482              % (tmp_msx_hpfi, tmp_msx_hpfi, tmp_pan_hpfi_2, weighting_2)
483     grass.mapcalc(add_back)
484
485     # 2nd Pass history entry *****
486     cmd_history += "2nd Pass Weighting: %s / %s * %s | " \
```

```

487         % (msx_sd, hpf_2_sd, modulator_2)
488
489     if color_match:
490         g.message("\n|* Matching output's to input's color table")
491
492         run('r.colors',
493             map=tmp_msx_hpf, rast=msx)
494
495     # -----
496     # 6. Stretching linearly the HPF-Sharpene image(s) to match the Mean
497     #    and Standard Deviation of the input Multi-Sectral image(s)
498     # -----
499
500     if histogram_match:
501
502         # adapt output StdDev and Mean to the input(ted) ones
503         g.message("\n|+ Matching histogram of Pansharpened image "
504                 "to %s" % (msx), flags='v')
505
506         # Collect stats for linear histogram matching
507         msx_hpf_avg = avg(tmp_msx_hpf)
508         msx_hpf_sd = stddev(tmp_msx_hpf)
509
510         # expression for mapcalc
511         lhm = "%s = (%s - %f) / %f * %f + %f" \
512             % (tmp_msx_hpf,
513               tmp_msx_hpf, msx_hpf_avg,
514               msx_hpf_sd, msx_sd, msx_avg)
515
516         # compute
517         grass.mapcalc(lhm, quiet=True, overwrite=True)
518
519         # update history string *****
520         cmd_history += "Linear Histogram Matching: %s |" % lhm
521
522     # -----
523     # End of Algorithm //////////////////////////////////////
524     # -----
525
526     # history entry
527     run("r.support", map=tmp_msx_hpf, history=cmd_history)
528
529     # add suffix to basename & rename end product
530     msx_nam = ("%s.%s" % (msx.split('@')[0], outputsuffix))
531     run("g.rename", rast=(tmp_msx_hpf, msx_nam))
532
533     # visualising-related information
534     grass.del_temp_region() # restoring previous region settings
535     g.message("\n|! Region's resolution restored!")
536     g.message("\n>>> Rebalancing colors "
537             "(i.colors.enhance) may improve appearance of RGB composites!",

```

```
538         flags='i')
539
540 if __name__ == "__main__":
541     options, flags = grass.parser()
542     atexit.register(cleanup)
543     sys.exit(main())
```

License(s) of Data

GeoEye

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1

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