**Summary of Richard Massey’s Object-based Classification for North America**

James C. Tilton and Richard Massey

1. **Overview**

We used the RHSeg software (Tilton, 2016) version 1.64 to identify individual crop fields and further refine the pixel-based classification output from the Random Forest approach.

1. **Software**

We used RHSeg software version 1.64 provided by Dr. James C. Tilton of the NASA Goddard Space Flight center for our analysis, plus additional RHSeg compatible utility programs specially developed for this work by Dr. Tilton. In addition we used ENVI 5.3 (*Exelis Visual Information Solutions, Boulder, Colorado*) for some pre- and post- processing steps.

1. **Data**

We used Landsat 5 TM maximum (85%) NDVI value composite data from two seasons in the nominal year 2010. The data is composed as a seamless mosaic for the region. The bands included are bands 1, 2, 3, 4, 5, and 7 for two seasons (summer and spring) making a total of 12 bands. The region mosaics were then subset into multiple 1 deg. by 1 deg. tiles for processing by RHSeg.

1. **Definitions**

***Digitized field samples***: Polygons digitized from crop field boundaries to assess the accuracy of object-based classification.

***1 deg. by 1 deg. tile***: Each irregular region divided into square tiles with side 1.2 degree (132.66 km), which include a 0.1 degree buffer on all sides, to be processed by RHSeg in multiple parallel processes on the region.

***Hierarchy level***: Level of region segmentation hierarchy produced by the RHSeg program.

***Error rate***: (False positive pixels + False negative pixels)/(Total number of pixels in the sample).

***Median error rate***: Median of error rates of all the samples in a region, which includes multiple tiles.

***Sample tiles***: Tiles that have digitized samples inside their extents. Not all tiles contain digitized samples inside their extents. Each region has a total of 15-20 samples distributed across the region. On average there are 2-3 samples in the tiles that contain them.

***Region***: Large are to be classified. For example, the entire Heartland, which is the Corn Belt of the USA or the entire Mississippi basin. The decreasing spatial extent hierarchy is: region > tile > sample > pixel.

1. **Workflow**

**Step 1**: Run RHSeg on the subset of 1 deg. by 1 deg. tiles that contain digitized field samples:

For example, for the tile named Heartland\_2010\_58\_input.tif, with an accompanying mask file named Heartland\_2010\_58\_mask.tif (value “0” designating “no data” areas and areas covered by large water bodies), the edge program is first run followed by the rhseg\_run program (the rhseg\_run program should be run on a parallel processing cluster – 64 CPUs is ideal). The recommended parameters for the edge program are:

-input\_image Heartland\_2010\_58\_input.tif

-mask Heartland\_2010\_58\_mask.tif

-bias\_value 1000

-edge\_operation Frei-Chen

-output\_type 3

-output\_image Heartland\_2010\_58\_edge.tif

-output\_mask\_image Heartland\_2010\_58\_edge\_mask.tif

The recommended parameters for the rhseg\_run program are:

-program\_mode RHSEG

-input\_image Heartland\_2010\_58\_input.tif

-mask Heartland\_2010\_58\_mask.tif

-edge\_image Heartland\_2010\_58\_edge.tif

-edge\_mask Heartland\_2010\_58\_edge\_mask.tif

-log Heartland\_2010\_58\_rhseg.log

-class\_labels\_map Heartland\_2010\_58\_rhseg\_class\_labels\_map.tif

-region\_classes Heartland\_2010\_58\_rhseg\_region\_classes

-object\_labels\_map Heartland\_2010\_58\_rhseg\_object\_labels\_map.tif

-region\_objects Heartland\_2010\_58\_rhseg\_region\_objects

-spclust\_wght 0.5

-oparam Heartland\_2010\_58\_rhseg.oparam

-edge\_threshold 0.002

-edge\_wght 0.25

-region\_sum 1

-region\_std\_dev 1

-region\_threshold 1

-gdissim 1

-rnb\_levels 5

-min\_nregions 60000

-chk\_nregions 220000

-conv\_nregions 10000

Note: The edge program is a “gdal\_utilities” program from Dr. Tilton’s Common software version 1.70.

**Step 2**: Produce field sample tiles corresponding to each 1 deg. by 1 deg. tile that contains digitized field samples. These field sample tiles have value “0” everywhere except for the pixels in a particular field sample, where value is the field sample number value. These field sample tiles must be of the same size of and geographically registered with the input data files.

For example, for the tile named Heartland\_2010\_58\_input.tif, let the accompanying field sample file be named Heartland\_2010\_58\_samples\_mask.tif (this file happens to contain field samples with labels 11 and 41).

**Step 3**: Run the new hsegrefcomp program on the outputs from rhseg\_run from Step 1 and the field sample tiles from Step 2.

For example, for the tile named Heartland\_2010\_58\_input.tif and field sample file named Heartland\_2010\_58\_samples\_mask.tif the parameters for the hsegrefcomp program are:

-oparam Heartland\_2010\_58\_rhseg.oparam

-training\_samples Heartland\_2010\_58\_samples\_mask.tif

-log\_file Heartland\_2010\_58\_hsegrefcomp.log

Note: The hsegrefcomp program is a new “utilities” program from Dr. Tilton’s RHSeg software package version 1.64.

The hsegrefcomp program produces an ASCII table output that is readable by the new find\_best\_thresh program (to be described later). A formatted version of this ASCII table for the example case follows:

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| h\_level | classes | objects | merge thresh | sample label | samplepixels | object label | object pixels | overlap pixels | error\_rate |
| 0 | 220000 | 232069 | 7.06377 | 41 | 472 | 154558 | 272 | 223 | 0.400538 |
| 0 | 220000 | 232069 | 7.06377 | 11 | 333 | 205361 | 132 | 132 | 0.432258 |
| 1 | 136481 | 148297 | 9.66024 | 11 | 333 | 205361 | 132 | 132 | 0.432258 |
| 1 | 136481 | 148297 | 9.66024 | 41 | 472 | 154558 | 421 | 223 | 0.50056 |
| 2 | 87306 | 99275 | 13.0247 | 11 | 333 | 205361 | 132 | 132 | 0.432258 |
| 2 | 87306 | 99275 | 13.0247 | 41 | 472 | 133482 | 443 | 224 | 0.510383 |
| 3 | 71051 | 83272 | 14.8438 | 11 | 333 | 175755 | 252 | 252 | 0.138462 |
| 3 | 71051 | 83272 | 14.8438 | 41 | 472 | 133482 | 443 | 224 | 0.510383 |
| 4 | 61716 | 74217 | 16.2227 | 11 | 333 | 175755 | 252 | 252 | 0.138462 |
| 4 | 61716 | 74217 | 16.2227 | 41 | 472 | 133482 | 443 | 224 | 0.510383 |
| 5 | 56450 | 69114 | 17.1291 | 41 | 472 | 133482 | 443 | 224 | 0.510383 |
| 5 | 56450 | 69114 | 17.1291 | 11 | 333 | 175755 | 252 | 252 | 0.138462 |
| 6 | 46757 | 59738 | 19.1673 | 41 | 472 | 133482 | 443 | 224 | 0.510383 |
| 6 | 46757 | 59738 | 19.1673 | 11 | 333 | 175755 | 252 | 252 | 0.138462 |
| 7 | 41507 | 54793 | 20.5188 | 41 | 472 | 133482 | 443 | 224 | 0.510383 |
| 7 | 41507 | 54793 | 20.5188 | 11 | 333 | 175755 | 252 | 252 | 0.138462 |
| 8 | 36200 | 49985 | 22.0949 | 41 | 472 | 133482 | 443 | 224 | 0.510383 |
| 8 | 36200 | 49985 | 22.0949 | 11 | 333 | 175755 | 252 | 252 | 0.138462 |
| 9 | 32619 | 46982 | 23.2483 | 11 | 333 | 175755 | 252 | 252 | 0.138462 |
| 9 | 32619 | 46982 | 23.2483 | 41 | 472 | 133482 | 443 | 224 | 0.510383 |
| 10 | 26433 | 41952 | 25.5966 | 11 | 333 | 175755 | 252 | 252 | 0.138462 |
| 10 | 26433 | 41952 | 25.5966 | 41 | 472 | 46312 | 764 | 224 | 0.63754 |
| 11 | 22310 | 39067 | 27.3366 | 11 | 333 | 175755 | 252 | 252 | 0.138462 |
| 11 | 22310 | 39067 | 27.3366 | 41 | 472 | 46312 | 764 | 224 | 0.63754 |
| 12 | 17196 | 36159 | 29.6899 | 11 | 333 | 175755 | 252 | 252 | 0.138462 |
| 12 | 17196 | 36159 | 29.6899 | 41 | 472 | 46312 | 764 | 224 | 0.63754 |
| 13 | 10000 | 32906 | 33.7281 | 11 | 333 | 175755 | 252 | 252 | 0.138462 |
| 13 | 10000 | 32906 | 33.7281 | 41 | 472 | 46312 | 764 | 224 | 0.63754 |

The interpretation of this table can be illustrated by describing the interpretation of the first line of the table. This line says that at hierarchical (h\_level) 0, the segmentation consists of 220,000 region classes and 232,069 region objects. Field sample 41 contains 472 pixels and the region object with the largest overlap with field sample 41 is the region object with label 154,558 containing 272 pixels. Field sample 41 and region object 154,558 overlap by 223 pixels. The error rate is 0.400538 (= ((472 – 223) + (272 – 223)/(472 + 272))).

**Step 4**: Run the new find\_best\_thresh program on the combined outputs of the runs of hsegrefcomp in Step 3 on all the 1 deg. by 1 deg. tiles from Step 1 and the field sample tiles from Step 2.

For the Heartland case, the parameters for the find\_best\_thresh program are:

-input\_log\_files hsegrefcomp.logs

-output\_log\_file find\_best\_thresh\_out.txt

where the hsegrefcomp.logs file contains:

Heartland\_2010\_102\_hsegrefcomp.log

Heartland\_2010\_103\_hsegrefcomp.log

Heartland\_2010\_110\_hsegrefcomp.log

Heartland\_2010\_16\_hsegrefcomp.log

Heartland\_2010\_17\_hsegrefcomp.log

Heartland\_2010\_24\_hsegrefcomp.log

Heartland\_2010\_25\_hsegrefcomp.log

Heartland\_2010\_26\_hsegrefcomp.log

Heartland\_2010\_29\_hsegrefcomp.log

Heartland\_2010\_2\_hsegrefcomp.log

Heartland\_2010\_32\_hsegrefcomp.log

Heartland\_2010\_35\_hsegrefcomp.log

Heartland\_2010\_40\_hsegrefcomp.log

Heartland\_2010\_43\_hsegrefcomp.log

Heartland\_2010\_4\_hsegrefcomp.log

Heartland\_2010\_53\_hsegrefcomp.log

Heartland\_2010\_56\_hsegrefcomp.log

Heartland\_2010\_58\_hsegrefcomp.log

Heartland\_2010\_59\_hsegrefcomp.log

Heartland\_2010\_5\_hsegrefcomp.log

Heartland\_2010\_60\_hsegrefcomp.log

Heartland\_2010\_61\_hsegrefcomp.log

Heartland\_2010\_64\_hsegrefcomp.log

Heartland\_2010\_68\_hsegrefcomp.log

Heartland\_2010\_72\_hsegrefcomp.log

Heartland\_2010\_77\_hsegrefcomp.log

Heartland\_2010\_99\_hsegrefcomp.log

Heartland\_2010\_9\_hsegrefcomp.log

Note: The find\_best\_thresh program is a new “utilities” program from Dr. Tilton’s Common software package version 1.70.

The find\_best\_thresh program examines the data from all of the log files, and determines (i) the maximum number of hierarchical levels (max\_nb\_levels), (ii) the minimum merge threshold (min\_mg\_thresh) and (iii) the maximum merge threshold. It then determines a merge threshold increment (mg\_thresh\_incr = max\_mg\_thresh – min\_mg\_thresh)/max\_nb\_levels, and resets min\_mg\_thesh = min\_mg\_thresh – mg\_thresh\_incr and max\_mg\_thresh = max\_mg\_thresh + mg\_thresh\_incr. It then produces a table of average and median error rate values over mg\_thresh values in bins with width mg\_thresh\_incr, as follows:

|  |  |  |
| --- | --- | --- |
| mg\_thresh\_center | ave\_error\_rate | median\_error\_rate |
| 2.5356 | 0.401465 | 0.371429 |
| 4.7857 | 0.363679 | 0.299838 |
| 7.0358 | 0.336315 | 0.346939 |
| 9.2859 | 0.310911 | 0.279748 |
| 11.536 | 0.325855 | 0.323529 |
| 13.7861 | 0.298126 | 0.299544 |
| 16.0362 | 0.311379 | 0.323529 |
| 18.2863 | 0.362195 | 0.323529 |
| 20.5364 | 0.315011 | 0.338235 |
| 22.7865 | 0.303601 | 0.338235 |
| 25.0366 | 0.402678 | 0.398295 |
| 27.2867 | 0.409878 | 0.397571 |
| 29.5368 | 0.276404 | 0.239146 |
| 31.7869 | 0.413968 | 0.397571 |
| 34.037 | 0.440116 | 0.581893 |
| 36.2871 | 0.406849 | 0.494 |
| 40.7873 | 0.305532 | 0.494 |

**Step 5**: Import the table produced in Step 4 into MS Excel and look at the plot of the average error rate and median error rate. This plot follows:

Examining this plot, we decided that the merge threshold value of 14.0 (rounded from 13.7861) was the best overall merge threshold to use for the rhseg\_run runs over all the data sets. Even though this value is not at the absolute minimum over the entire graph, it is in a relatively stable area of the curve. The lower minimum at 29.5368 is in the middle of a very unstable part of the graph where minor perturbations of the merge threshold value lead to large increases in error rate. This is also true to a lesser extent for the other lower minimum at 9.2859.

**Step 5**: Run RHSeg on all the subset of 1 deg. by 1 deg. tiles (including those that do not contain digitized field samples):

For example, for the tile named Heartland\_2010\_56\_input.tif, with an accompanying mask file named Heartland\_2010\_56\_mask.tif (value “0” designating “no data” areas and areas covered by large water bodies), the edge program is first run followed by the rhseg\_run program (the rhseg\_run program should be run on a parallel processing cluster – 64 CPUs is ideal). The recommended parameters for the edge program are:

-input\_image Heartland\_2010\_56\_input.tif

-mask Heartland\_2010\_56\_mask.tif

-bias\_value 1000

-edge\_operation Frei-Chen

-output\_type 3

-output\_image Heartland\_2010\_56\_edge.tif

-output\_mask\_image Heartland\_2010\_56\_edge\_mask.tif

The recommended parameters for the rhseg\_run program are:

-program\_mode RHSEG

-input\_image Heartland\_2010\_56\_input.tif

-mask Heartland\_2010\_56\_mask.tif

-edge\_image Heartland\_2010\_56\_edge.tif

-edge\_mask Heartland\_2010\_56\_edge\_mask.tif

-log Heartland\_2010\_56\_rhseg.log

-class\_labels\_map Heartland\_2010\_56\_rhseg\_class\_labels\_map.tif

-region\_classes Heartland\_2010\_56\_rhseg\_region\_classes

-object\_labels\_map Heartland\_2010\_56\_rhseg\_object\_labels\_map.tif

-region\_objects Heartland\_2010\_56\_rhseg\_region\_objects

-spclust\_wght 0.5

-oparam Heartland\_2010\_56\_rhseg.oparam

-edge\_threshold 0.002

-edge\_wght 0.25

-region\_sum 1

-region\_std\_dev 1

-region\_threshold 1

-gdissim 1

-rnb\_levels 5

-min\_nregions 60000

-hseg\_out\_thresholds 14.0

**Step 6**: Run hswo with a selected “minimum mapping unit” on all the outputs from Step 5:

For our case we chose to use a minimum mapping unit of 9 pixels. For the Heartland\_2010\_56 file, the recommended parameters for hswo are:

-input\_image Heartland\_2010\_56\_input.tif

-mask Heartland\_2010\_56\_mask.tif

-region\_map\_in Heartland\_2010\_56\_rhseg\_object\_labels\_map.tif

-min\_map\_unit 9

-log hswo.log

-class\_labels\_map Heartland\_2010\_56\_hswo\_object\_labels\_map.tif

-region\_classes Heartland\_2010\_56\_hswo region\_objects

-oparams Heartland\_2010\_56\_hswo.oparam

-region\_sum 1

-region\_std\_dev 1

-region\_threshold 1

-gdissim 1

The hswo program runs the Hierachical Step-Wise Optimization program (equivalent to HSeg with spclust\_wght = 0.0) on the data set starting from the “region\_map\_in” region object segmentation and merging only that have fewer than the “min\_map\_unit” number of pixels into the most similar neighboring region.

Note: The hswo program is a component of Dr. Tilton’s RHSeg software package version 1.64.

**Step 7**: From the pixel-wise Random Forest classification of cropland extent, produce cropland extent tiles corresponding to each 1 deg. by 1 deg. tile. These field sample tiles have value “1” for cropland pixels and value “0” otherwise. These cropland extent tiles must be of the same size of and geographically registered with the input data files.

For example, for the tile named Heartland\_2010\_56\_input.tif, let the accompanying cropland extent file be named Heartland\_2010\_56\_crop\_extent.tif.

**Step 8**: Run the combineff program on the outputs from rhseg\_run from Step 6 and the cropland extent tiles from Step 7.

For the Heartland\_2010\_56 tile example, the program parameters for combineff are:

-region\_segmentation Heartland\_2010\_56\_hswo\_object\_labels\_map.tif

-pixel\_cropextent Heartland\_2010\_56\_crop\_extent.tif

-region\_cropextent Heartland\_2010\_56\_region\_crop\_extent.tif

The combineff program produces a map with values 0 to 100 corresponding to the percentage of pixels in each region object that are cropland pixels.

The output from the combineff program can be thresholded as desired to produce a region-based cropland extent map.

**Step 9**: Mosaic the final cropland extent files together.