Release Notes for HSeg/RHSeg version 1.59, February 7, 2014

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- If the region_map_in labeling is complete, modified the program to initialize from "do_region_classes_init" instead of "first_merge_reg_grow."

- Implemented a more efficient version of the connected_component_init routine.

- Modified the programs to convert signed short integer data to 32-bit float when negative values are present (instead of converting to unsigned short integer and, thus, improperly reading negative values).

- Default format for regionMapInImage corrected to be 32-bit unsigned integer.

- Added the sort_flag parameter.

- Fixed a bug involving region_sum_flag.

- Corrected code to always set the value of "threshold" to zero upon calling the lrhseg subroutine. With this correction, the rhseg/rhseg_run/rhseg_run_3d software was validated to produce consistent results across serial and parallel versions.

- Corrected code in image.cc of CommonV1.59 and hsegviewer.cc to enable hsegviewer_3d to function properly and hsegviewer to function properly when the RHSeg/HSeg result was generated without GDAL.

- Modified code in the "lhseg" routine to prevent the setting of "max_threshold" to "FLT_MAX" when no merges are performed in a call to lhseg.

- Corrected code for keeping track of the maximum merge threshold encountered in the region growing process (this maximum was being inappropriately reset to zero).

- Added a user parameter (random_init_seed) to request a "random" seed for the random sampling procedure utilized in the initial fast merging process in rhseg (defaulted to 'true').

- Removed NGHBRS_LABEL_SET_SIZE_LIMIT approximation from the first merge region growing algorithm (see Release Notes for version 1.45) in rhseg.

- Upgraded rhseg, rhsegGUI, rhseg_run, hseglearn and hsegviewer to output images in the same image format as the input image format when the input image format is capable of handling non-Byte data. Otherwise, the output format is taken to be ENVI (the same as the previous assumed format for the output images). Geotransform and projection information is included, if available.

- Modified rhseg code to consistently use the 'float' value of the dissimilarity value (instead of 'double').

- Modified code to be compatible with changes in CommonV1.59 image class.

- For both HSegLearn and HSegViewer;
  1. Modified the color of the cloned cursor cross-hair to be more visible.
  2. Add the capability to change the red, green, blue display band combination without restarting the programs.
  3. Bug fixes.

- For HSegLearn;
  1. Modified the approach for selecting regions for highlighting.
  2. Added the capability to undo the previous submission of negative and/or positive examples.

- Modified the CommonV1.59 image class code to consistently use "open" functions for initial access to existing image data files and "create" or "create_copy" for initial creation of new image data files. Eliminated the "read_info" and "read_meta_info" functions (replaced by versions of "open").

Release Notes for HSeg/RHSeg version 1.58, June 8, 2012

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- Upgraded rhseg_run to be able to utilize GDAL if available.

- Numerous improvements were implemented in the HSegLearn program, including:

  1. Added a cursor cross-hair symbol that is visible in all image windows and tracks along with the actual cursor as it travels over one of the image windows.
  2. The circle drawn with the ROI option appears on all of the image panels and not just the "current region labels" panel.
  3. The projected latitude and longitude values are displayed (if available) along with the column and row values at the bottom of the image panels as the cursor is moved over the image display.
  4. Added a button on the HSegLearn GUI panel that brings up a window containing the text of the log file output from HSeg (this log file contains such information as the number of region classes and objects at each level of the segmentation hierarchy).
  5. An option was added to import the corresponding panchromatic image (if available – such as is the case with Quickbird and WorldView data) for viewing in a separate display panel which tracks with the other image display panels.
  6. Utilized the fast, approximate histogram finding utility in GDAL to speed up creating histogram equalization look-up tables for the multispectral and panchromatic image displays.
  7. Implemented a special option for the GLS-IMP group (included when the compile flag GLSIMP is defined upon compilation) that gives the option of selecting or specifying the "input_image" independent from the *.oparam file.

- Improvements 1-3, 6 and 7 above also apply to HSegViewer.

Release Notes for HSeg/RHSeg version 1.57, March 7, 2012

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- Upgraded the boundary map output from 8-bit unsigned char to 16-bit short integer. As a side-effect of this upgrade, an error in the boundary map output was corrected for RHSeg – as shown in the validation test for the DC Mall Image.

- Changed the default for "chk_nregions" to the number of regions at which min_npixels reaches "1" for HSeg or the last stage of RHSeg.

Release Notes for HSeg/RHSeg version 1.56, February 29, 2012

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- Corrected the initialization of "min_npixels" for the recursive version. This included passing the current value of min_npixels to the subtasks in the parallel version. Retroactively made the same correction in all archival versions of RHSeg back through version 1.50. This error had a relatively minor effect on the segmentation results when small region merge acceleration is selected, and did not affect the results with small region merge acceleration was not selected.

- Upgraded to gtkmm-3.0 (from gtkmm-2.4). The program can be built with either gtkmm-3.0 or gtkmm-2.4.

- Implemented a new build process based on makepp (http://makepp.sourceforge.net/) and reorganized the source code tree slightly to better accommodate the new build process. With the new build process only one makefile is required per directory, and a single invocation of the makepp command adaptively builds the code for all available test environments (32-bit and 64-bit Windows and RedHat and Centos Linux). The new build process automatically detects which system it is one and adjusts the build process accordingly. In the process build process, specific prewritten makefiles had to be selected for each build environment.

Release Notes for HSeg/RHSeg version 1.55, January 4, 2012

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- Modified the code in "lhseg" to initialize the region_heap for region_heap_size > 0 instead of region_heap_size > 1.

- Corrected an error in the code for initializing HSeg/RHSeg with a pre-segmentation (with -region_map_in).

- Made some code changes to set the current directory for GUI file selection forced by a change in a new version of the gtkmm software.

- Added a new "hseglearn" program as an HSeg/RHSeg utility.

Release Notes for HSeg/RHSeg version 1.54, September 29, 2011

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- Corrected the code for generating shape files in hsegextract. The previous version did not trace the region boundaries accurately and did not handle region holes properly.

- Corrected a programming error that led to program failure for certain input data types when compiled with GDAL.

Release Notes for HSeg/RHSeg version 1.53, July 6, 2011

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- To reduce usage of RAM memory, the region_object_label_map is allocated only when really needed – and corrected some "bugs" in the code where the region_object_label_map was referenced when it shouldn't have been.

- Renamed the "MAXMDIR" constant to "MAXNBDIR," making the name more consistent with the meaning.

- Added the optional capability to perform 4nn connected component labeling for the optional region_object_label_map output, instead of the 8nn or higher connectivity that may be selected for the region growing analysis. The "object_conn_type1" parameter and "params.set_object_maxnbdir()" function were added as part of this upgrade.

- Add capabilities required for a Lidar Fusion project: Added a "get_std_dev" function to the RegionClass and RegionObject classes to compute the standard deviation of a region class or object for a particular band. Added to the "hsegextract" utility function the capability to output class and object shape files containing information similar to that currently and previously contained in the "region_classes" and "region_objects" output files, plus "shapefile" information describing the 4nn region_object_level_map in vector format.

- The formula for the merge acceleration factor for small regions was modified and the default for small region merge acceleration was set to false.

Release Notes for HSeg/RHSeg version 1.52, May 9, 2011
(internal release)

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- Removed the #DEFINES of WINDOWS, SERIALKEY, THREEDIM, PARALLEL, GDAL, GTKMM, CONSOLIDATED, RHSEG_RUN, RHSEG_EXTRACT, RHSEG_READ, RHSEG_SETUP, FUSION, and SHAPEFIL from "defines.h" and instead modified the Makefiles to define these contants there. This will allow these constants to be set by running a "configure" script. Deleted the OPARAM_FILE constant.

- Revised the counting of the recursive levels to start at level = 0 (instead of level = 1).to make this counting consistent with usual C++ programming practices.

- Performed a major revision of the process for recursively subdividing the input image data into smaller subsections for RHSEG. The revision was needed to enable RHSEG to more efficiently process images and image volumes with dimension (col, row, slice) sizes that differ by more than a factor of two. This revision includes the following:
  1. Determining a "prime_dimension" parameter as the dimension of largest size (ties are determined by giving preference to columns over rows and slices and rows over slices).
  2. Based on the "prime_dimension" value, recursively divide the prime dimension by 2, and the other dimensions by 2 only if the current size of the dimension is more than the divide value of the prime dimension, until the number of pixels in the resulting image or volume is the value of the "MAX_NREGIONS" constant.
  3. Encode the above determined dimension divisions in a "recur_mask_flag" for each recursive level. The recur_mask_flag is defined as follows: 1=> division of the column dimension only, 2 => row only, 3 => column and row only, 4 => slice only, 5=> column and slice only, 6 => row and slice only, 7 => column, row and slice.
  4. Wrote a "set_recur_flag" routine that, based on the "recur_mask_flag" at a particular recursion level determines the flags "col_flag," "row_flag" and "slice_flag" that are true only if the named dimension is divided at that recursive level. The "set_recur_flag" also returns the value of "nb_strides" (number of strides)for the designated recursion level, where "strides" is the increment to the start of next image section at the designated recursion level.
  5. Write a "set_strides_sections" routine that uses the "recur_mask_flag" at each recursive level to determine the "stride" (spacing between data sections or tasks covered by each child task) and the "nb_sections" (number of data sections (or tasks) covered by the current section or task).
  6. Added a border_flag to designate which set of borders are to be "gotten".in the "get_border_index_data" function.
  7. Added a seam_flag to designate which set of seams are to be "gotten".in the "get_seam_index_data" function.
  8. Modified the "lrhseg," "eliminate_artifacts," "split_pixels," "remerge," "set_contagious_flags," "connected_component," "boundary_map," and other functions to take into account the suppression of the division of a particular dimension as determined by the "recur_mask_flag" at each recursive level.

- Augmented the "rhseg_setup" program to output the value of "nb_sections" in the output parameter file. The value of "nb_sections" is equal to the number of CPUs that should be requested when RHSeg is run in parallel. Previously the number of CPUs was easily determined from the recursive level at which the input data was initially loaded. However, with the new adaptive recursive subdivision of the image data, this determination is more complicated. It is therefore useful for "rhseg_setup" to calculate and output this value along with output other needed parameters to it output parameter file.

Release Notes for HSeg/RHSeg version 1.51, February 11, 2011

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- Added a SPCLUST_MIN constant (in defines.h) and "spclust_min" parameter. This new constant and parameter are used together with the previously defined SPCLUST_MAX constant and "spclust_max" parameter in the implementation of a modified approach for controlling the run time value of the "min_npixels" parameter. In this approach the run time value of "min_npixels" is adjusted to have the smallest value for which the number of large regions (regions with number of pixels greater or equal to "min_npixels") is no more than "spclust_max." However, if this results in the number of large regions being less than "spclust_min," the value of "min_npixels" is reduced by one (unless it is already equal to one) and the number of large regions with this new value of "min_npixels" is checked. If this new value of "min_npixels" results in the number of large regions being more than 6*"spclust_max," the value of "min_npixels" is incremented back up by one, unless this would result in the number of large regions becoming less than two. In the later case, the value of *min_npixels* as is left as is even though this results in the number of large regions exceeding 6*"spclust_max." The value for SPCLUST_MIN was set to 512 and the value for SPCLUST_MAX was set to its previous value of 1024.

- Modified the code for rhseg and hsegextract so that these programs will not fail when run remotely in command line mode even when compiled with the "GTKMM" option.

- The value of the "MAX_NREGIONS" constant was increased from 262,144 to 1,048,576 (1024*1024) for improved processing efficiency. The value of "MAX_NREGIONS" is used to set the default value for the number of recursive levels such that the size of a processing window at the deepest level of recursion does not exceed MAX_NREGIONS pixels or regions (assuming initialization with one-pixel sized regions). However, for parallel processing, the value of the "MAX_NREGIONS" constant was decreased to 16,384 (128*128), also for improved processing efficiency.

- The default method of selecting a subset of segmentations that are output as the segmentation hierarchy was modified. The new method selects the minimal subset of hierarchical levels in which no large region (a region with number of pixels greater or equal to "min_npixels") is involved in more than one spatially adjacent merge. The previous method selected the minimal subset of hierarchical levels in which no region of any size was involved in more than one merge of any type.

Release Notes for HSEG/RHSEG version 1.50, October 7, 2010

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- Changed the definition of the "min_npixels" parameter and made it a program variable. The program variable "min_npixels" now designates the minimum number of pixels that a region must contain for it to be involved in non-adjacent region merges ("spectral clustering"). This variable is only effective in the HSEG and RHSEG program modes.

- Changed the definition of the "spclust_start" parameter and renamed it "spclust_max." "spclust_max" is now used to control the value of the "min_npixels" program variable. When the number of "large regions" (i.e., the number of regions with number of pixels >= min_npixels) exceeds "spclust_max," the value of "min_npixels" is adjusted upwards such that the number of "large regions" does not exceed "spclust_max." In addition, when the number of "large regions" is less than 0.75*spclust_max, the program adjusts the value of "min_npixels" downward to the smallest value where the number of "large regions" is no more than "spclust_max." This parameter applies only to the HSEG and RHSEG program modes.

NOTE: The above two changes cause a major change in the operation of the HSEG algorithm that allows it to process large images much faster. These changes also significantly affect the operation of the RHSEG algorithm.

- Modified code to make sure pixel_data masking is accounted for consistently.

- To ensure consistency of results on disparate computing platforms, set dissimilarity criterion values to zero when less than SMALL_EPSLION.

- Implemented a facility to enter Serial Key information from a Graphical User Interface panel. Previously, Serial Key information had to be entered from a DOS window or terminal window.

- Changed the way the "region_classes" and "region_objects" vectors are initialized. A similar change was made in the way the "nghbr_heap" and "region_heap" vectors are initialized.

- The "max_nregions" program variable was eliminated as it was no longer needed due to the change in the initialization of "region_classes" and "region_objects" vectors.

- The "program_mode" program variable was added. This program variable allows the user to select between "HSWO," "HSEG," and "RHSEG" program modes, and the program sets default parameters accordingly. HSWO => Hierarchical Step-Wise Optimization (no non-adjacent region merging), HSEG => Hierarchical Segmentation, and RHSEG => Recursive Hierarchical Segmentation.

- Added the "insert_into_region_heap" function to facilitate inserting a region into the region heap when it grows to have at least "min_npixels" pixels.

- Regions containing fewer than "min_npixels" pixels no longer participate in the pixel splitting stage of processing window artifact elimination.

- Due to the ability of version 1.50 of the hseg algorithm to more quickly process large images, the value of the "MAX_NREGIONS" constant was increased from 4000 to 262144 (512*512). The value of "MAX_NREGIONS" is used to set the default value for the number of recursive levels such that the size of a processing window at the deepest level of recursion does not exceed MAX_NREGIONS pixels or regions (assuming initialization with one-pixel sized regions).

- For program mode RHSEG, the value of the "SPLIT_PIXELS_FACTOR" constant (default for the "split_pixels_factor" parameter) was changed from 1.4 to 1.5. Also, the value of the "SEAM_THRESHOLD_FACTOR" constant (default for the "seam_threshold_factor" parameter) was changed from 1.3 to 1.5. The value of the "REGION_THRESHOLD_FACTOR" constant (default for the "region_threshold_factor" parameter) remains as 0.0.

- For program modes HSEG and HSWO, the default value of "split_pixels_factor" remains as 0.0, and the only allowed values for seam_threshold_factor and region_threshold_factor are 1.0 and 0.0, respectively. However, "split_pixels_factor" is now allowed to be > 0.0 and a split-remerge process is defined for this case based on the split-remerge process used for processing window artifact elimination. In this case, outlier pixels out split out from each region, based on thresholding the dissimilarity of the pixel with respect to the region it is assigned to, and the split out pixels are remerged by a similar process.

Release Notes for RHSEG version 1.47, December 2, 2009

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- Replaced "strftime" (with its use of a character buffer) with "ctime" (with no character buffer). This eliminated a program error that occurred in certain computing environments

- The "Extract Region of Interest" option in the HSEGViewer displayimages was changed to "Circle Region of Interest" (just a renaming).

- An option to display Region Classes in grey scale rather than pseudo color was added to HSEGViewer.

- Some minor bug fixes were made to the user interface code.

Release Notes for RHSEG version 1.46, October 6, 2009

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- The "region of interest" capability was restored to HSEGViewer that was lost in the conversion of HSEGViewer from JAVA to C++ that occurred with the release of Version 1.40 of HSEGViewer.

- The reading of parameter values from parameter files was made much more robust. With this version there can be any number of spaces or tabs between the parameter name and parameter value.

- The makefiles were simplified by adding the capability to automatically generate the compile and load flags for GDAL, gtkmm and pthreads. (Except the compile and load flags for pthreads are hard coded for MinGW-msys.)

- Some minor bug fixes were made to the user interface code.

Release Notes for RHSEG version 1.45, July 30, 2009

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- Renamed the "Region" object class to the "RegionClass" object class.
- Renamed the "ConnRegion" object class to the "RegionObject" object class.
- Revised/Reorganized the on-line help.
- Removed NGHBRS_LABEL_SET_SIZE_LIMIT approximation from hseg merges, but retained it in first merge region growing algorithm. In this approximation, a region is removed from consideration for merging when the number of neighboring regions exceeds the NGHBRS_LABEL_SET_SIZE_LIMIT threshold.
- Added the capability to input float format input image data.
- The "dtype" parameter designations were changed as follows:

```
-dtype                    Input image data type. Currently must be either
(string)
                          UInt8   => "unsigned char (8-bit)" or
                          UInt16  => "unsigned short int (16-bit)"
                          Float32 => "float (32-bit)"
```

- Reorganized C++ code to maximize code reuse.
- Added an optional complete Graphical User Interface (GUI) for parameter input utilizing gtkmm (C++ Interface for GTK+: a toolkit for creating graphical user interfaces. See http://www.gtkmm.org/ and http://www.gtk.org/.
- Added an optional capability to utilize the Geospatial Data Abstraction Library (GDAL) for image data I/O. See http://www.gdal.org/.

Release Notes for RHSEG version 1.42, October 7, 2008
(internal release)

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- Added "percent complete" tracking in both command line and GUI form.

Release Notes for RHSEG version 1.41, August 29, 2008
(internal release)

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- Removed the optional "chk_mn_std_dev" and "conv_mn_std_dev" parameters (introduced in version 1.32) for starting and ending hierarchical segmentation output based on the (mean normalized) standard deviation values of the regions.

- The "region_std_dev" parameter is no longer overriden when the "std_dev_wght" parameter value is 0.0.

- Added the "hseg_out_thresholds" and "hseg_out_nregions" parameters to control the hierarchical segmentation output. The help output was modified accordingly as follows:

-chk_nregions (short unsigned int)	Number of regions at which hierarchical segmentation output is initiated (2 <= chk_nregions < 65535, default = 64 if "hseg_out_nregions" and "hseg_out_thresholds" not specified)
-nb_hseg_out_nregions (short unsigned int)	Number of number of region levels at which hierarchical segmentation outputs are made (default = 0)
-hseg_out_nregions (short unsigned int)	The set of number of region levels at which hierarchical segmentation outputs outputs are made (no default, ignored if "nb_hseg_out_nregions" = 0)
-nb_hseg_out_thresholds (short unsigned int)	Number of merge thresholds at which hierarchical segmentation outputs are made (default = 0)
-hseg_out_thresholds (float)	The set of merge thresholds at which hierarchical segmentation outputs are made (no default, ignored if "nb_hseg_out_thresholds" = 0)

NOTE: -chk_nregions, -nb_hseg_out_nregions and -nb_hseg_out_thresholds are mutually exclusive. If -chk_nregions is specified, -nb_hseg_out_nregions and -nb_hseg_out_thresholds are assumed = 0. If -nb_hseg_out_nregions is specified, -nb_hseg_out_thresholds is assumed = 0. -nb_hseg_out_nregions and -nb_hseg_out_thresholds may not be specified for -spclust_wght > 0.0 and -rnb_levels > 1.

Release Notes for RHSEG version 1.40, July 28, 2008

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Added the option for a rudimentary Graphical User Interface (GUI) using the gtkmm library. gtkmm is the official C++ interface for the GUI library, GTK+ (see http://www.gtkmm.org/). This initial GUI simply allows one to enter the RHSEG parameter file name through a GUI instead of on the command line. The intention is to provide in future release the option to enter all parameters all parameters through an elaborated GUI, while retaining the option of entering the parameters through a parameter file, as in this and previous versions.

This GUI option makes it possible to make RHSEG a desktop function in Windows. NOTE for the demonstration version: For the initial run of RHSEG, serialkey information must be entered via the command line (non-GUI) version of RHSEG, called from a DOS command window or a LINUX terminal window. Subsequent runs of RHSEG (within the demonstration period) may be run, if desired, through the GUI version.

HSEGViewer was converted from JAVA to C++ using gtkmm library functions. The functionality of HSEGViewer is nearly the same as before with the following exceptions: The "Region of Interest" facility is not implemented in the new version. Additional features can be displayed, including the region class and region object standard deviation and boundary pixel ratio features.

A new program, HSEGReader, is provided with this release. HSEGReader is a graphical user interactive (GUI) program written in C++, utilizing the gtkmm library, that enables an analyst to examine the feature values of the region classes and region objects contained in the hierarchical segmentation results produced by HSEG or RHSEG.

For DOS, the default install directory is C:/Program Files/RHSEG instead of C:/RHSEG.

Added the following Copyright statement in appropriate places:

Release Notes for RHSEG version 1.32, May 1, 2008
(internal release)

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The following changes were made:

- Combined all region feature output into region_classes and, if requested, region_objects files. Renamed the corresponding region label maps to class_labels_map" and "object_labels_map," respectively. This makes the RHSEG output uncompatible with previous HSEGViewer versions. Version 1.40 or later of "hsegviewer" must be used with RHSEG Version 1.32 or later.

- Replaced std_dev feature with mean normalized std_dev feature.

- Changed input data normalization to minimum value = 1.0 and std_dev = 1.0 (unnormalized) for all dissimilarity criterion (not just Entropy as before). This change in normalization was made necessary by the use of the mean normalized std_dev feature.

- Because version 1.40 of HSEGViewer is written in C++ rather than JAVA, byteswapping is no longer required for the outputs of RHSEG when HSEGViewer is run on a machine of the same architecture as that used for running RHSEG. Byteswapping on output is no longer an option.

- Name for input region (label) map changed from "rlblmap_in" to "region_map_in."

- Added optional "chk_mn_std_dev" and "conv_mn_std_dev" parameters to start and end hierarchical segmentation output based on the (mean normalized) standard deviation values of the regions.

Release Notes for RHSEG version 1.31, November 2, 2007
(internal release)

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A significant change was made in the manner in which the iterations are selected for output into the segmentation hierarchy. The methods for detecting "significant convergences" are abandoned with this release and replaced with a simple method that outputs the minimum number of hierarchical levels necessary to guarantee that each region is involved in no more than one merge from one hierarchical level to the next. As a result of this change, the conv_criterion," "conv_factor," "gdissim_crit," and "gstd_dev_crit" parameters were eliminated, the "rconv_critlist" parameter was renamed to "rthreshlist," and the "gdissim" parameter was added.

Release Notes for RHSEG version 1.30, August 1, 2007

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Several changes were made in RHSEG for this release. Most changes were made to improve processing efficiency. Some bug fixes are also included, and a new dissimilarity criterion is added. Also, with the release of the RHSEG and HSEGViewer software, the three dimensional version is debundled from the release package. Only the two dimensional version is included in the provided RHSEG_setup program. The three dimensional version will be provided only by specific special request to U. S. A. users who have already obtained this (and subsequent) releases.

A summary of the significant changes follows:

(i) The parameter "min_npixels_pct" was replaced by the parameter "min_npixels." Previously the parameter "min_npixels_pct" was used to calculate "min_npixels" as the percentage of the number of pixels in the current processing window. Now the value for "min_npixels" is specified directly by the user (a default value is provided) and does not vary with processing window size. In addition, the formula was modified for calculating the merge acceleration factor for small regions, using "min_npixels" as an input parameter (See the User's Manual for more details).

(ii) The merge acceleration factor for small regions is now employed in the processing window artifact elimination step (it previously was not).

(iii) Added a constant "NGHBRS_LABEL_SET_SIZE_LIMIT" (set to 200) which is used to improve the computational efficiency of RHSEG. Regions with the number of neighbors greater than this limit are not updated and are taken out of consideration as the "best merge" region by setting the value of its most similar neighbor dissimilarity (best_nghbr_dissim) to the maximum floating point value (FLT_MAX). This does not prevent such regions from merging - these regions can still be involved in a merge if a neighboring region, with a smaller number of neighboring regions, is selected as the "best merge" region. However, this does cause some larger regions to be merged into smaller regions, which is contrary to the previously established convention. One should note that as neighboring regions merge with each other, a region that had been previously taken out of consideration as the "best merge" region due to this limit can have its number of neighboring regions become less than this limit and return to consideration as the "best merge" region. This change can significantly improve computationally efficiency if there are large regions present with a large number of neighboring regions. However, if there are no large regions, this change has very little if any effect on the processing time or segmentation results.

(iv) The "region_label_map member" variable for the "spatial" data object was upgraded from "unsigned short int" to "unsigned int" (to prevent overflow).

(v) The default value of "split_pixels_factor" was changed from 1.5 to 1.4, the default value of "seam_threshold_factor" was changed from 1.5 to 1.3 and the default value of "region_threshold_factor" was changed from 1.5*spclust_wght to 0.0. The first two changes were made to insure that

the processing window artifacts are indeed eliminated in all (known) cases, and the last change was made to improve processing efficiency.

(vi) The SAR Speckle Noise criterion is added (see the User's Manual for more details).

Here are processing time results using a computer with 2.4 GHz CPUs each with 1 GByte RAM:

Image Size	Number of processors	rnb_levels	spclust_wght 0.0	0.1	1.0
			Run Times (min:sec)		
0064 x 0064	1	1	<0:01	<0:01	0:33
0128 x 0128	1	1	0:02	0:06	10:04
0256 x 0256	1	1	0:06	1:46	>60:00
0512 x 0512	1	1	0:25	30:23	>60:00
1024 x 1024	1	1	1:55	>60:00	>60:00
2048 x 2048	1	1	3:27†	>60:00	>60:00
0064 x 0064	1	2*	0:01	0:01	0:08
0128 x 0128	1	3*	0:02	0:04	0:35
0256 x 0256	1	4*	0:08	0:13	2:29
0512 x 0512	1	5*	0:46	1:01	10:27
1024 x 1024	1	6*	4:56	4:50	42:42
2048 x 2048	1	7*	36:16	24:01	>60:00
0064 x 0064	4	2*	<0:01	<0:01	0:04
0128 x 0128	16	3*	<0:01	0:01	0:07
0256 x 0256	64	4*	0:01	0:01	0:11
0512 x 0512	256	5*	0:01	0:01	0:18
1024 x 1024	256	6*	0:03	0:03	0:35
2048 x 2048	256	7*	0:12	0:13	1:34
4096 x 4096	256	8*	1:15	0:51	5:01
6912 x 6528	256	8*	2:28	3:24	46:15
6912 x 6528	256	9	2:29	2:23	8:11

* Default value for this image size.
† With init_threshold = 0.50.

NOTE: The fastest single processor processing times for spclust_wght = 0.0 are for rnb_levels = 1, i.e., (non-recursive) HSEG. In this case the size of the image that can be processed is limited mainly by the computer's RAM. The fastest single processor processing times for spclust_wght > 0.0 are for rnb_levels > 1, i.e., (recursive) RHSEG.

Release Notes for RHSEG version 1.28, April 20, 2007
(internal release)

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Modifications to the RHSEG implementation were made to reduce the RAM memory requirements of the program by eliminating redundant storage of input image data information. In addition, a change was made in the first stage of the restricted version of HSEG used in processing window artifact elimination (CONV_FACTOR was set to 0).

Release Notes for RHSEG version 1.27, March 2, 2007
(internal release)

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A fast method for initializing the region growing process is implemented in this release. Processing results are identical to the previous version for init_threshold = 0.0. However, for init_threshold > 0.0, the RHSEG region growing process is initialized with the results from a "first merge" region growing process based on the region growing procedure proposed by Muerle and Allen in:

[1] J. L. Muerle, D. C. Allen, Experimental evaluation of techniques for automatic segmentation of objects in a complex scene, in G. C. Cheng, et al. (Eds.), Pictorial Pattern Recognition, Thompson, Washington, DC, 1968, pp. 3-13.

See the User's Manual for implementation details.

Release Notes for RHSEG version 1.26, February 9, 2007
(internal release)

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The method for combining the standard deviation feature with the dissimilarity function was changed in this version. The previous additive method only worked reasonably with the vector norm and mean squared error based dissimilarity functions. A new multiplicative approach is implemented in this version of RHSEG which works equally well with all dissimilarity functions. See the User's Manual for implementation details.

Release Notes for RHSEG version 1.25, December 14, 2006

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This is a bug fix for the RHSEG code.

(i) The default calculation for rnb_levels was modified to match the User's Manual documentation. In version 1.25, rnb_levels is calculated such that the initial number of regions at the deepest level of recursion is in the range of 1000 to 4000. Previously, the intial number of regions ranged from to 512 to 2048. (An inconsistency related to this in the User's Manual was also corrected.)

(ii) Corrections were made for the case when the initial iteration of spectral clustering occurs with a dissimilarity value of 0.0.

Release Notes for RHSEG version 1.21, November 14, 2006

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This is a bug fix for the RHSEG and HSEGViewer code.

(i) There is a problem in RHSEG version 1.20 that occurs when spclust_wght > 0.0, and spclust_start < min_nregions. A work-around for RHSEG Version 1.20 is to set region_threshold_factor = 1.0. This problem is fixed in RHSEG version 1.21. Also, the default value for region_threshold_factor is reset to 1.5*spclust_wght in RHSEG version 1.21.

(ii) For dtype = 16 (UNSIGNED SHORT) in sequential processing mode with ionb_levels > 1, the input data is read incorrectly in RHSEG Version 1.20. This is corrected in RHSEG version 1.21.

(iii) For dtype = 16 (UNSIGNED SHORT) the histogram equalization for display of the RGB and Region Mean images in HSEGViewer version 1.20 does not work properly for values more than 32767. This is corrected in HSEGViewer version 1.21.

In addition, in the distribution version of RHSEG version 1.20, the sample data set, girl.raw, is corrupted. This problem is also corrected with the RHSEG version 1.21 release.

Release Notes for RHSEG version 1.20, October 27, 2006

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This is a significant rewrite of the RHSEG and HSEGViewer code. The most significant improvements are the upgrading of RHSEG to process three-dimensional data, and the upgrade of HSEGViewer to view and interact with two-dimensional planes of three-dimensional data, and the implementation in RHSEG of additional dissimilarity criteria. There are additional minor changes as noted below.

Since the three-dimensional code imposes measurable overhead when processing two-dimensional data, separate two-dimensional and three-dimensional versions are provided: rhseg_2d and rhseg_3d. The rhseg_3d version will process two-dimensional data (or one-dimensional) data, but it will run slower than the rhseg_2d version. An additional parameter "nslices" is provided to specify the size of the third dimension for rhseg_3d. This parameter is ignored by rhseg_2d.

Four new dissimilarity criteria are provided in this version of RHSEG (rhseg_3d and rhseg_2d). These new criteria are the "Spectral Angle Mapper" criterion, the "Spectral Information Divergence" criterion, the "Normalized Vector Distance" criterion and the "Entropy" criterion. The "Spectral Angle Mapper" and Spectral Information Divergence" criteria are often used in the analysis of hyperspectral data, while the "Normalized Vector Distance" criterion is useful in the analysis of color (e.g., RGB), multispectral and hyperspectral data. The "Entropy" criterion is original to RHSEG (at least I haven't seen it implemented anywhere else). It is useful in the analysis of grey scale, color and multispectral data - and perhaps hyperspectral data as well.

New input parameters include "scale" and "offset." These new parameters were added to facilitate the input of MODIS data into RHSEG. The MODIS multispectral data are normally stored in scaled short integer format (16 bit), with scale and offset factors provided to rescale the data into calibrated reflectance and/or radiance values.

The "conn_type" parameter has been modified appropriately to properly specify neighborhood connectivity for one-dimensional and three-dimensional data, in addition to two-dimensional data.

HSEGViewer has been augmented to accommodate the "nslices" parameter from the RHSEG analysis of three-dimensional data. However, HSEGViewer can be only used to visualize and interact with two-dimensional planes from the three-dimensional RHSEG analysis results.

RHSEG now orders the region labeling in an approximate order from "darker" to "brighter" regions (instead of the previous ordering of largest to smallest region).

HSEGViewer now attempts to color the "Segmentation Slice View" image with darker colors for regions with smaller region label values and with brighter colors for regions with larger region label values, according to a fix, non-random, color table scheme (previous versions of HSEGViewer used randomized colors).

Release Notes for RHSEG version 1.10, August 15, 2005

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This is a significant rewrite of the RHSEG and HSEGViewer code. The most significant improvements are the implementation in RHSEG of a scheme for swapping portions of the data to temporary disk files and an addition of an option for selecting between different convergence criterion in RHSEG.

The swapping scheme is based on the scheme used in the parallel implementation to distribute the data out to processing nodes. This makes it possible to process larger data sets, since the program was previously memory bound for larger images. See the updated User's Guide for instruction on how to use this added RHSEG feature through the new "ionb_levels" parameter. The default value of this parameter should work well for most single CPU computer systems, assuming sufficient space is provided in the specified temporary disk space.

The major impact of this improvement is that large images can now be processed with the sequential version of RHSEG - if one is willing to devote sufficient processing time to the task. Here are the processing times I obtained for a 6912 column, 6528 row, 6 band Landsat TM image using program default values (except as noted):

spclust_wght	parallel timing	sequential timing	parallel speed-up*
0.0	1.4 minutes	8.0 hours	171
0.1	7.5 minutes	43.3 hours	173
1.0	2.5 minutes	15.0 hours	180

*taking into account differences in clock speed.

The recommended optional "rmeanlist," "rconv_critlist," "boundary_npix," and "boundary_map" outputs were created and the "byteswap_out" flag was set to 1 (TRUE). The sequential version was run on a single 1.2 GHz CPU with 1.5 GBytes of RAM. The parallel version was run with 256-2.4 GHz CPUs with 1.0 GBytes of RAM each. Of course, identical hierarchical segmentation results were produced with each version.

As mentioned above, this version of RHSEG includes an option to select between different convergence criterion. See the User's Guide for instructions on how to utilized this added RHSEG feature through the new "conv_criterion" parameter. Note that along with the addition of this feature, the old "convfact" parameter has been renamed to "conv_factor."

In addition to the above major changes to RHSEG, previously known bugs in RHSEG related to image masking and connected component labeling have been corrected, as well as a newly discovered bug in the calculation of the global dissimilarity criterion values. Another minor change to the RHSEG code makes it more efficient in processing images with large constant areas. Some minor bugs were also corrected in HSEGViewer. In addition, improvements were made in the HSEGViewer histogram equalization code used to create the "RGB Image" and "Region Mean Image" views of the data (for 16-bit input data).

**Special note for users of earlier versions of Java: The current default release of HSEGViewer can only be run with version 1.5 (or later) of Java. However, included in this release of HSEGViewer is a version compatible with

Java version 1.4. To invoke this version run the "HSEGViewer1_4" MS-DOS Batch File instead of HSEGViewer.

Release Notes for RHSEG version 1.03, April 1, 2005

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This version of RHSEG includes code to prevent the overwriting of any input file with any output file, along with a minor correction of the on-line help for RHSEG. It also includes a new version of HSEGViewer with bug fixes for the rthreshlist input file and for the reference1, reference2 and reference3 input files. The new version of HSEGViewer also uses histogram equalization when the input data is unsigned short in order to create viewable images for the "RGBImage" and "Region Mean Image."

Release Notes for RHSEG version 1.02, March 1, 2005

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This version of RHSEG provides a reorganization and minor correction of the on-line help for RHSEG. It also includes a more complete user's guide.

Release Notes for RHSEG version 1.01, February 18, 2005

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This version of RHSEG includes a correction of an implementation oversight in the processing window artifact elimination process for spclust < 1.0. This correction should optimize the segmentation results by a minor amount versus the previous version.

Release Notes for RHSEG version 1.0, February 10, 2005

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This version of RHSEG incorporates a significant fundamental improvement in the underlying implementation of the RHSEG algorithm. It also includes important bug fixes that correct earlier implementation errors. These errors resulted in slightly suboptimal results for cases with spclust_wght < 1.0. Further, the definition of the parameters "dtype," "dissim_crit" and "gdissim_crit" were changed, the rnb_levels parameter was made optional, and some cosmetic changes where made in the screen and log file outputs.

Included with this release are the executables and source code for a couple utility programs for extracting particular information from the RHSEG output files (see below).

As noted in the on-line help (available with the "rhseg -help" command), the definition of the "dtype" parameter is now:

```
-dtype     (short unsigned int)    Data type of input image data
                                     dtype = 8 => "unsigned char (byte)"
                                     dtype = 16 => "short unsigned int"
                                   (otherwise undefined)
```

This makes the definition more rational: the designator now corresponds to the number of bits per pixel.

NOTE: Because of this change, versions of HSEGViewer with release dates prior to February 8, 2005 will no longer work with RHSEG. The newest release of HSEGViewer is contained in the "jar" file named hsv20050208.jar.

The definition of "dissim_crit" and "gdissim_crit" were changed to include a new "SAR Speckle Noise" criterion. This criterion was taken from a recent paper by J.-M. Beaulieu (Utilisation of contour criteria in micro-segmentation of SAR images, Int. J. Remote Sensing, 10, September, 2004, Vol. 25, No. 17, 3497-3512).

```
-dissim_crit      (short unsigned int)    Dissimilarity criterion
                                   1. "1-Norm,"
                                   2. "2-Norm,"
                                   3. "Infinity Norm,"
                                   4. "(undefined),"
                                   5. "(undefined),"
                                   6. "Square Root of Band Sum Mean
                                      Squared Error,"
                                   7. "Square Root of Band Maximum Mean
                                      Squared Error."
                                   8. "(undefined),"
                                   9. "SAR Speckle Noise Criterion."
                                 (default: 6. "Square Root of Band
                                      Sum Mean Squared Error")
-gdissim_crit     (short unsigned int)    Global dissimilarity criterion
                                   1. "1-Norm,"
                                   2. "2-Norm,"
                                   3. "Infinity Norm,"
                                   4. "(undefined),"
```

5. "(undefined),"
6. "Square Root of Band Sum Mean Squared Error,"
7. "Square Root of Band Maximum Mean Squared Error."
8. "(undefined),"
9. "SAR Speckle Noise Criterion."

(default = {none})

The "rnb_levels" parameter has been made optional. When not specified, the value for rnb_levels is calculated as the smallest value that would make the number of pixels <= 2048 in the processing window at the deepest level of recursion. Experience has shown this to be a good choice for the value of rnb_levels vis-a-vis processing time.

The cosmetic changes in screen and log file output are as follows:

"rhseg -v" how gives the version number and date.

With the "debug" parameter set to 0, no log file is generated, and the parameter settings and information about the hierarchical levels output are printed to the screen.

With the "debug" parameter set to 1, a log file is generated, and the parameter settings and information about the hierarchical levels output are printed to this log file. Only the program start and end time are output to the screen.

With the "debug" parameter set to 2, in addition to the same outputs generated for debug = 1, some program progress statements are output to the log file.

With the "debug" parameter set to 3, additional detailed information concerning region merging is output to the log file.

Finally, significant fundamental improvement in the underlying implementation of the RHSEG algorithm is included in this release of RHSEG. This has resulted in improvements in processing throughput, which are most significant for spclust_wght = 0.0. This improvement was achieved by using a "data heap" to determine the optimal regions to merge at each iteration instead of a fully sorted list. For information on data heaps, see Chapter 11 of "Algorithms" by Robert Sedgewick (1983, Addison-Wesley Publishing Company, Inc.) or other algorithms textbooks.

Included with this release are the executables and source code for a couple utility programs for extracting particular information from the RHSEG output files. The source code for these programs can be found in the "Sample Source Code" directory under the RHSEG installation directory.

The RHSEG programs outputs files that do not have obvious interpretations. The "rlblmap" file contains just the region label map from hierarchical level 0 (the finest level of detail) and the "regmerges" file contains information on how to translate the "rlblmap" at hierarchical level 0 to the region label map at other hierarchical levels. The "rlblmap_extract" program demonstrates how the "regmerges" file is used to determine the region label map at other hierarchical levels.

The "rlblmap_extract" program is designed to use the "oparam" output file from RHSEG to obtain most of its input parameter information. The preferred usage of "rlblmap_extract" is:

```
rlblmap_extract parameter_file_name rlblmap_extract_file_name hlevel_extract
```

where parameter_file_name is the name of the input parameter file name (normally the output "oparam" file from RHSEG), rlblmap_extract_file_name is the name of the output file to contain the region label map at the selected hierarchical level, and hlevel_extract is the hierarchical level desired. More detailed help can be obtained from the "rlblmap_extract -help" command.

An additional sample utility program, regmean_extract, demonstrates how to generate a region mean image for a particular hierarchical level from the RHSEG outputs. Like the "rlblmap_extract" program, the "regmean_extract" program is designed to use the "oparam" output file from RHSEG to obtain most of its input parameter information. The preferred usage of "regmean_extract" is:

```
regmean_extract parameter_file_name regmean_extract_file_name hlevel_extract
```

where parameter_file_name is the name of the input parameter file name (normally the output "oparam" file from RHSEG), regmean_extract_file_name is the name of the output file to contain the region mean image at the selected hierarchical level, and hlevel_extract is the hierarchical level desired. More detailed help can be obtained from the "regmean_extract -help" command.

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