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DGS_toolbox_Jan2011
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Intro
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A collection of MATLAB tools for the automated estimation of grain size from digital images of sediment, using autocorrelation techniques originated by Rubin (2004), plus supporting procedures.

The following brief decription of each function and how to get started. We assume you have a basic understanding of what matlab is and how to use it. Some of these functions require inputs/outputs from the command line, and others prompt the user for inputs - these are termed 'interactive' in what follows.

For the technical background, please refer to the publications listed in the references below. Before use, please familiarise yourself with the help sections of each of the main functions (calib_grainsize.m; and magic_grainsize.m), which for convenience are also copied below

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Contents
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MAIN FUNCTIONS

calib_grainsize.m
estimate of grain size and grain-size distribution from an image of sediment,
in calibration mode following Rubin (2004) and Buscombe(2008)
this original method requires a calibration catalogue containing autocorrelation sequences from images of sediment of known size (e.g. sieved fractions)
grain size is calculated from autocorrelation coefficients from an image of sediment with unknown grain size
this approach has been shown to give mean grain size to within 15 rms error (see Warrick et al 2009), if the images are well resolved, have enough grains, and calibration procedures are carefully carried out
the distribution is possible, and included in the outputs, but more problematic. The distribution estimation techniques may or may not give adequate results for specific sediment populations. Do not use without proper validation
see: Rubin (2004), Rubin et al (2007), Barnard et al (2007), Buscombe (2008), Buscombe and Masselink (2009), Buscombe et al (2010a), Warrick et al (2009)

CALIB_GRAINSIZE
function to compute estimates of mean grain size (following Rubin 2004) and grain size distribution (following Buscombe 2008) from an image of sediment where grains are clearly resolved
REQUIRES CALIBRATION

INPUTS:
imagefile a filename of an image which must be on the path (e.g.'047080139.tiff')
calibrationfile a txt file which contains the calibration matrix (rows
are autocorrelation coefficients and columns represent different grain size fractions)
calibrationsizes vector of grain size fractions corresponding to the
columns in 'calibrationfile'
Optional:
filter = 0 if no filtering carried out on image
= 1 if homomorphic filter applied
filtoptions see 'homomorphic.m' (in this toolbox). Note this function
was written by P. Kovesi, School of Computer Science & Software Engineering,
The University of Western Australia
http://www.csse.uwa.edu.au/
e.g. filtoptions.boost=3; filtoptions.CutOff=.2;
filtoptions.order=2;

OUTPUTS: 'out_cal', a structure containing the following fields:
MeanGrainSize: mean grain size (units same as those given in input 'calibrationsizes')
classes: grain size bins (histogram)
freq: frequency of grain size bins 'classes'
hyperbolic_dens log-hyperbolic probability density function for grain size bins 'classes'
pvals_est: [5,10,16,25,50,75,84,90,95]th percentiles of cumulative distribution
gm_est: Folk & Ward 1957 geometric graphic mean
gs_est: Folk & Ward 1957 geometric graphic sorting
gsk_est: Folk & Ward 1957 geometric graphic skewness
bandwidth: optimal bandwidth, calculated from the data, used for kernel smoothing
usedImage: actual image used (it may have been filtered, depending on input options)

References
1) Rubin, D.M. (2004) A simple autocorrelation algorithm for determining grain size from digital images of sediment.
Journal of Sedimentary Research 74, 160-165

2) Buscombe, D. (2008) Estimation of Grain Size Distributions and
Associated Parameters from Digital Images of Sediment. Sedimentary Geology 210, 1-10

3) Botev. Z.I., Grotowski J.F and Kroese D. P. (2010). Kernel density
estimation via diffusion. Annals of Statistics. Accepted for publication.

Examples:
1) use all defaults
[out_cal]=calib_grainsize('047080139.tiff','calibdata.txt',[58,107,152,239,362,512,724]);

2) say no to filter
[out_cal]=calib_grainsize('047080139.tiff','calibdata.txt',[58,107,152,239,362,512,724],0);

3) filter and use own filter options
filtoptions.boost=3; filtoptions.CutOff=.2; filtoptions.order=2;
[out_cal]=calib_grainsize('047080139.tiff','calibdata.txt',
[58,107,152,239,362,512,724],1,filtoptions);

magic_grainsize.m
estimate of grain size and grain-size distribution from an image of sediment, in non-calibration mode
following Buscombe et al (2010)
- the major drawback from the above is the calibration procedure, which must be done carefully with sufficient number of size
fractions and at grain sizes with sufficient spacing, as well as potentially inherent errors associated with the least-squares
approach to a solution
- the alternative: with the universal method, grain size read directly from the image using information
in the frequency domain
- it has been shown to give rms errors of within 20 for grain sizes across 3 orders of magnitude.
Errors may get as low as 10 or less if the method is 'calibrated'.
Calibration involves correcting for population-specific bias.
This may be achieved through carrying out manual point counts on 'end members' of the population (i.e. finest and coarsest
fractions, perhaps a few more in the middle of the size range).
Correct the output grain size with using slope and intercept
from a linear regression between estimated and measured mean size

MAGIC_GRAINSIZE
function to compute estimates of mean grain size (following Buscombe et al, 2010a) and grain size distribution (following Buscombe et al, 2010b) from an image of sediment
where grains are clearly resolved
DOES NOT REQUIRE CALIBRATION

INPUTS:
imagefile   a filename of an image which must be on the path (e.g.'047080139.tiff')
res   spatial resolution of camera in mm/px (if unsure set to 1 - you can multiply by mm/pixel afterwards)
R   the value at which the correlogram represents mean grain size (almost always 0.5)
filter   = 0 if no filtering carried out on image
= 1 if homomorphic filter applied
filtoptions   see 'homomorphic.m' (in this toolbox). Note this function
was written by P. Kovesi, School of Computer Science & Software Engineering,
The University of Western Australia
http://www.csse.uwa.edu.au/
e.g. filtoptions.boost=3; filtoptions.CutOff=.2;
filtoptions.order=2;

OUTPUTS:
a structure, GrainSize, containing the following:
s1,s2,s3:   three measures of the mean of intermediate diameters.
MeanGrainSize: Usually, point counts correspond most closely to the minimum of these three, which is what this is
options)

References
1) Buscombe D., Rubin, D.M., and Warrick, J.A. Universal Approximation to

Grain Size from Images of Non-Cohesive Unlithified Sediment.
Journal of Geophysical Research - Earth Surface(2010)

3) L. Khachiyan, An inequality for the volume of inscribed ellipsoids,
Discrete Comput. Geom. 5 (3) (1990), pp. 219–222.

Examples:
1) use all defaults
GrainSize=magic_grainsize('047080139.tiff');

2) use own image resolution (outut in real length units rather than pixels)
GrainSize=magic_grainsize('047080139.tiff',0.01,0.5);

3) do not filter
GrainSize=magic_grainsize('047080139.tiff',1,0.5,0);

4) filter and use own filter options
filtoptions.boost=3; filtoptions.CutOff=.2; filtoptions.order=2;
GrainSize=magic_grainsize('047080139.tiff',1,0.5,1,filtoptions);

batch_calib.m
INTERACTIVE batch-process a folder of images in calibration mode using 'calib_grainsize'

batch_magic.m
INTERACTIVE batch-process a folder of images in non-calibration mode using 'magic_grainsize'

SUBFOLDERS
1) subfunctions
containing ...

col2gray.m
convert RGB image to HSI colourspace, and return Intensity (greyscale) image
estparams.m
subfunction used by pdf.m to estimate the parameters of the log-hyperbolic density function
homomorphic.m
#Written by Peter Kovesi (see http://www.csse.uwa.edu.au/) to efficiently filter the images, which can substantially aid grain size estimations
loglikelyhood.m
subfunction used by pdf.m to estimate the parameters of the log-hyperbolic density function
pdf.m
returns the log-hyperbolic density function of the grain size distribution
ReadImDir.m
reads the images in a folder
rescale.m
rescales an image to a defined range

2) utilities
containing ...
crop_eyeball.m

INTERACTIVE tool for cropping images (for example removing non-granular objects from the scene)
- greyscales, crops, filters, and saves a directory of eyeball images ready for analysis with one of the functions above
(size_eyeball.m, auto_im_process.m or magic_size.m)
- modified from Jon Warrick's 'Cobble Cam' routines (see-
[http://walrus.wr.usgs.gov/staff/jwarrick/])
- user-interactive - select the folder of images, and crop each in turn to remove blur, shells, organic material, etc.
Automatically creates and moves cropped images into new folder, at full resolution.
- KNOWN ISSUE: crop within the confines of the axes on the first image. Thereafter, you may crop outside the axes
(makes the process a little quicker)

eyeball_pc.m
INTERACTIVE tool for carrying out manual point-counts of grain lengths on images, for method validation purposes
- interactive function for carrying out manual 'point-counts' of grain diameters on a single image
- USAGE: C=eyeball_pc(im,n,split)
Out: C - vector of grain diameters
In:
im - image matrix (read image into matlab using imread - see 'help imread')
optionals:
n - number of grain diameters to count (recommended between 100 and 500). Defaults to 100
split - either 1, 4, or 16. Number of windows the image will be split into, for counting purposes. Defaults to 4

GSDparams.m
calculation of geometric and arithmetic measures from a grain-size distribution

measure_mm2pix.mINTERACTIVE tool for determining spatial resolution of the image, in mm/pixel
- modified from Jon Warrick's 'Cobble Cam' routines (see-
[http://walrus.wr.usgs.gov/staff/jwarrick/])
- user-interactive function to measure spatial resolution (mm/pixel) in a folder of images taken from different heights
above the bed (with ground scale)

HELP & EXAMPLES
047080139.tiff
sample from the Santa Cruz seafloor observatory (see Buscombe et al (2010b))
calibdata.txt
calibration data for the population of grains from which 047080139.tiff is taken
README.txt
this mini manual

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References
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1. Rubin (2004)

Rubin, D.M. (2004) A simple autocorrelation algorithm for determining grain size from digital images of sediment.
Journal of Sedimentary Research 74, 160-165

2. Rubin et al (2007)
Rubin, DM, Chezar, H, Harney, JN, Topping, DJ, Melis, TS, Sherwood, CR (2007)
Underwater microscope for measuring spatial and temporal changes in bed-sediment grain size.
Sedimentary Geology 202, 402-408.

3. Barnard et al (2007)
Barnard, PL, Rubin, DM, Harney, J, Mustain, N (2007)
Field test of an autocorrelation technique for determining grain size using a digital 'beachball' camera versus traditional methods.
Sedimentary Geology 201, 180-195

4. Buscombe (2008)
Buscombe, D. (2008) Estimation of Grain Size Distributions and Associated Parameters from Digital Images of Sediment.
Sedimentary Geology 210, 1-10

5. Buscombe and Masselink (2009)
Buscombe, D., and Masselink, G. (2009) Grain Size Information from the Statistical Properties of Digital Images of Sediment.
Sedimentology 56, 421-438

6. Warrick et al (2009)
Warrick, J.A., Rubin, D.M., Ruggiero, P., Harney, J., Draut, A.E., and Buscombe, D. (2009)
Cobble Cam: Grain-size measurements of sand to boulder from digital photographs and autocorrelation analyses.
Earth Surface Processes and Landforms 34, 1811 - 1821

7. Buscombe et al (2010)
Buscombe D., Rubin, D.M., and Warrick, J.A. Universal Approximation to Grain Size from Images of Non-Cohesive Unlithified Sediment.
Journal of Geophysical Research - Earth Surface(2010) June 2010