coralCT Documentation

Methods description (adapted from DeCarlo et al., 2015 in *Geology*)

coralCT analyzes computerized tomography (CT) scans of coral skeletal cores for annual calcification and bioerosion rates. CT scanners generate 3-dimensional reconstructions as stacks of 2-dimensional images in Digital Imaging and Communications in Medicine (DICOM) format. Typically, these images have horizontal resolution of ~0.1 mm and vertical resolution of 0.1 to 0.2 mm. Each image is 512x512 pixels, and a scan of a 3 cm diameter and 20 cm long coral core would thus have dimensions 512 by 512 by $1\text{-}2 \times 10^3$ voxels (3-dimensional pixels). coralCT reads DICOM metadata to identify the scan resolution and the slice location of each image. This information is used to build the scaled 3-dimensional core reconstruction. DICOM images store data of X-ray beam attenuation, in Hounsfield units (HU) (Hounsfield, 1973). In substances with composition similar to water, such as soft tissue, HU can be readily converted to density (Prokop and Galanski, 2003). However, this relationship does not translate directly to coral skeleton and instead aragonite-based standards are required (DeCarlo et al., 2015).

The first step in analysis is to map the location of the core in each scan. This is accomplished based on the differences in density between the coral skeleton and surrounding air. However, we must include the pore spaces within the skeleton while only excluding the air space outside of the core. In coralCT, a 2-dimensional Gaussian filter (standard deviation 0.39 mm and clipped at 1.17 mm) is passed over each image to smooth the density contrast between skeletal walls and pore spaces. The filtered image is then converted to binary (within core or outside core) using Otsu's thresholding method (Otsu, 1975), which minimizes within-group variance and maximizes between-group variance.

Coral calcification rate (g cm^{-2} yr^{-1}) is calculated as the product of extension of the coral colony surface during one year (cm yr^{-1}) and density of skeleton over the year's extension (g cm^{-3}). coralCT analyses extension rates by tracing the growth paths of corallites throughout the core. Corallites are identified in each DICOM image by finding local density minima, which are the porous centers of calyces surrounded by dense thecal walls. DICOM images are first filtered with a 2-dimensional Gaussian filter (standard deviation 0.29 mm and clipped at 0.97 mm), which produces one local density minima per corallite. Euclidian-distance nearest neighbors is used to assign each voxel within the core to the nearest corallite center. The mean of all voxels in each DICOM image assigned to a given corallite is the corallite density in that image. Corallites are connected throughout the core by finding the corallite in each image nearest to the location of a corallite in the previous image.

Annual density bands are identified by visual inspection of slabs digitally cut along the vertical growth axis of the core. Local density minima (annual bands) are identified by the software user in several locations in each slab and repeated in at least 4 slabs throughout the core. Low-density bands are mapped in 3-dimensions by interpolating between the coordinates where the bands are marked.

Corallite density tracks are used to objectively adjust the locations of annual density bands. coralCT searches all corallites passing through each annual band for a density minimum within 1 mm of the user-identified band location. If a density minimum is found, the annual band at the location of the given corallite is shifted to match the density minimum. After making adjustments for all corallites passing through each band, the new coordinates of the band are interpolated to map the band in 3-dimensions. Annual bands are then smoothed by a 2-dimensional Gaussian filter (standard deviation 0.97 mm and clipped at 0.97 mm).

For each year's growth (region between 2 low-density bands), extension rates are calculated as the mean length of all corallites traced between the two bands. Annual density for a given corallite is the mean of all voxels, in HU, assigned to that corallite between annual bands and converted to g cm^{-3} based on a density calibration curve (DeCarlo et al., 2015). Calcification rate for each corallite is the product of annual extension and density, and all corallite calcification rates are averaged to calculate the annual whole-core calcification rate.

The above description is based on the default analysis settings for *Porites*. Some parameters are user-adjustable and different coral genera require different filter sizes, which are documented within the coralCT script.

References

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