Litholog generation with the StratigrapheR package & Signal decomposition for cyclostratigraphic purposes

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Keywords: Wouters StratigrapheR
Two main approaches for astrochronology:

- Visual analysis
- Time-series analysis
High resolution precession correlations and tuning (Hilgen et al., 2014)
Time–Frequency Weighted Fast Fourier Transform (Martinez et al., 2015)

Taner band-pass filtering (Martinez et al., 2015)
Introduction

Two main approaches for astrochronology:

- **Visual analysis:**
  - Mainly on **lithological information**, but can be performed on proxy data

- **Time-series analysis**
  - Mainly on **proxies**, but can be performed on lithological information
**Introduction**

Two main approaches for astrochronology:

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Introduction

Two main approaches for astrochronology:

- Visual analysis:
  - Mainly on lithological information, but can be performed on proxy data
- Time-series analysis
  - Mainly on proxies, but can be performed on lithological information

Data processing challenges:

- Visual analysis:
  - High resolution visualisation on large datasets
- Time-series analysis
  - Having intuitive understanding of the mathematic transformations & avoiding misinterpretation
Stratigrapher

Stratigrapher: Integrated Stratigraphy

Version: 0.0.2
Depends: R (≥ 3.5.0)

https://CRAN.R-project.org/package=Stratigrapher

- R package available on the Comprehensive R Archive Network (CRAN)
- Entirely open source
- Implements R functions for integrated stratigraphy, to be used in combination of base R functions
**StratigrapheR**

- Comes with help, information and examples for each function in the common R format calling `?name_of_function`

- A general example of litholog generation is provided in the main help calling `?StratigrapheR`

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### Description

This package includes bases for litholog generation: graphical functions based on R base graphics (e.g. `multisqrs()`), interval gestion functions (with the `as.clim()` function, and other related `clim` functions) and simple svg importation functions (e.g. `pointsng()`), among others. It also includes stereographic projection functions (e.g. the `earnet()`, `earpoints()` and `earplanes()` functions; ear standing for equal area), and other functions made to deal with large datasets while keeping options to get into the details of the data. **IF YOU WANT TO START LEARNING HOW TO CREATE LITHOLOGS WITH STRATIGRAPHER GO SEE THE EXAMPLE BELOW.**

A `StratigrapheR()` function is provided: it generates organisational charts for common use of the functions in the package.

#### Usage

```
StratigrapheR(i = 1:3)
```

#### Arguments

- `i` the index(es) of the organisational charts of the functions in the `StratigrapheR` package

#### Details

- **Package:** StratigrapheR
- **Type:** R package
- **Version:** 0.0.2 (January 2019)
- **License:** GPL-3
Stratigrapher

**pdfDisplay()**

- Uses the default **PDF** reader as a graphical window
- Each plot can be generated as a **PDF** or **SVG** (the name changes incrementally)
```r
library(stratigrapher)
library(dplyr)

basic.log <- litholog(l = bed.example$l, r = bed.example$r, h = bed.example$h, i = bed.example$i)

legend <- data.frame(litho = c("S", "L", "C"),
                      col = c("grey30", "grey90", "white"),
                      density = c(30, 0.10),
                      angle = c(180, 0, 45), stringsAsFactors = FALSE)

bed.legend <- left_join(bed.example, legend, by = "litho")

par(mar = c(1, 5, 1, 2))

plot.new()
plot.window(xlim = c(0, 5), ylim = c(-1.77))
multitrigs(basic.log$xi, x = basic.log$xsy, y = basic.log$stdt,
          col = bed.legend$col, density = bed.legend$density,
          angle = bed.legend$angle)

minorAxis(2, pos = -0.5, las = 1, n = 4)
```

```
> bed.example[1:5,]
  l  r  h colour litho id
1 10 1 3 grey   S B1
2 11 3 4 grey   L B2
3 33 4 5 black C B3
4 44 9 4 white L B4
5 55 1 4 white L B5
```
Stratigrapher

- The package is based on the **incremental addition of elements to a drawing**

- It allows importation of **simple SVG objects**: polygons and polylines (nodes connected by straight lines)
StratigrapherR

- Commitment to **generality**, **versatility**, **modularity**, and **open source**

```R
library(StratigrapherR)
labels <- c("High 5", "Low 5", "5")
ymin <- c(10, -10, 2.5)
ymax <- c(20, 0, 7.5)
plot.new()
plot.window(xlim = c(-0.5, 1.5), ylim = c(-20, 20))
infobar(xmin = 0, xmax = 1, ymin = ymin, ymax = ymax, labels,
  m = list(col = c("grey", "grey", "red"),
            border = "black", density = 10), srt = 0,
  t = list(cex = 1.5, col = "white"))
```
- Basic oriented data functions (visualisation, rotation, data conversion)

- Complete set of functions to deal with stratigraphic interval data

- [-1,1] form for instance
Signal decomposition
Theoretical advances
Signal decomposition

- IMF: Intrinsic Mode Functions

Figure 2. A typical intrinsic mode function with the same numbers of zero crossings and extrema, and symmetry of the upper and lower envelopes with respect to zero.

(Huang et al., 1998)
Signal decomposition

- IMF: Intrinsic Mode Functions

Figure 2. A typical intrinsic mode function with the same numbers of zero crossings and extrema, and symmetry of the upper and lower envelopes with respect to zero.

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Signal decomposition

Fig. 9. The IF of the sample data based on various methods: direct quadrature (DQ), HT, and NHT, with the data plotted at one-tenth scale.

(Huang et al., 2009)

Fig. 14. The amplitude determined from various methods: TEO, GZC, and HT, spline fitting used in DQ and NHT. The spline line is identical to the theoretic value; therefore, it is defined as the envelope in the direct quadrature method.
Signal decomposition: the **EMD**

- **EMD**: Empirical Mode Decomposition

(Huang & Wu, 2008)
Signal decomposition: the EMD

EMD: Empirical Mode Decomposition

(Huang & Wu, 2008)
Signal decomposition: the EMD

○ EMD: Empirical Mode Decomposition

(modified from Huang & Wu, 2008)
Signal decomposition: the **EMD**

- **EMD**:
  - Empirical
  - Mode
  - Decomposition

(modified from Huang & Wu, 2008)
Signal decomposition: the **EMD**

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Signal decomposition: the **EMD**

- **EMD**: *Empirical Mode Decomposition*
- Local extrema
- Envelopes (spline)
- Mean of envelopes
- Prototype of IMF (Signal – Mean)
- Repetition of process to refine IMF (sifting)

(modified from Huang & Wu, 2008)
Signal decomposition: the EMD

- Empirical Mode Decomposition

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- Repetition of process to refine IMF (sifting)
- Remainder (Signal – refined IMF)

(modified from Huang & Wu, 2008)
Signal decomposition: the **EMD**

- **EMD**: Empirical Mode Decomposition
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(modified from Huang & Wu, 2008)
Hilbert spectrum of a digitalised sound “Hello”  
(Wu & Huang, 2009)
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Figure 1: (a) Clean insolation signal, showing variations in insolation with time for 65° N 21 June. (b) Clean insolation periodogram, depicting the frequency spectrum of the signal. (c) Insolation signal with white and red noise and varying sedimentation rate. (d) Modified insolation periodogram, illustrating the changes in the frequency spectrum. (e) Modified insolation spectrogram, highlighting frequency changes over depth. (f) Estimated insolation spectrogram, providing a visual representation of the insolation variations. 

Sinnesael et al., 2016
20 kyr (precession), 40 kyr (obliquity), 100 kyr & 400 kyr (eccentricity)
EMD: allows decomposition in IMF,
In turn it allows the determination of \textit{instantaneous frequency, amplitude and ratio}
\textbf{Entirely reversible}: from the instantaneous parameters you can go back to the position in the components (modes) and in the original signal

No matter the decomposition algorithm, you can verify its result visually
Conclusion

- Two tools to link visual and time-series analysis approaches for cyclostratigraphy:

  - **Stratigrapher**: Deal with lithological information in R
  - **EMD**: Provides a new (rough?) time-series analysis scheme, allowing reversibility and visual checking
Thank you for your attention 😊
References


