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

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Introduction

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

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- 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
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Data processing challenges:

- Visual analysis:
  - High resolution visualisation on large datasets

- Time-series analysis
  - Having **intuitive understanding** of the mathematic transformations & **avoiding** misinterpretation
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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**Stratigrapher: integrated stratigraphy for R**

**Description**

This package includes bases for litholog generation: graphical functions based on R base graphics (e.g. multigens()), interval gestion functions (with the as.lim() function, and other related .lim functions) and simple svg importation functions (e.g. pointsvg()) 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**

```r
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))

multitons(basic.log$s, x = basic.log$x, y = basic.log$d,
          col = bed.legend$col,
          density = bed.legend$density,
          angle = bed.legend$angle)

minorAxis(x = 2, pos = -0.5, las = 1, n = 4)
```
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).
Commitment to **generality**, **versatility**, **modularity**, and **open source**

```{r}
library(Stratigrapher)
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.

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.

(Huang et al., 2009)
Signal decomposition: the **EMD**

- **EMD**: Empirical Mode Decomposition

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

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Signal decomposition: the \textbf{EMD}

\begin{itemize}
  \item EMD: \textbf{E}mpirical \textbf{M}ode \textbf{D}ecomposition
\end{itemize}

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

- **EMD**: Empirical Mode Decomposition

- **Signal**
- **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**

- **EMD**: Empirical Mode Decomposition

Local extrema
- Envelopes (spline)
- Mean of envelopes

Prototype of IMF
- (Signal – Mean)

Repetition of process to refine IMF (sifting)

Remainder
- (Signal – refined IMF)

(modified from Huang & Wu, 2008)
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)
- Remainder (Signal – refined IMF)

(modified from Huang & Wu, 2008)
Hilbert spectrum of a digitalised sound “Hello”

(Wu & Huang, 2009)
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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.

(Fontugne et al., 2013) (Huang et al., 2009)
20 kyr (precession), 40 kyr (obliquity), 100 kyr & 400 kyr (eccentricity)
Signal decomposition: the **EMD**

- **EMD**: allows decomposition in **IMF**,
- In turn it allows the determination of **instantaneous frequency, amplitude and ratio**
- **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


