When did author B take over for author A? Confidence Distributions for Change-Points

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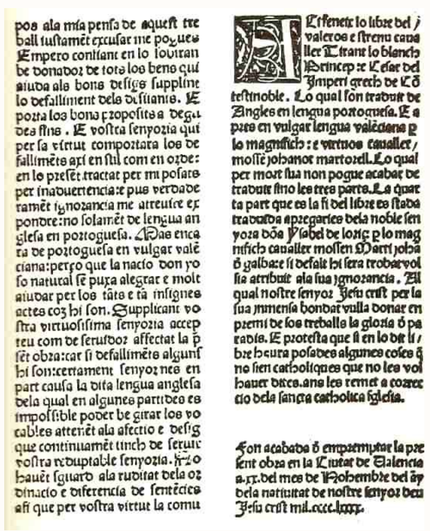
Introduction

The 15th century Catalan chivalry romance *Tirant lo Blanch* is an important work in medieval literature, and a perfect subject for a change-point analysis. The first author, Joanot Martorell, died before the completion of the novel and his friend and fellow knight, Marti Joan de Galba, took over the task. Many analyses, both statistical and literary, have attempted to identify exactly where the change-of-author takes place. Here, we propose our solution, using a new method which both estimates the change-point and provides the associated confidence curve.

Data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Our data is the text of an ancient Catalan book with 487 chapters and we search for the chapter where author B takes over from author A. From the text we can measure, for all chapters $i = 1, \ldots, 487$:

- y_i = average word length in chapter i, m_i = number of words in chapter i
- $\mathbf{z}_i$ = the vector of proportions of words of length 1 to 10 in chapter i.

For example $z_1 = (0.08, 0.23, 0.17, 0.08, 0.13, 0.08, 0.06, 0.07, 0.04, 0.07)$, so 8% of the words in chapter 1 are one-letters words (length 1), and 7% of the words have more than 10 letters.

General method

We denote the unknown change-point by τ. To estimate τ and the associated uncertainty we use a method described in Cunen, Hermansen and Hjort (2016). In this case, we assume independent data y_i, following a parametric model with

$$Y_i \sim f(y, \theta_L) \quad \text{for } i \leq \tau$$
$$Y_i \sim f(y, \theta_R) \quad \text{for } i \geq \tau + 1$$

We can then form the profile log-likelihood function

$$\ell_{\text{prof}}(\tau) = \max\{\ell(\tau, \theta_L, \theta_R) \colon \text{all } \theta_L, \theta_R\}$$
$$= \sum_{i \leq \tau} \log f(y_i, \widehat{\theta}_L(\tau)) + \sum_{i \geq \tau+1} \log f(y_i, \widehat{\theta}_R(\tau)).$$

The maximiser $\widehat{\tau}$ of this function is a good estimate of the change-point. From this we form the deviance function

$$D(\tau, Y) = 2\{\ell_{\text{prof}}(\widehat{\tau}) - \ell_{\text{prof}}(\tau)\}.$$

In order to find the full confidence curve (essentially confidence intervals at different levels) we need the estimated distribution of $D(\tau, Y)$ for each position τ,

$$\text{cc}(\tau) = \Pr_{\tau, \widehat{\theta}_L, \widehat{\theta}_R}\{D(\tau, Y) < D(\tau, y_{\text{obs}})\}.$$

This can be computed via stochastic simulation: we generate a large number B of simulated datasets Y^* from $f(y, \widehat{\theta}_L)$ to the left of τ and $f(y, \widehat{\theta}_R)$ to the right, at each candidate value τ, and calculate

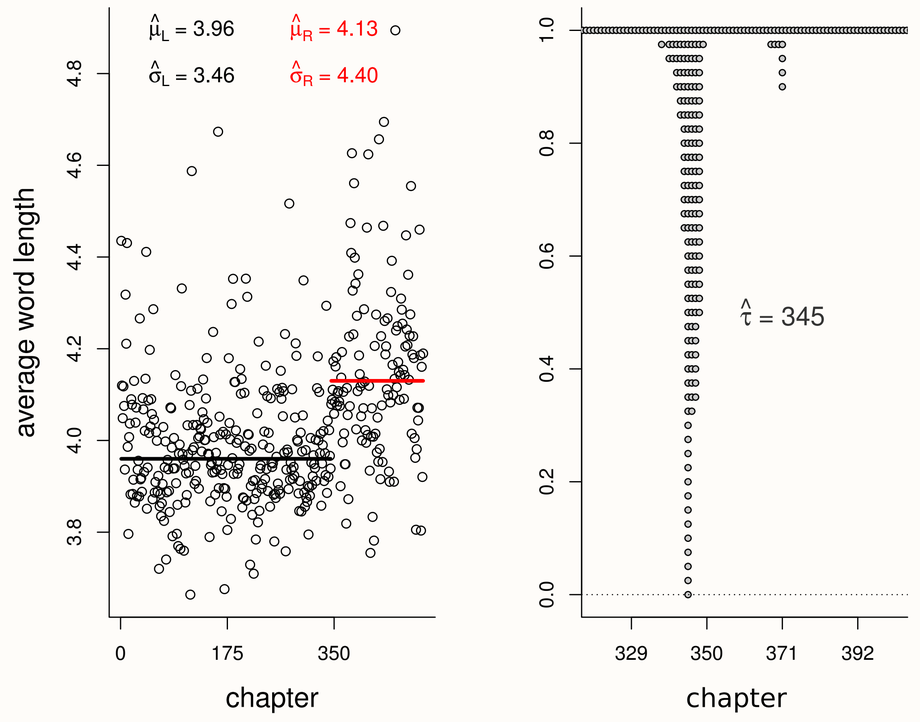
$$\text{cc}(\tau) = \frac{1}{B} \sum_{j=1}^{B} I\{D(\tau, Y_j^*) < D(\tau, y_{\text{obs}})\}.$$

Average word length

For the average word length in each chapter we assume the following model,

$$y_i \sim \text{N}(\mu_L, \sigma_L^2/m_i) \text{ for } i \leq \tau$$
$$y_i \sim \text{N}(\mu_R, \sigma_R^2/m_i) \text{ for } i \geq \tau + 1.$$

According to this model, our best guess is that the change of author takes place in chapter 345. Author B uses longer words on average, and is also more variable across chapters. (The mean number of words per chapter is $\bar{m} = 927$.)

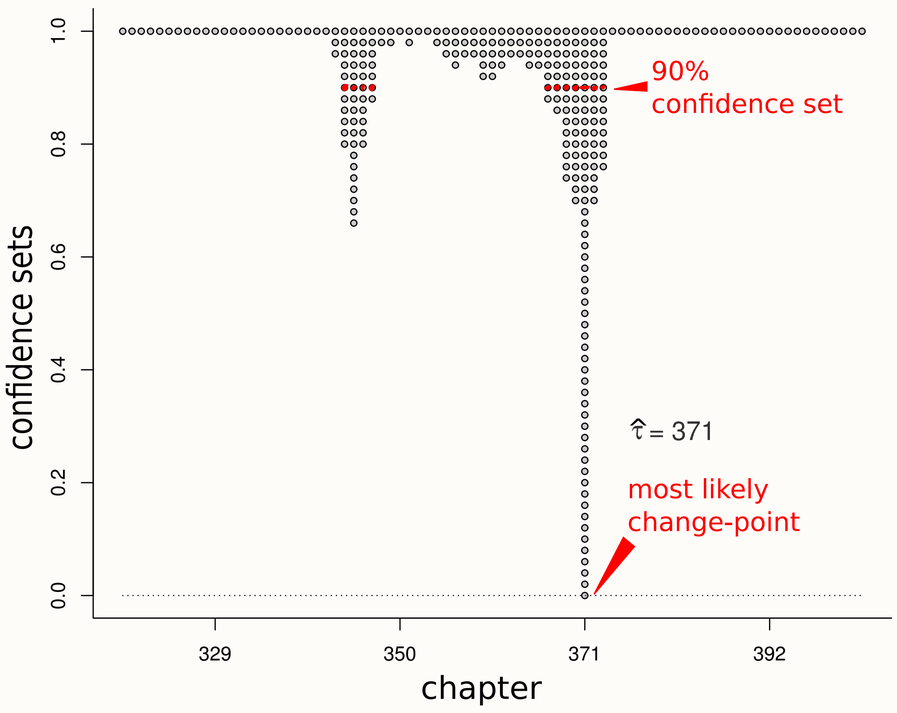


Proportion of words of different length

For the vector of proportions of words of length 1 to 9 (disregarding element no. 10, since the proportions sum to one) we assume the following multinormal distribution,

$$\boldsymbol{z}_i \sim \text{N}_9(\boldsymbol{\xi}_L, \Sigma_L/m_i) \text{ for } i \leq \tau$$
$$\boldsymbol{z}_i \sim \text{N}_9(\boldsymbol{\xi}_R, \Sigma_R/m_i) \text{ for } i \geq \tau + 1.$$

The estimated mean vectors indicate that author B differs from author A in using more one-letter words and also using more long words (with more than 7 letters). The change-of-author point-estimate according to this model is chapter 371, but the model also places some confidence in the change taking place earlier, in chapter 345.



Conclusion and references

Using word lengths as a measure of literary style, we have discovered two clear candidates for the chapter where Marti Joan de Galba took over from Joanot Martorell. Both our analyses indicate that the change in *Tirant lo Blanch* takes place in the last quarter of the book. This is consistent with previous studies, both statistical and literary.

Chen, H. & Zhang, N. (2015). Graph-based change-point detection. *Annals of Statistics* 43, 139–176.

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Riba, A. & Ginebra, J. (2005). Change-point estimation in a multinomial sequence and homogeneity of literary style. *Journal of Applied Statistics* 32, 61–74.

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