COVID19 reproduction Number estimation

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Abstract
from numbers of daily infected people using nonsmooth convex optimization
This work reports the estimation of the space and time evolution of COVID19 reproduction Number for around 200 countries around the world, the 49 continental states of the USA and the 96 Metropolitan France counties. Estimation is based on the numbers of daily new infections provide by John Hopkins University, and Santé Publique France. Estimation makes uses of nonsmooth convex optimization. Work performed by the Signal, System and Physics team at ENS Lyon and CNRS. Full paper has been published in a major scientific journal PLoSOne:
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1 Introduction

This work proposes an original estimation of the space and time evolution of $R(t)$ for the Covid19 pandemic obtained by combining:

- a relevant epidemiological model proposed by an international group of epidemiologists from the study of several previous pandemics/epidemics [1];

- an original functional optimization based non linear filtering of daily new infections counts to provide piecewise smooth in time and space estimates of $R(t)$,

- the daily counts of new infections reported by Santé Publique France (for France) and John Hopkins University for the world.

Estimation is based on non-smooth (proximal-based) optimization, with a Poisson prior for the data fidelity term and a Laplacian penalization to favor piecewise linear estimate. Estimates are computed daily and reported automatically at perso.ens-lyon.fr/patrice.abry in the form of:

- time evolution plots for $R(t)$ per countries [https://perso.ens-lyon.fr/patrice.abry/Covid_France_today.png]

- space maps for $R(t)$ for the French Counties [http://perso.ens-lyon.fr/patrice.abry/FranceSPF.png]

- video along time for $R(t)$ for the French Counties [https://perso.ens-lyon.fr/patrice.abry/DeptRegul.mp4]

- space maps plots for the world [https://perso.ens-lyon.fr/patrice.abry/WorldR.png]

- space maps plots for the USA [http://perso.ens-lyon.fr/patrice.abry/USADeptReg.png]


- a detailed report for all the countries of the world [https://perso.ens-lyon.fr/patrice.abry/PlotCovid.pdf]

Further, animated and interactive maps are being developed and preliminary version are available at:


- For the World [http://betternet-rumbi.lhs.loria.fr/website/covid/monde].
These reports aim to make available scientific assessment of the pandemic growth:

- not only to scientific and experts;
- but also to the press and to decision makers;
- and to citizens and to anyone interested in a relevant independent scientific information on the status of the pandemic without media bias and noise.

Up to Dec. 14th. data were provided by the European center for Disease Control https://www.ecdc.europa.eu/. This was a great website, but data availability has been abruptly stopped on Dec. 14th, 2020, with no prior notice and
2 France

2.1 Population vs. Hospital based estimates

Figure 1: Daily Estimates for France from two different sources of data. Population daily new infection counts from John Hopkins University. Red (resp., Blue) correspond to rapidly (resp., slowly) varying estimates. $\beta$ is the derivative of $R$.
Figure 2: **Daily Estimates for France from two different sources of data.** Hospital based counts of daily new infection from Santé-Publique-France (right). Red (resp., Blue) correspond to rapidly (resp., slowly) varying estimates. $\beta$ is the derivative of $R$. 
2.2 Daily estimates for France from two datasources

Figure 3: **Daily Estimates for France from two different sources of data.** Population daily new infection counts from John Hopkins University (left) vs. Hospital based count of daily new infection from Santé-Publique-France (right). Red (resp., Blue) correspond to rapidly (resp., slowly) varying estimates. $\beta$ is the derivative of $\hat{R}$. 
2.3 France Départements

Figure 4: \( \hat{R} \) for the French Departments Independent (per département) estimates (left) vs. graph-based spatially regularized estimates (right). \( \hat{R} \) (top) vs. \( \beta \) (derivative of \( \hat{R} \)) (bottom). Movies for the whole period are made available at perso.ens-lyon.fr/patrice.abry/DeptRegul.mp4 and updated on a regular basis.
Figure 5: Graph-based spatially regularized estimates of $R$ for the 96 Metropolitan France Departments, as a functions of days. A Movie for the whole period is made available at perso.ens-lyon.fr/patrice.abry/DeptRegul.mp4 and updated on a regular basis. Hospital-based data from Source3 (SPF).
2.4 France: Impacts of outliers

Figure 6: **Daily Estimates for France** Estimation of $R(t)$ and of the outliers are performed in single step (left) vs. Outliers are preprocessed first followed by the estimate of $R(t)$. Population daily new infection counts from the European Centre for Disease Prevention. Red (resp., Blue) correspond to rapidly (resp., slowly) varying estimates. $\beta$ is the derivative of $\dot{R}$. 
3 Worldwide COVID-19

3.1 Map of the World

Figure 7: World Map for the current estimate of $R(t)$. 
3.2 Maps of the USA

Figure 8: Current estimate of $R(t)$ for the USA.
Figure 9: Continental USA Map for the current estimate of $R(t)$. 
3.3 Europe

Figure 10: Daily Estimates.
Figure 11: **Daily Estimates.** Red (resp., Blue) correspond to rapidly (resp., slowly) varying estimates. $\beta$ is the derivative of $R$. 
Figure 12: Daily Estimates.
3.4 America

Figure 13: Daily Estimates.
Figure 14: **Daily Estimates.** Red (resp., Blue) correspond to rapidly (resp., slowly) varying estimates. $\beta$ is the derivative of $R$. 

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3.5 Asia

Figure 15: **Daily Estimates.** Red (resp., Blue) correspond to rapidly (resp., slowly) varying estimates. $\beta$ is the derivative of $R$. 
Figure 16: **Daily Estimates.** Red (resp., Blue) correspond to rapidly (resp., slowly) varying estimates. $\beta$ is the derivative of $R$. 
3.6 Africa

![Graphs showing daily estimates for Morocco, Algeria, Tunisia, and Egypt from June 2021 to January 2021.](image)

**Figure 17:** Daily Estimates. Red (resp., Blue) correspond to rapidly (resp., slowly) varying estimates. $\beta$ is the derivative of $R$.

References

Figure 18: **Daily Estimates.** Red (resp., Blue) correspond to rapidly (resp., slowly) varying estimates. $\beta$ is the derivative of $R$. 