



- Health studies @ IFISC
- Projects on health management
- Biomedical data analysis and modeling projects
- Projects on disease spread and human mobility
- Projects in collaboration with HUSE (Son Espases Hospital)

We are interested in health related problems ranging many scales.

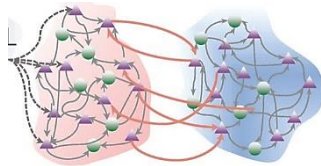
Molecular scale



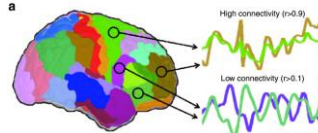
Cellular scale



Cell population scale



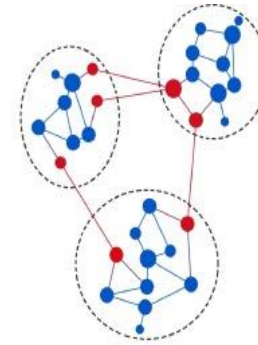
Organ scale



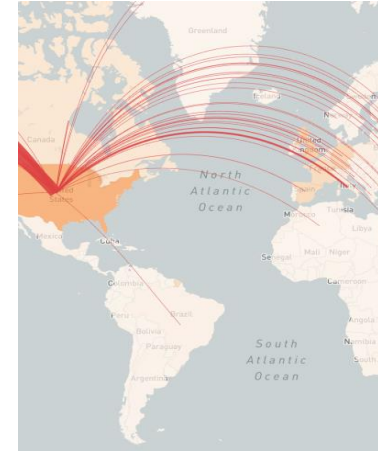
Human scale



Community scale



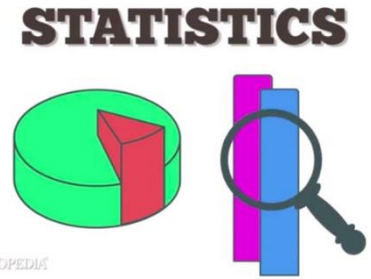
Global scale



# Statistical vs. mechanistic models in medicine

## Statistical models: Bayesian, Machine Learning, etc.

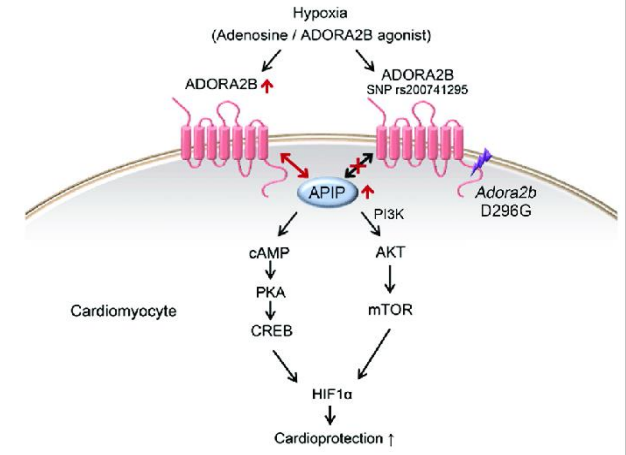
- Use data (e.g. medical trials, images, patient data)
- Look for patterns, correlations.
- Make predictions about patients (e.g., survival analysis).
- Extrapolates from the past.
- Advantage: rooted in real-world data.
- Disadvantage: Cannot do 'experiments'. Cannot answer 'what-if' questions.



## Mechanistic models

- Models of the actual processes
- Necessarily simplified (to different degrees)
- **Advantages:** can do in-silico experiments, can ask “what-if” questions, sharpens thinking about the processes, guide experiments.....
- **Disadvantages:** sometimes too far from reality

Ideally, a combination of the two approaches should be used:  
**Data-driven Models**



# Health management



## Analysis of Electronic Health Records



Massimiliano Zanin

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**Objective:** Reconstruct the history of patients from EHR, by analysing the doctors' notes, and using NLP

**Collaboration:** UPM, ETS Ingenieros Informáticos; Hospital Universitario Puerta de Hierro Majadahonda, Medical Oncology.

**Funding source:** EU H2020 program, Project CLARIFY: 875160.

**Results:** Several algorithms were developed to process Spanish texts. There was a data analysis phase, to understand what the risk factors were for each patient. A Portuguese SME developed a web portal, where physicians could enter and consult all patient information.

## Emergency departments: modeling and prediction of patient flow



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**Type of data:** Data provided by IBSalut / anonymized information of patients arriving at the emergency departments of the public hospitals (2014-2019).

**Collaboration:** work done @ IFISC in collaboration with HSLL

## Scientific questions:

- Statistical analysis of data; Modelling of patient flux using stochastic queue theory, agent based models, etc.
- Predictions using general autoregressive models and ML tools.

**Results:** prediction in the number of arrival patients per hour with an accuracy of 62 % (1 SD) and 92 (2 SD) (1/2 days in advance).

**Outcome:** 2 TFM. 1 about time series analysis & prediction and a second one on modeling patient flux, including ED and UCE

**Future Opportunities:** 1 PhD student (La Caixa Foundation program) working with a complete dataset (pandemic and post-pandemic data)

**Aim:** Develop tools to advice hospital management in order to reduce the overflow of the service

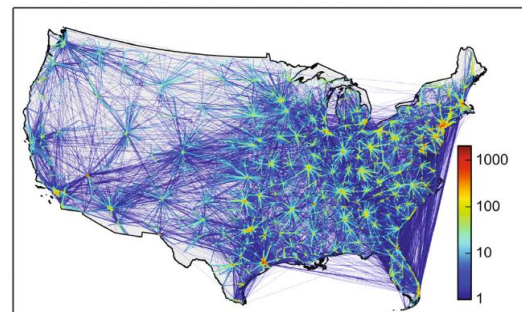




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Juan Fernández-Gracia

Víctor M. Eguíluz

**Partners:** Harvard School of Public Health, IFISC

**Funding:** NIH (National Institute of Health), HRSA (Health Resources and Services Administration), Spain y EU-FEDER; Finished.

**Objectives:** To evaluate the effect of the hospital transfer network on the prevalence of hospital-acquired infections.

**IFISC contribution:** Data analysis, modeling, visualization and interpretation of the results.

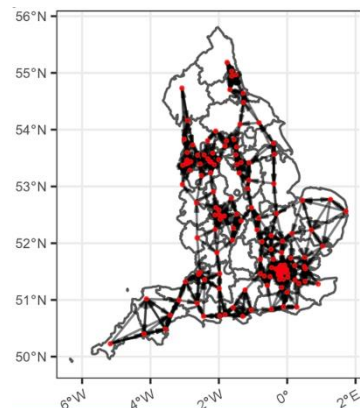
**Results:** The knowledge of the network structure allowed us to detect 80% of infections by monitoring only 2% of the hospitals.

# Optimization and transfer of ICU patients in hospital networks

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Lucas Lacasa



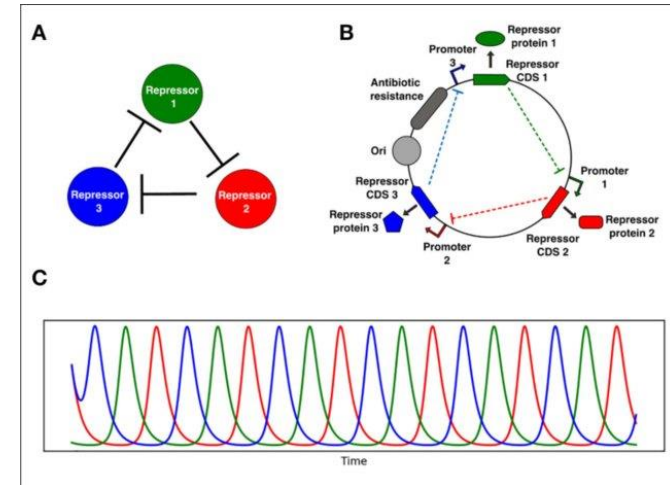
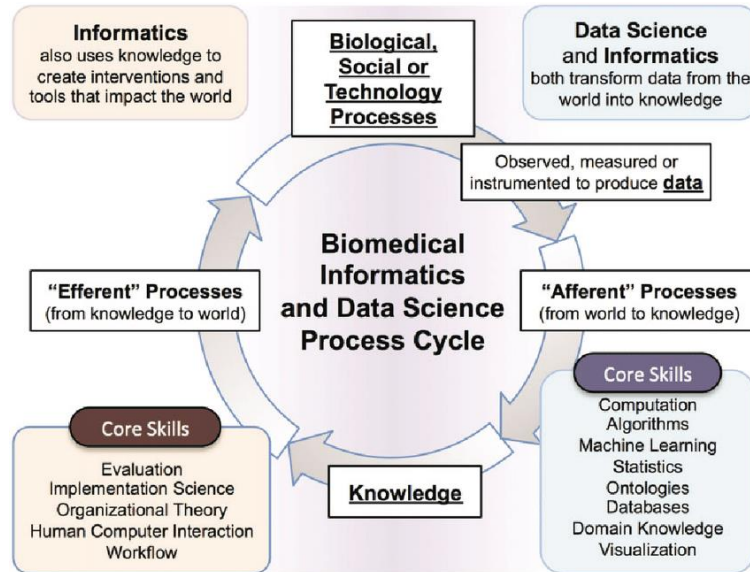
**Type and source of data:** ICU capacity (geopositioned), hospitals in UK

**Type of collaboration:** Univ. Exeter, Bristol, QMUL, NHS; Funding: QMUL

**Question:** Can we apply routing methods to optimally transfer patients in hospital networks?

**Results:** Optimization of patient distribution to maximize care. Additional ~ 300-500 patients could be cared without increasing the hospital capacity.

# Biomedical data analysis and modeling projects



## Mechanistic models of biological populations

- Evolution of cancer
- Emergence of antibiotic resistance
- Optimal screening strategies for multiple myeloma
- Modelling progression of atrial fibrillation
- Network meta analysis (medical trials)
- Brain circuits; Synchronization, neuronal modulation



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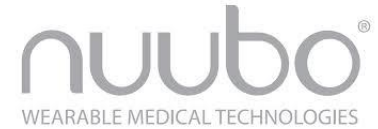
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**Detection of cardiac arrhythmias** using a single lead and ML techniques; Collaboration agreement with the company Nuubo to develop software for the early detection of cardiac arrhythmias.

**Data analyzed:** MIT-BIH Arrhythmia Database and American Heart Association (AHA) ECG Database.

**International patent:** "System and methods for the classification of cardiac beats related to arrhythmia" (US10383539B2; active until 30/11/2037)



Yolanda Sanz

## Collaborative project: Predicting obesity in children

IATA (Instituto de Agroquímica y Tecnología de Alimentos)

**Funding:** EC, Program EIT food, 2021-2022. (Budget: ~ 715 k€)

Develop machine learning tools to:

- predict infancy obesity
- identify biomarkers for personalized treatment and prevention



Silvia Ortín



Claudio Mirasso

- **Objectives:** To study the impact of microbiota/diet on the development of childhood obesity (1000 children aged 3 to 7 years).
- **Preliminary results:** data from 70 children, the inclusion of microbiota improves the prediction of the development obesity; accuracy ~ 72%.

- **Partners:** Instituto de Neurociencias (Alicante) and Fundación para el Fomento de la Investigación Sanitaria y Biomédica de la C. Valenciana



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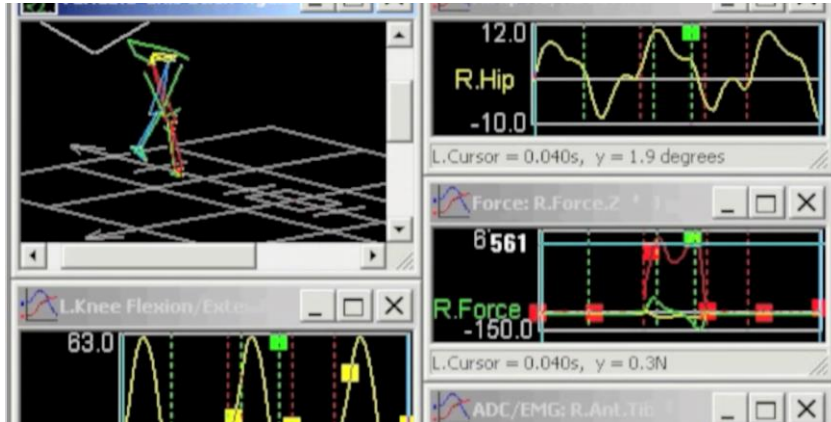
Silvia Ortín

Develop ML tools to predict survival time using data from:

- EHR and questionnaires filled out by clinical staff every 8h.
  - Temperature, electrodermal activity, acceleration and cardiac activity, during 24/7 using a wrist-wearable.
- **Funding:** AVI (2018-2022); Budget: 50 k€.
  - **Objectives:** Improve palliative care and the dying process in terminally ill cancer patients admitted to hospital units.
  - **Results:** A ML program (~300 patients) predicted with 80% accuracy the probability that the patient dies in the next 3 days.



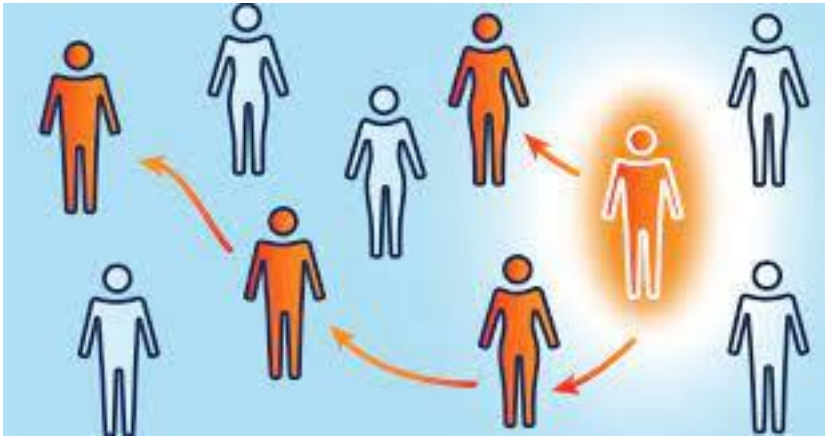
- **Data:** Gait (kinetics and cinematics) data: children with Cerebral Palsy and Idiopathic Toe Walking; Elders with MCI and AD.
- **Collaboration:** UAM, Dep. Anatomía, Histología y Neurociencia; Escuela de Fisioterapia de la ONCE; Vall d'Hebron University Hospital, Paediatric Neurology
- **Objective:** Use statistical physics' concepts to identify what is wrong in the gait of patients, and, create models to diagnose and treat them.



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## Disease spread and human mobility



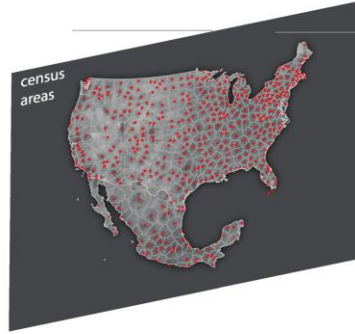
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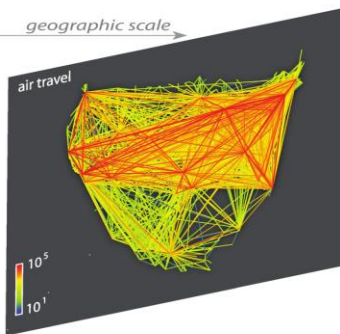
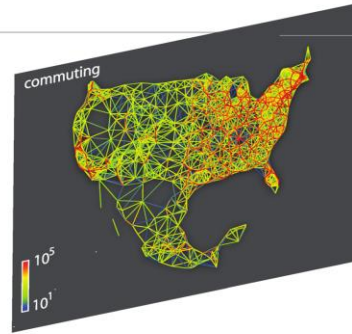


Jose Ramasco  
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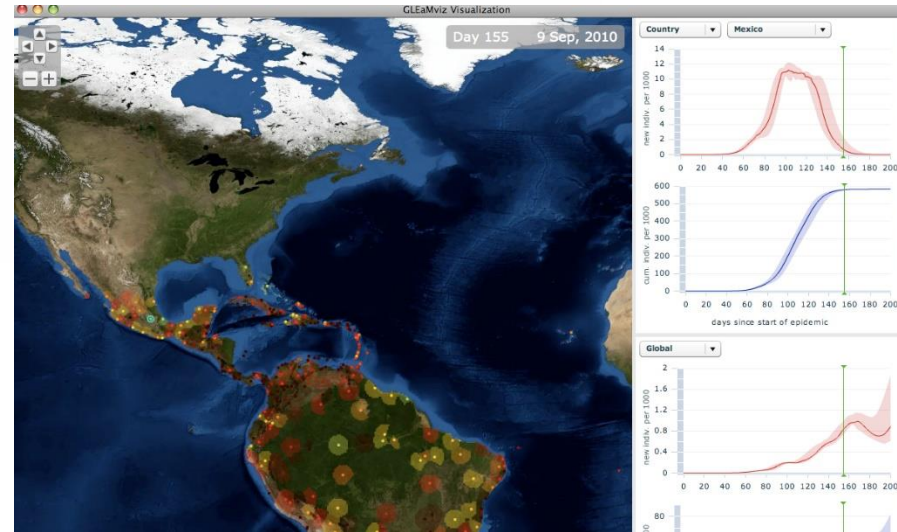
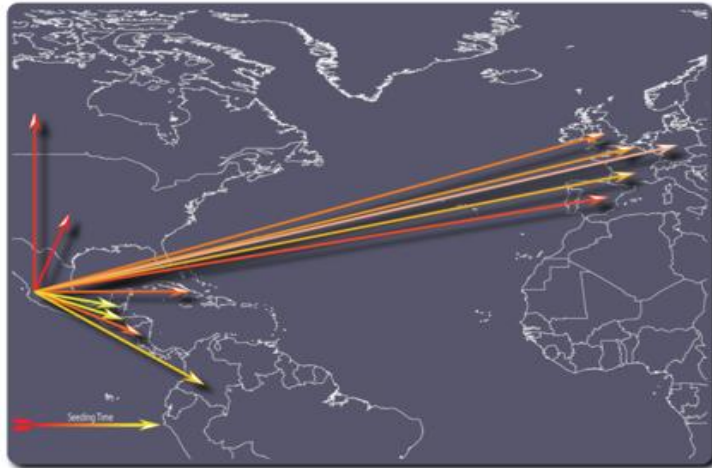
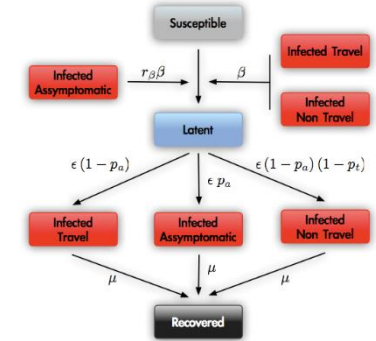
population layer



mobility layers



geographic scale

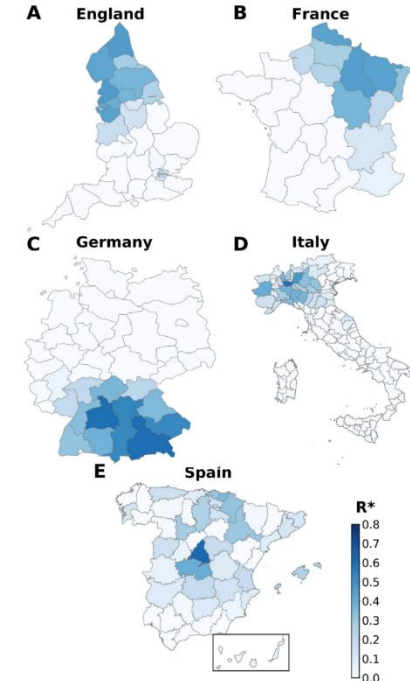
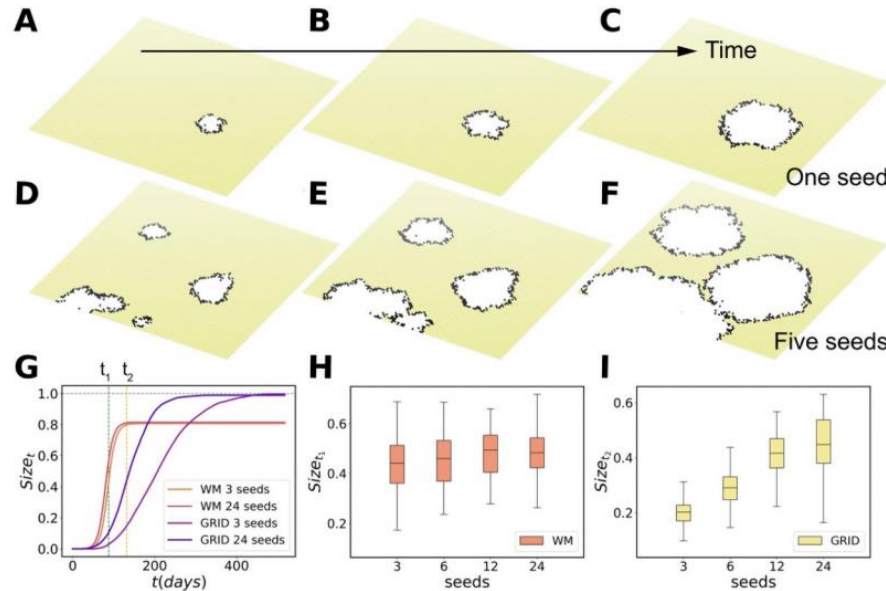




## Models: importance of multiple seeds

Interplay between mobility, multi-seeding and lockdowns shapes COVID-19 local impact

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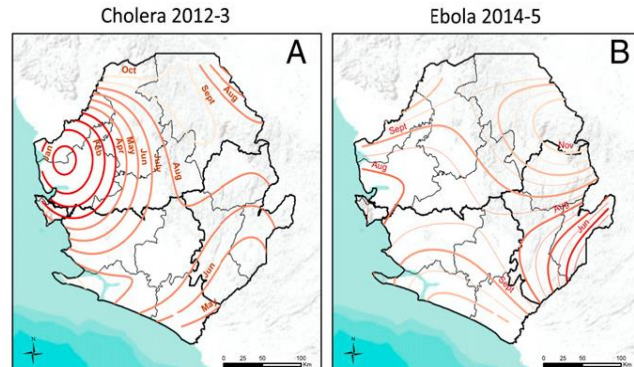


**Partners:** Harvard School of Public Health, IFISC

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Juan Fernández-Gracia



**Funding:** National Institute of Health & World Health Organization; finished.

**Objectives:** Study the propagation of Cholera and Ebola in Sierra Leone.

**IFISC:** Mathematical modeling, computational implementation, visualization and interpretation of the results.

**Results:** Unified spatio-temporal patterns were found using the same model by changing only 1 parameter.



Advisor to the Ministry of Science and Innovation and Balearic Islands Government.

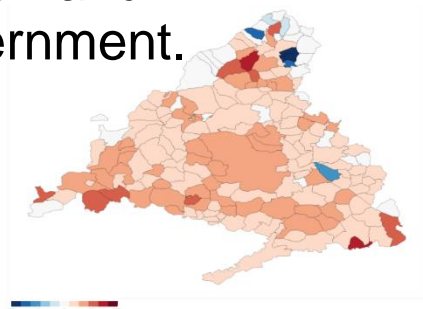


Javier Ramasco

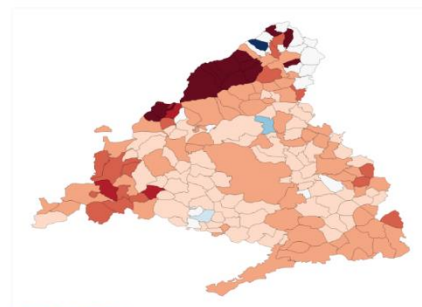
jramasco@ifisc.uib-csic.es

Mobile telephone data

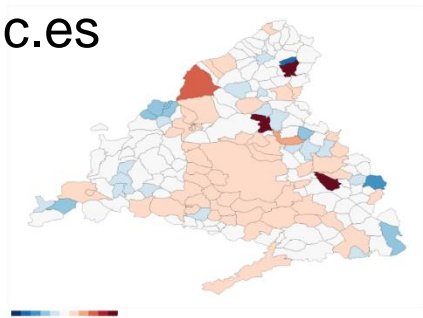
Pioneering studies: March 2020



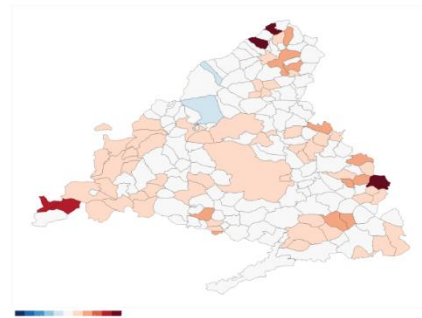
(a) Confinamiento (fase 0) a fase 0 con medidas de alivio



(b) Fase 0 con medidas de alivio a fase 1

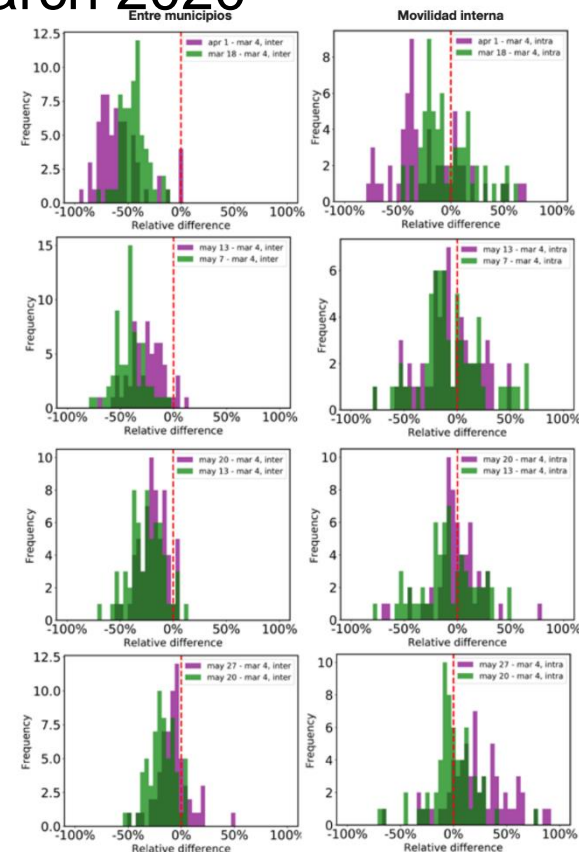


(c) Fase 1 a fase 2



(d) Fase 2 a nueva normalidad

Figura 17: Cambio de movilidad entre municipios entre fases de desconfinamiento



<https://distancia-covid.csic.es>

Balearic Islands

**Partners:** Harvard School of Public Health, IFISC, Hospital Vall d'Hebron, EAWAG

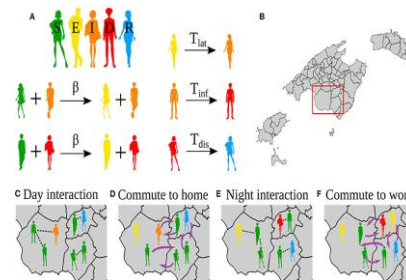


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Víctor M. Eguíluz



Juan Fernández-Gracia

**Funding:** Ministry of Science and Innovation of Spain; finished

**Objectives:** Analyze the first wave of covid in the Balearic Islands and its implication for the risk of subsequent waves.

**IFISC contribution:** Data gathering and analysis, mathematical modeling, computational implementation, visualization and interpretation of the results.

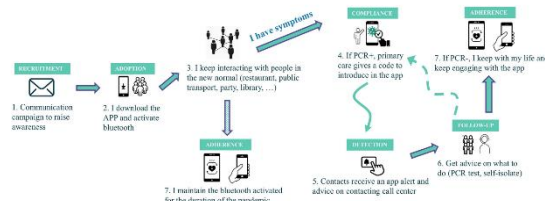
**Results:** High risk of second waves were found due to low immunization rates

## Validation of the radar-COVID contact tracing APP



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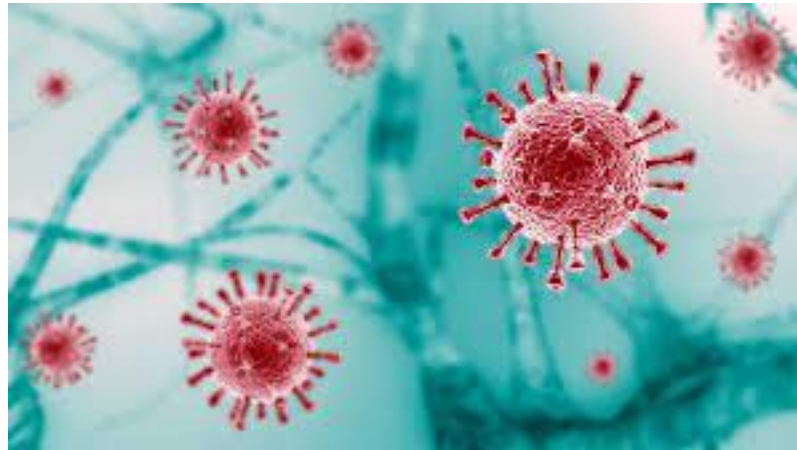


**Type and origin of data:** Experiment on the Canary Islands (La Gomera) pilot test contact tracing app Radar Covid /App developed by Indra.

**Type of collaboration:** SEDIA (Ministerio de Economía) + universities (QMUL, Harvard, URV, etc.) + Indra. 2020-2021; **Funding:** SEDIA

**Results:** Positive validation with bottleneck in the need for critical adoption (P2P).

## Projects developed jointly with HUSE





# COVID-19: Predicting ICU hospitalization/death events using medical care records and machine learning tools

Tarun Khajuria<sup>1</sup>, J A. Pou Goyanes<sup>2</sup>, Claudio Mirasso<sup>3</sup>, Raul Vicente<sup>1</sup>

1- Institute of Computer Science, University of Tartu, Estonia; 2- HUSE; 3- IFISC



UNIVERSITY OF TARTU  
Institute of Computer Science



**Data:** Provided by HUSE. Anonymized information of COVID-19 patients

**Funding:** No funding

We trained three algorithms to predict clinical severity of patients 2, 3, and 5 survival days, ICU admission or discharge events.

	5 días antes del evento	3 días antes del evento	2 días antes del evento
# de pacientes	247	285	309
Pacientes con "Evolución severa"	37	53	61
Precisión	0.86261	0.88771	0.92688
Sensibilidad	0.21621	0.62264	0.70491

**Precision:** proportion of correct global predictions

**Sensitivity:** proportion of correctly predicted cases of severe evolution

## Comparative study between 1st and 2nd wave of COVID-19 on Mallorca.

- We evaluated whether clinical markers of patients admitted to HUSE with COVID-19 have changed during the two waves.
- We developed a stratified analysis & machine learning
- Patients were classified into Wave 1 or Wave 2 with an accuracy  $\sim 83\%$

- **Partners:** IDISBA, IB SALUT, IFISC and UIB (IP: Ignacio Ricci Cabello)



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- **Funding:** Ministerio de Ciencia e Innovación. Proyectos I+D+i Pruebas de Concepto
- **Objectives:** Boost the transferability of DiabeText, a digital tool that integrates medical records and sends messages to patients with diabetes to encourage improve self-care; Starts in 2023.
- **IFISC contribution:** To develop machine learning tools to improve the personalization and effectiveness of sent messages.