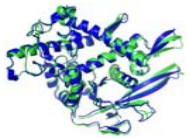
Health Research and Management

- 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)

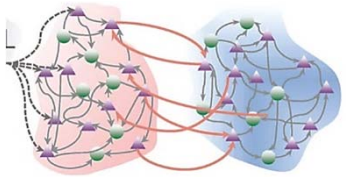
We are interested in health related problems ranging many scales.

Molecular scale

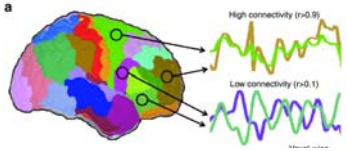


Cellular scale

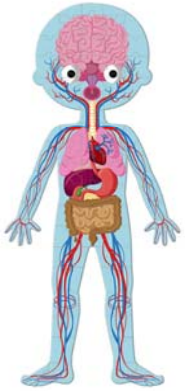
Cell population scale



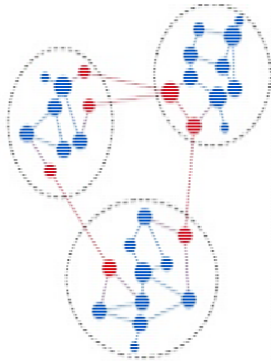
Organ scale



Human scale



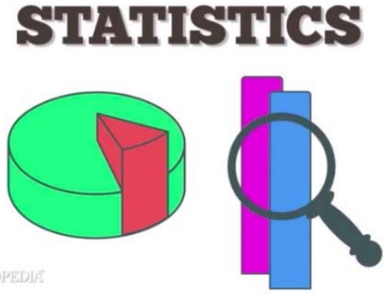
Community scale



Global scale

Statistical vs. mechanistic models in medicine

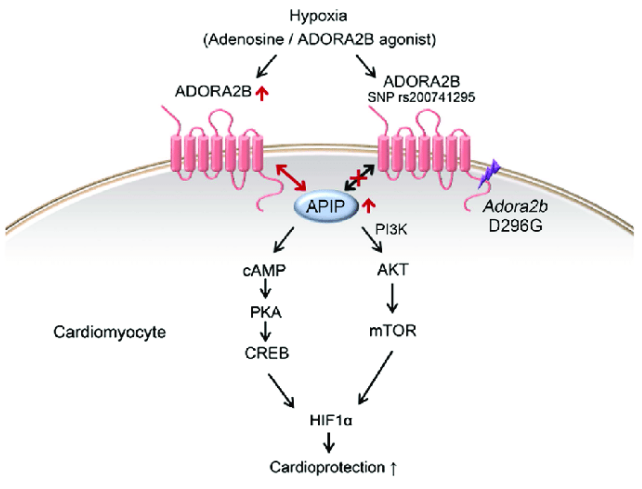
Statistical models: **Bayesian, Machine Learning, etc.**



- 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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Ángel del Río, HSLL
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Claudio Mirasso
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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

Health management

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Juan Fernández-Gracia

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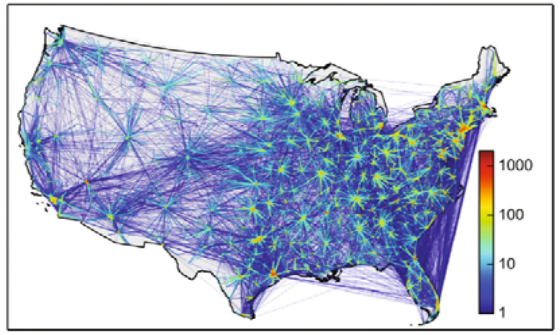
Víctor M. Eguíluz



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.

Scientific Reports 7, 2930 (2017)

Optimization and transfer of ICU patients in hospital networks

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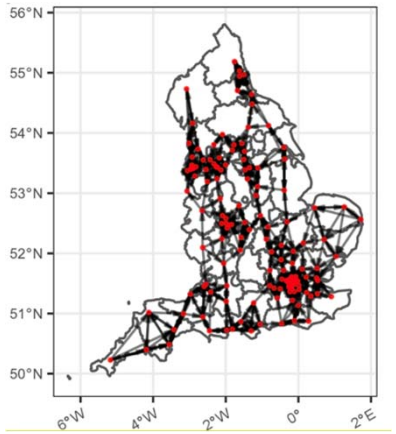
Lucas Lacasa



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

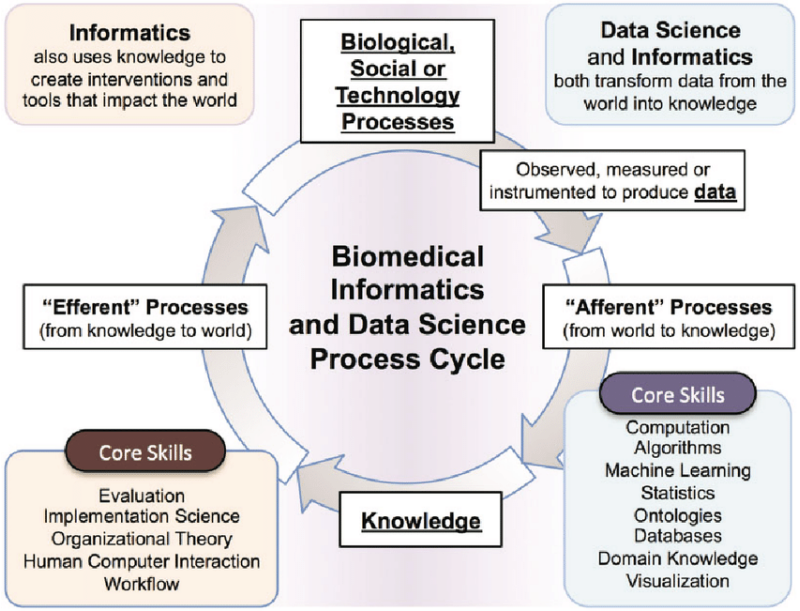
Type of collaboration: Univ. Exeter, Bristol, QMUL, NHS; Funding: QMUL

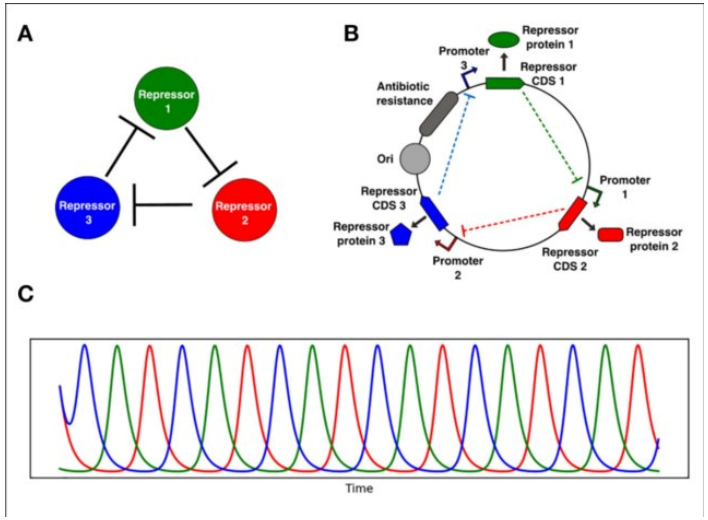
Question: Can we apply routing methods to optimally transfer patients in hospital networks?

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

PLoS ONE **15**, e0241027 (2020)

Biomedical data analysis and modeling projects





Mechanistic models of biological populations

Tobias Galla
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- 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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nuubo® WEARABLE MEDICAL TECHNOLOGIES

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)

Front. in Phys. 7, 103 (2019); Computer Meth. and Programs in Biomed., 169: 1 (2019)

Collaborative project: Predicting obesity in children

Yolanda Sanz

IATA (Instituto de Agroquímica y Tecnología de Alimentos)

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

Silvia Ortín

Claudio Mirasso

Develop machine learning tools to:

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

- **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

INSTITUTO DE NEUROCIENCIAS CSIC UNIVERSITAS Miguel Hernández

silvia@ifisc.uib-csic.es

Silvia Ortín

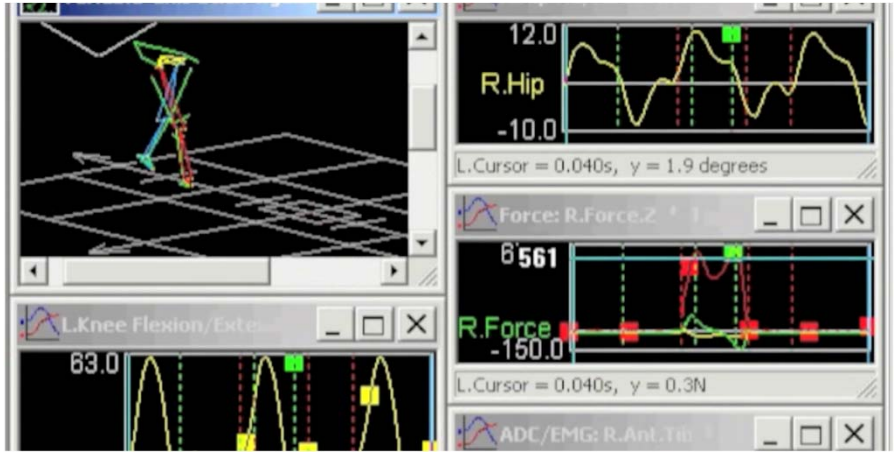
Develop ML tools to predict survival time using data from:

- 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.

Biomedical data analysis and modeling projects *

- **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.



Massimiliano Zanin

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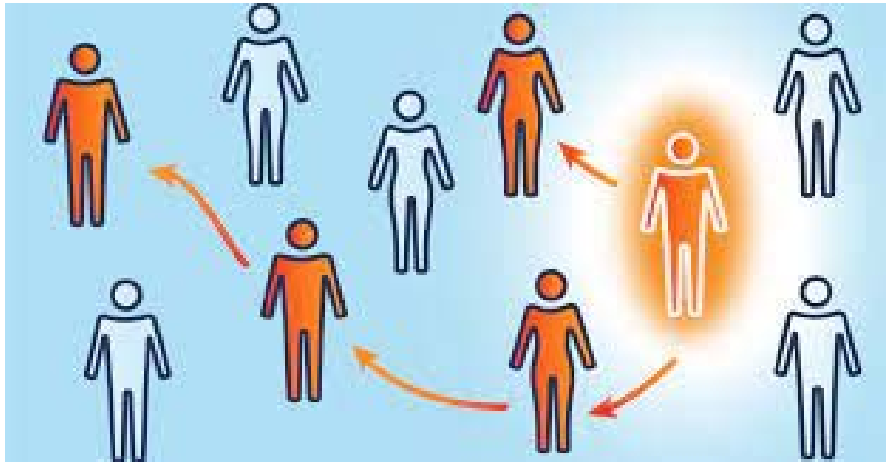
Comput. & Struct. Biotech. J. ***20****, 3257, (2022)*

Disease spread and human mobility



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Disease spread and human mobility *

Jose Ramasco
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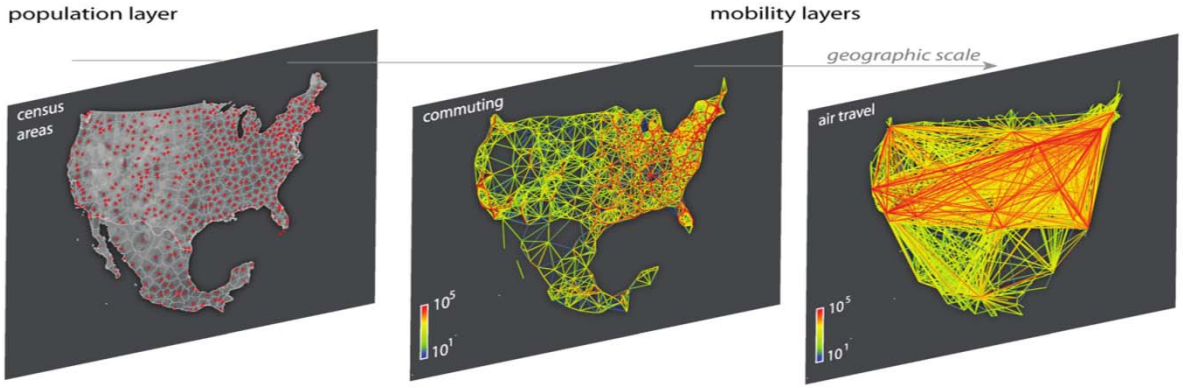

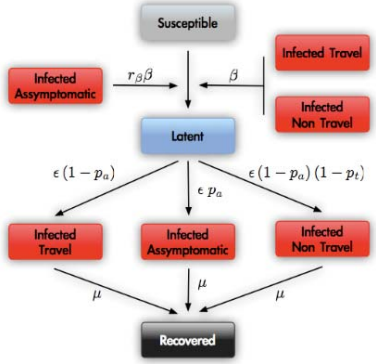

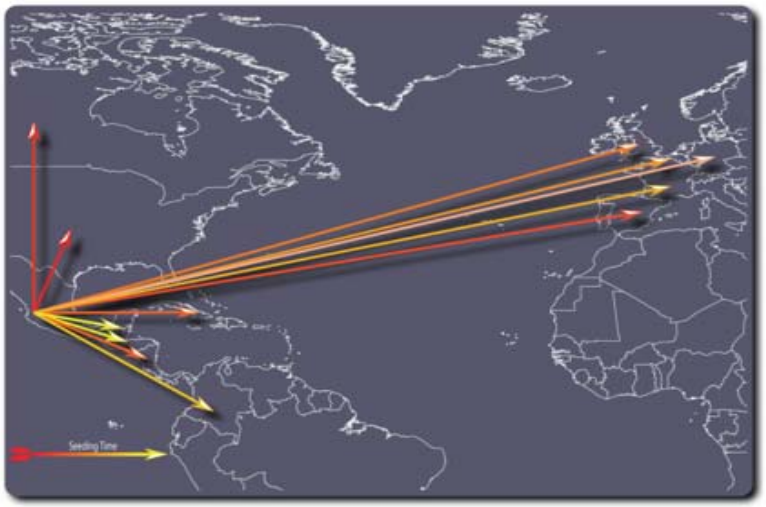

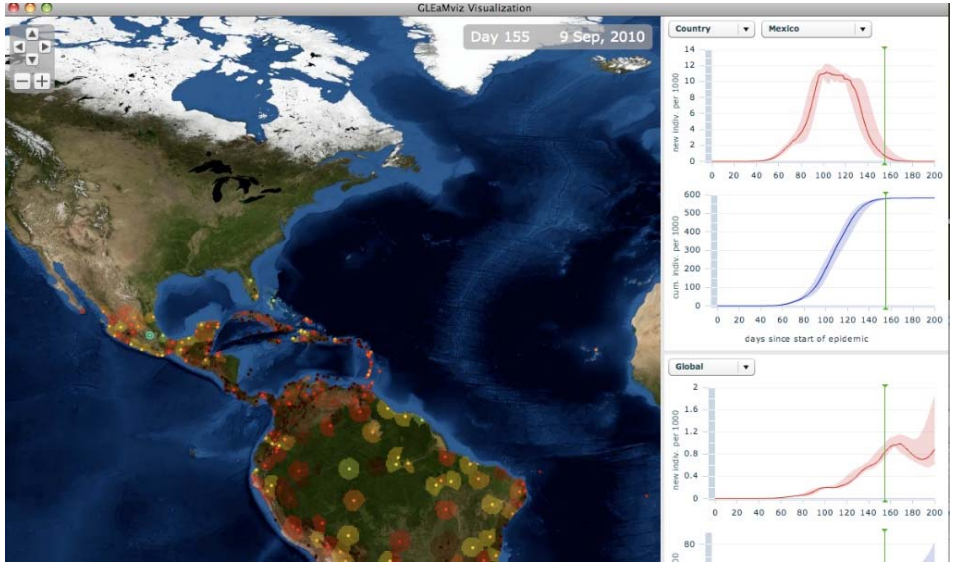

Models: importance of multiple seeds

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

Jose Ramasco
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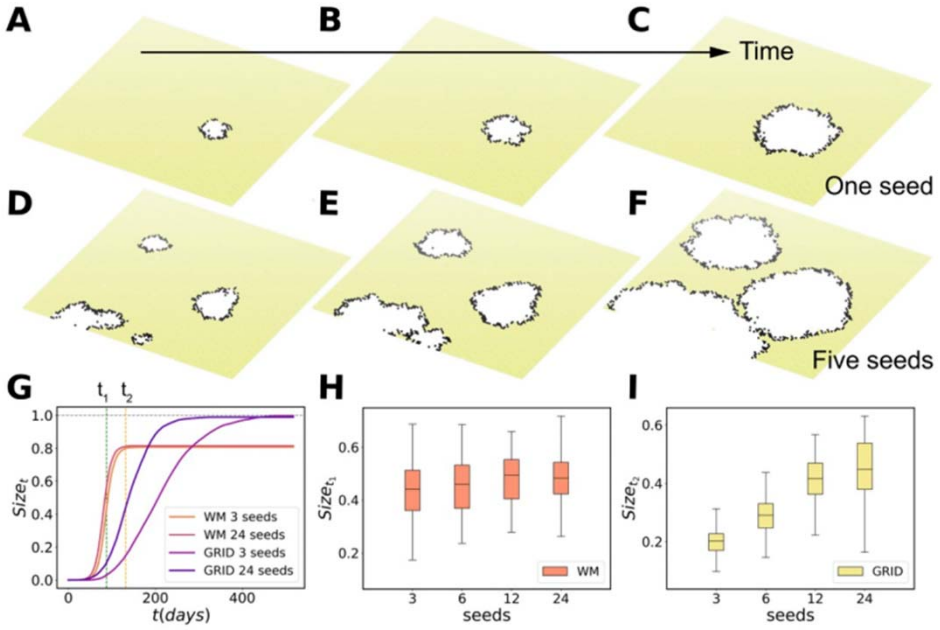
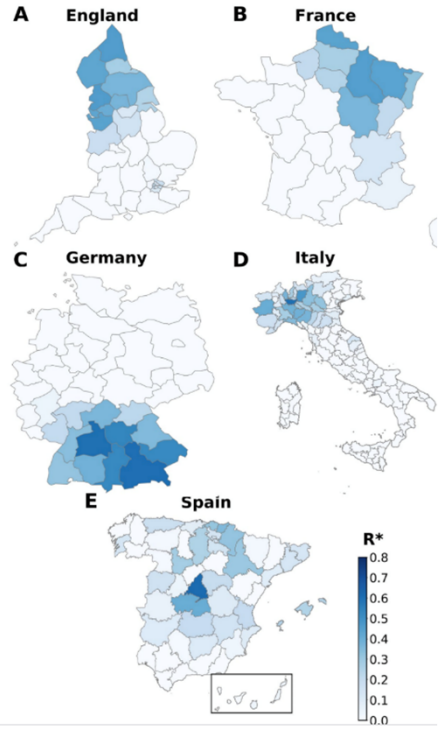




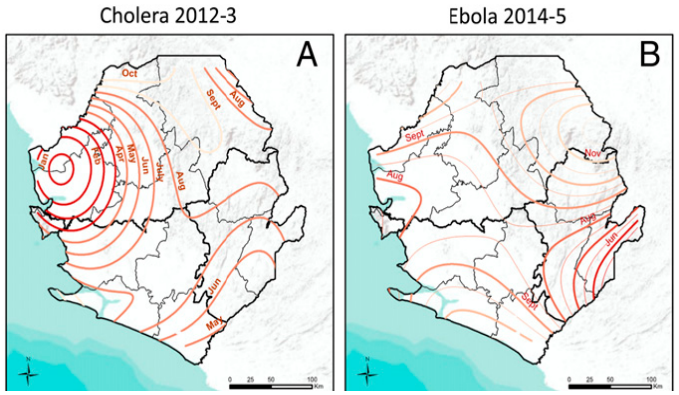
PloS Comp. Biol. **17**, e1009326 (2021)

Disease spread and human mobility *

Partners: Harvard School of Public Health, IFISC

juanf@ifisc.uib-csic.es

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.

PNAS 117 (9), 5067 (2020)

Disease spread and human mobility: COVID-19 *

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

Javier Ramasco
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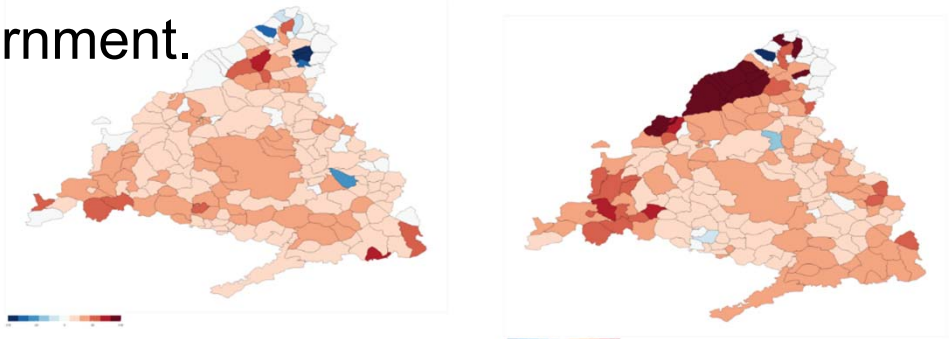
Mobile telephone data

Pioneering studies: March 2020



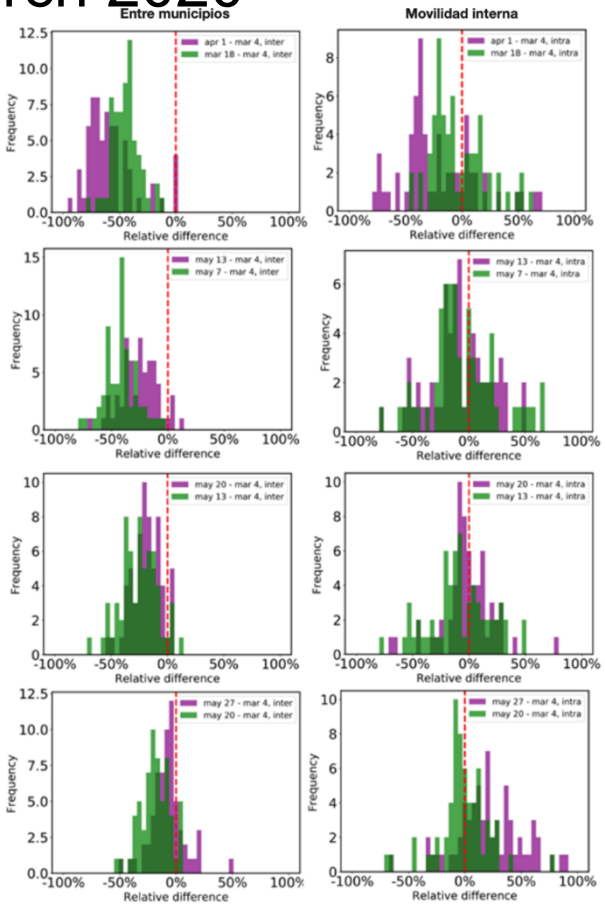
(a) Confinamiento (fase 0) a fase 0 con medidas de alivio

(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

Disease spread and human mobility *

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

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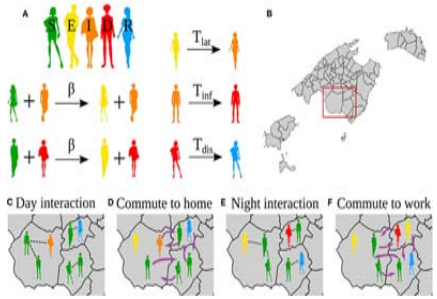

Funding: Ministry of Science and Innovation of Spain; finished

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

Frontiers in medicine 7, 563455 (2020)

Validation of the radar-COVID contact tracing APP

Lucas Lacasa

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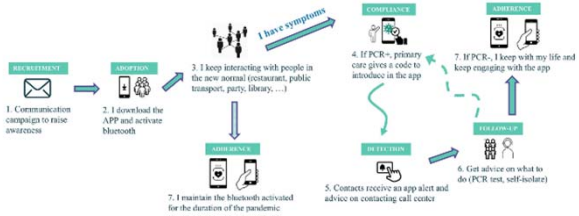


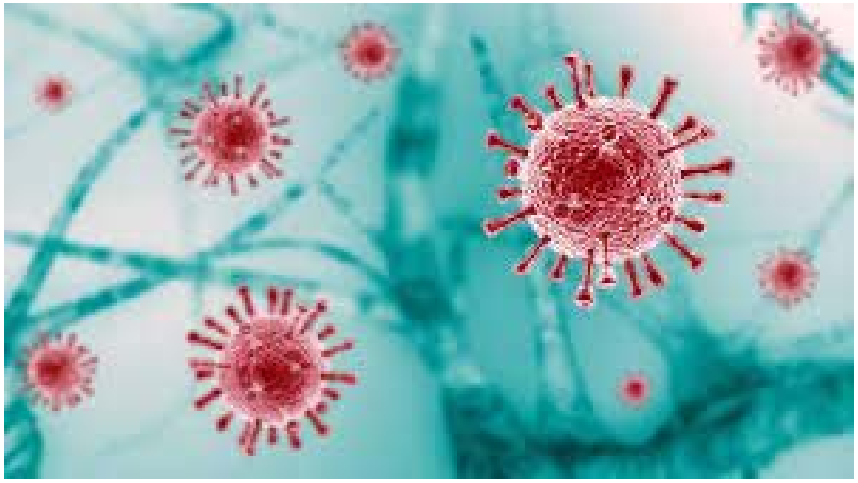
Type and origin of data: Experiment on the Canary Islands (La Gomera) pilot test contact tracing app Radar Covid /App developed by Indra.

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).

Nat. Comm. **12**, 587 (2021)

Projects developed jointly with HUSE



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

Tarun Khajuria[1], J A. Pou Goyanes[2], Claudio Mirasso[3], Raul Vicente[1]

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

Projects developed jointly with HUSE*

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 ~ 83%

Projects developed jointly with HUSE*

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

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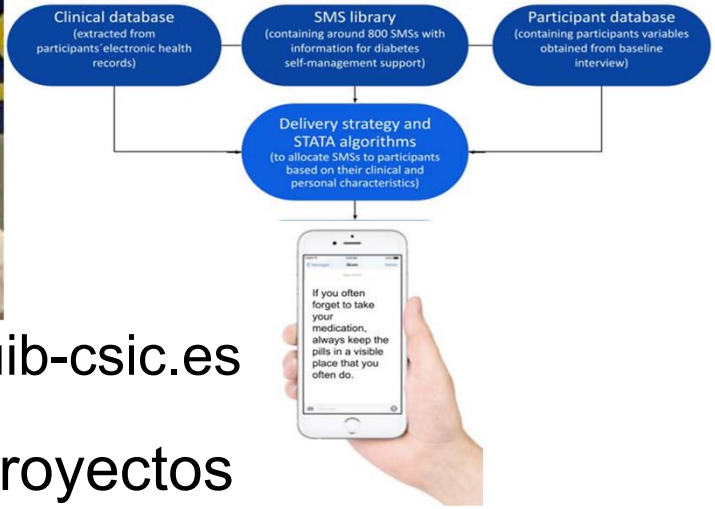

- **Funding:** Ministerio de Ciencia e Innovación. Proyectos I+D+i Pruebas de Concepto
- **Objectives:** Boost the transferability of DiabeText, a digital tool that integrates medical records and sends messages to patients with diabetes to encourage improve self-care; Starts in 2023.
- **IFISC contribution**: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