# Algorithmic Law Design and Implementation

## From Grave to Cradle

Joost J. Joosten

Universitat de Barcelona

28 April 2022

Proyecto RTC6740-2017–7 financiado por MCIN/AEI/10.13039/501100011033 y por FEDER Una manera de hacer Europa

# Welcome

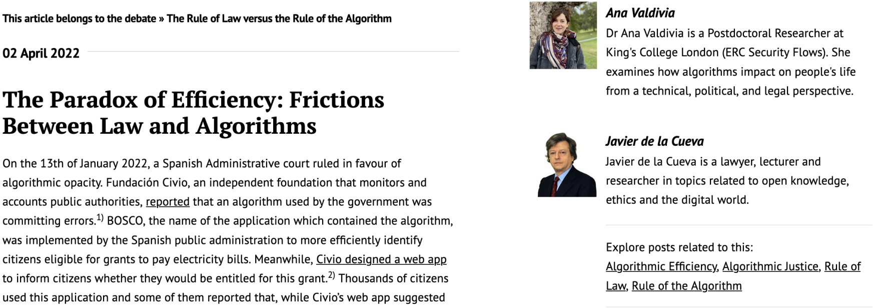
**Welcome**

**Grave**: Group Genesis

**The Conference**: A one-night stand?

**Cradle**: Future projects

# Welcome: Rule of Law vs Rule of Algorithm



**This article belongs to the debate » The Rule of Law versus the Rule of the Algorithm**

**02 April 2022**

**The Paradox of Efficiency: Frictions Between Law and Algorithms**

On the 13th of January 2022, a Spanish Administrative court ruled in favour of algorithmic opacity. Fundación Civio, an independent foundation that monitors and accounts public authorities, reported that an algorithm used by the government was committing errors.[1)] BOSCO, the name of the application which contained the algorithm, was implemented by the Spanish public administration to more efficiently identify citizens eligible for grants to pay electricity bills. Meanwhile, Civio designed a web app to inform citizens whether they would be entitled for this grant.[2)] Thousands of citizens used this application and some of them reported that, while Civio's web app suggested

***Ana Valdivia***

Dr Ana Valdivia is a Postdoctoral Researcher at King's College London (ERC Security Flows). She examines how algorithms impact on people's life from a technical, political, and legal perspective.

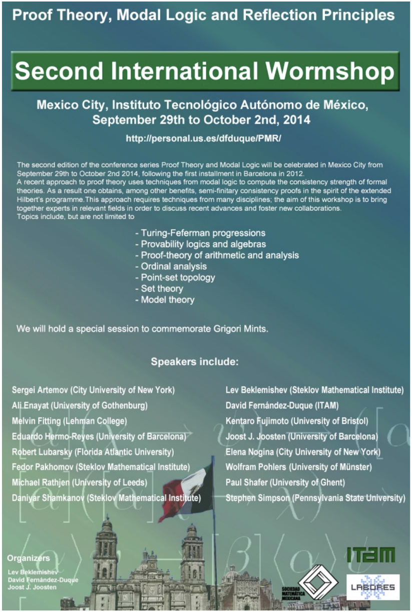
***Javier de la Cueva***

Javier de la Cueva is a lawyer, lecturer and researcher in topics related to open knowledge, ethics and the digital world.

Explore posts related to this:
Algorithmic Efficiency, Algorithmic Justice, Rule of Law, Rule of the Algorithm

Programs to enforce law can contain biases, errors or mistakes.
Civio, Dutch government, traffic law.
How to go about this?

# Group Genesis: The result of over 7 years of research



**Proof Theory, Modal Logic and Reflection Principles**

## Second International Wormshop

**Mexico City, Instituto Tecnológico Autónomo de México,**
**September 29th to October 2nd, 2014**

**http://personal.us.es/dfduque/PMR/**

The second edition of the conference series Proof Theory and Modal Logic will be celebrated in Mexico City from September 29th to October 2nd 2014, following the first installment in Barcelona in 2012.
A recent approach to proof theory uses techniques from modal logic to compute the consistency strength of formal theories. As a result one obtains, among other benefits, semi-finitary consistency proofs in the spirit of the extended Hilbert's programme.This approach requires techniques from many disciplines; the aim of this workshop is to bring together experts in relevant fields in order to discuss recent advances and foster new collaborations.
Topics include, but are not limited to

- Turing-Feferman progressions
- Provability logics and algebras
- Proof-theory of arithmetic and analysis
- Ordinal analysis
- Point-set topology
- Set theory
- Model theory

We will hold a special session to commemorate Grigori Mints.

**Speakers include:**

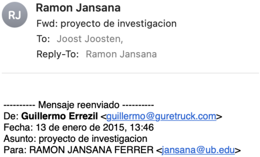
Sergei Artemov (City University of New York)
Ali Enayat (University of Gothenburg)
Melvin Fitting (Lehman College)
Eduardo Hermo-Reyes (University of Barcelona)
Robert Lubarsky (Florida Atlantic University)
Fedor Pakhomov (Steklov Mathematical Institute)
Michael Rathjen (University of Leeds)
Daniyar Shamkanov (Steklov Mathematical Institute)

Lev Beklemishev (Steklov Mathematical Institute)
David Fernández-Duque (ITAM)
Kentaro Fujimoto (University of Bristol)
Joost J. Joosten (University of Barcelona)
Elena Nogina (City University of New York)
Wolfram Pohlers (University of Münster)
Paul Shafer (University of Ghent)
Stephen Simpson (Pennsylvania State University)

Organizers

Lev Beklemishev
David Fernández-Duque
Joost J. Joosten

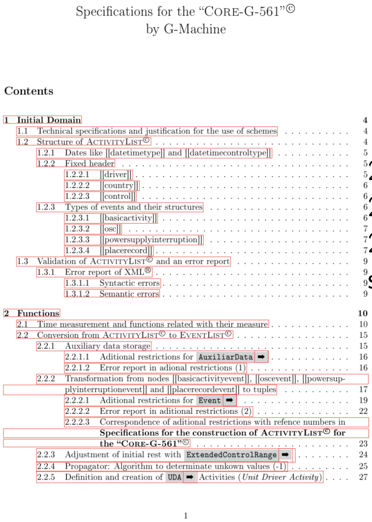
# Group Genesis: The result of over 7 years of research



**Ramon Jansana**
Fwd: proyecto de investigacion
To: Joost Joosten,
Reply-To: Ramon Jansana

---------- Mensaje reenviado ---------
De: **Guillermo Errezil** <guillermo@guretruck.com>
Fecha: 13 de enero de 2015, 13:46
Asunto: proyecto de investigacion
Para: RAMON JANSANA FERRER <jansana@ub.edu>

# Group Genesis: The result of over 7 years of research



Specifications for the "CORE-G-561"©
by G-Machine

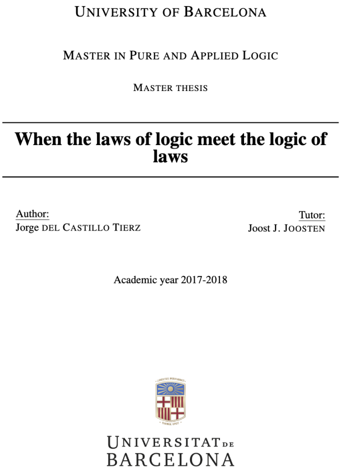
**Contents**

1

2015, First analysis after one year;
2016, Formal Vindications S.L. founded;
2017, Two Industrial Doctorate Students start: +/- 100 K subsidy.

# Group Genesis: The result of over 7 years of research

# Group Genesis: The result of over 7 years of research



UNIVERSITY OF BARCELONA

MASTER IN PURE AND APPLIED LOGIC

MASTER THESIS

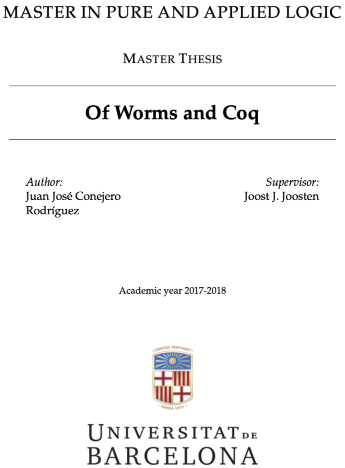
**When the laws of logic meet the logic of laws**

Author:
Jorge DEL CASTILLO TIERZ

Tutor:
Joost J. JOOSTEN

Academic year 2017-2018

UNIVERSITAT DE BARCELONA



MASTER IN PURE AND APPLIED LOGIC

MASTER THESIS

**Of Worms and Coq**

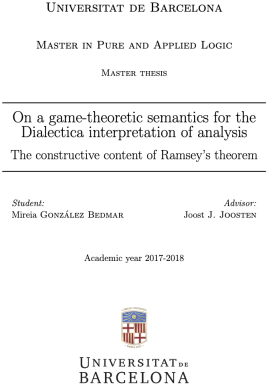
*Author:*
Juan José Conejero
Rodríguez

*Supervisor:*
Joost J. Joosten

Academic year 2017-2018

UNIVERSITAT DE BARCELONA

# Group Genesis: The result of over 7 years of research



Universitat de Barcelona

Master in Pure and Applied Logic

Master thesis

On a game-theoretic semantics for the Dialectica interpretation of analysis

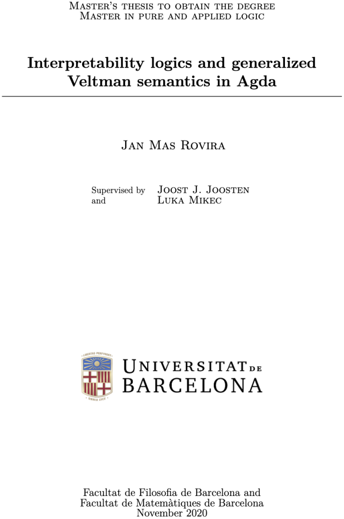
The constructive content of Ramsey's theorem

*Student:*
Mireia González Bedmar

*Advisor:*
Joost J. Joosten

Academic year 2017-2018

Universitat de Barcelona



Master's thesis to obtain the degree
Master in pure and applied logic

**Interpretability logics and generalized Veltman semantics in Agda**

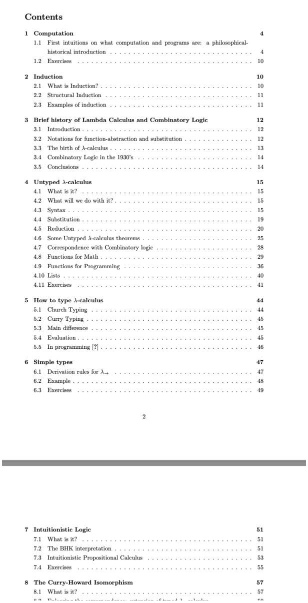
Jan Mas Rovira

Supervised by Joost J. Joosten
and Luka Mikec

Universitat de Barcelona

Facultat de Filosofia de Barcelona and
Facultat de Matemàtiques de Barcelona
November 2020

# Group Genesis: The result of over 7 years of research



## Contents

**Apprenticeships**

(UB 2017)
Type Theory: foundations and applications;

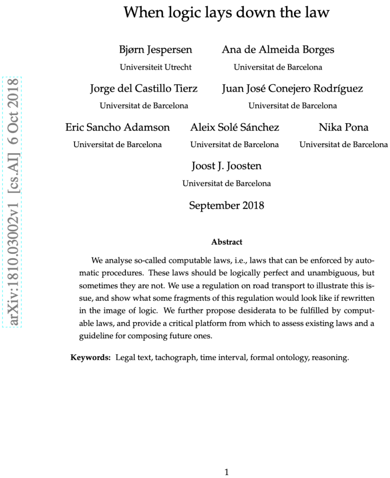
(UB 2018)
Verified programming and type theory;

(UB 2019)
Proof assistants: behind the scenes;

(UB 2019-2020)
Lambda-Calculus and Type Theory Revisited;

(UB 2020-2021)
Introduction to Model Checking.

# Group Genesis: The result of over 7 years of research



## When logic lays down the law

Bjørn Jespersen
Universiteit Utrecht

Ana de Almeida Borges
Universitat de Barcelona

Jorge del Castillo Tierz
Universitat de Barcelona

Juan José Conejero Rodríguez
Universitat de Barcelona

Eric Sancho Adamson
Universitat de Barcelona

Aleix Solé Sánchez
Universitat de Barcelona

Nika Pona
Universitat de Barcelona

Joost J. Joosten
Universitat de Barcelona

September 2018

**Abstract**

We analyse so-called computable laws, i.e., laws that can be enforced by automatic procedures. These laws should be logically perfect and unambiguous, but sometimes they are not. We use a regulation on road transport to illustrate this issue, and show what some fragments of this regulation would look like if rewritten in the image of logic. We further propose desiderata to be fulfilled by computable laws, and provide a critical platform from which to assess existing laws and a guideline for composing future ones.

**Keywords:** Legal text, tachograph, time interval, formal ontology, reasoning.

1

One can also argue that the law simply is not or should not be an algorithm. When writing the algorithm, this feels like an interpretation of a more fundamental law that is likely to be enunciated in natural language. However, a similar objection applies to a law formulated in natural language where one may maintain that this is just a linguistic projection of a collection of fundamental ethical intuitions and beliefs. The radical viewpoint would thus imply that law schools should include programming as an integral part of the curriculum.

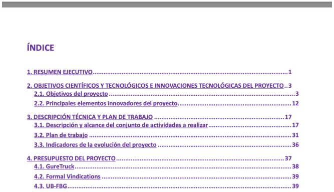
# Group Genesis: The result of over 7 years of research

***SOFTWARE DE FALLO CERO***

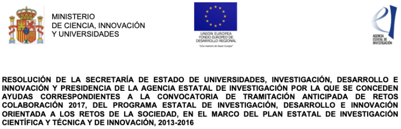
***Innovación para el sector del transporte***

- Iniciativa Conjunta de:
    - Guretruck SL
    - Formal Vindications SL
    - Universitat de Barcelona- Fundació Bosch Gimpera

0



ÍNDICE

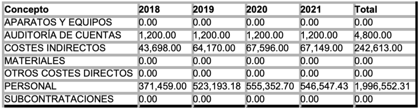


MINISTERIO
DE CIENCIA, INNOVACIÓN
Y UNIVERSIDADES

UNION EUROPEA
FONDO EUROPEO DE
DESARROLLO REGIONAL
"Una manera de hacer Europa"

AGENCIA
ESTATAL DE
INVESTIGACIÓN

**RESOLUCIÓN DE LA SECRETARÍA DE ESTADO DE UNIVERSIDADES, INVESTIGACIÓN, DESARROLLO E INNOVACIÓN Y PRESIDENCIA DE LA AGENCIA ESTATAL DE INVESTIGACIÓN POR LA QUE SE CONCEDEN AYUDAS CORRESPONDIENTES A LA CONVOCATORIA DE TRAMITACIÓN ANTICIPADA DE RETOS COLABORACIÓN 2017, DEL PROGRAMA ESTATAL DE INVESTIGACIÓN, DESARROLLO E INNOVACIÓN ORIENTADA A LOS RETOS DE LA SOCIEDAD, EN EL MARCO DEL PLAN ESTATAL DE INVESTIGACIÓN CIENTÍFICA Y TÉCNICA Y DE INNOVACIÓN, 2013-2016**



| Concepto | 2018 | 2019 | 2020 | 2021 | Total |
|---|---|---|---|---|---|
| APARATOS Y EQUIPOS | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| AUDITORÍA DE CUENTAS | 1,200.00 | 1,200.00 | 1,200.00 | 1,200.00 | 4,800.00 |
| COSTES INDIRECTOS | 43,698.00 | 64,170.00 | 67,596.00 | 67,149.00 | 242,613.00 |
| MATERIALES | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| OTROS COSTES DIRECTOS | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| PERSONAL | 371,459.00 | 523,193.18 | 555,352.70 | 546,547.43 | 1,996,552.31 |
| SUBCONTRATACIONES | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

# Group Genesis: The result of over 7 years of research

Industrial Software Homologation:
Theory and case study

Analysis of the European tachograph technology with EU transport Regulations 3821/85, 799/2016, and 561/06 and their consequences for Europeans citizens

Guillermo Errezil Alberdi
Formal Vindications S.L. & Guretruck S.L.

in collaboration with:[1]

| | | |
|---|---|---|
| Joost J. Joosten<br>Universitat de Barcelona | Gina García Tarrach<br>Universitat de Barcelona | Aleix Solé Sánchez<br>Universitat de Barcelona |
| Ana de Almeida Borges<br>Universitat de Barcelona | Eric Sancho<br>Universitat de Barcelona | David Fernández-Duque<br>Ghent University |

November 8, 2019

GURETRUCK

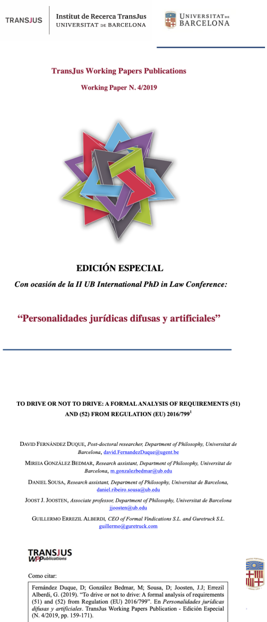
Agencia Estatal de Investigación

Universitat de Barcelona

Unió Europea
Fons Europeu de Desenvolupament Regional

Gobierno de España
Ministerio de Ciencia, Innovación y Universidades

[1] Project funded by the Spanish Ministry of Science, Innovation and Universities, the State Agency for Research and the European Regional Development Fund (ERDF).



TRANSJUS
Institut de Recerca TransJus
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Universitat de Barcelona

TransJus Working Papers Publications

Working Paper N. 4/2019

EDICIÓN ESPECIAL

*Con ocasión de la II UB International PhD in Law Conference:*

"Personalidades jurídicas difusas y artificiales"

TO DRIVE OR NOT TO DRIVE: A FORMAL ANALYSIS OF REQUIREMENTS (51) AND (52) FROM REGULATION (EU) 2016/799[1]

DAVID FERNÁNDEZ DUQUE, *Post-doctoral researcher, Department of Philosophy, Universitat de Barcelona*, david.FernandezDuque@ugent.be

MIREIA GONZÁLEZ BEDMAR, *Research assistant, Department of Philosophy, Universitat de Barcelona*, m.gonzalezbedmar@ub.edu

DANIEL SOUSA, *Research assistant, Department of Philosophy, Universitat de Barcelona*, daniel.ribeiro.sousa@ub.edu

JOOST J. JOOSTEN, *Associate professor, Department of Philosophy, Universitat de Barcelona* jjoosten@ub.edu

GUILLERMO ERREZIL ALBERDI, *CEO of Formal Vindications S.L. and Guretruck S.L.* guillermo@guretruck.com

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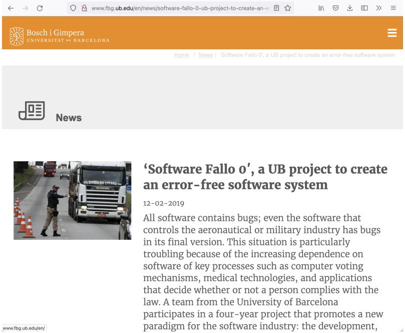
Como citar:

Fernández Duque, D; González Bedmar, M; Sousa, D; Joosten, J.J; Errezil Alberdi, G. (2019). "To drive or not to drive: A formal analysis of requirements (51) and (52) from Regulation (EU) 2016/799". En *Personalidades jurídicas difusas y artificiales*. TransJus Working Papers Publication - Edición Especial (N. 4/2019, pp. 159-171).

# Group Genesis: The result of over 7 years of research



www.fbg.ub.edu/en/news/software-fallo-0-ub-project-to-create-an-e

Bosch i Gimpera
UNIVERSITAT DE BARCELONA

Home / News / 'Software Fallo 0', a UB project to create an error-free software system

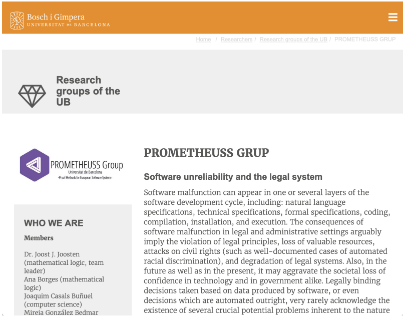
News

## 'Software Fallo 0', a UB project to create an error-free software system

12-02-2019

All software contains bugs; even the software that controls the aeronautical or military industry has bugs in its final version. This situation is particularly troubling because of the increasing dependence on software of key processes such as computer voting mechanisms, medical technologies, and applications that decide whether or not a person complies with the law. A team from the University of Barcelona participates in a four-year project that promotes a new paradigm for the software industry: the development,

www.fbg.ub.edu/en/



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Research groups of the UB

PROMETHEUSS Group
Universitat de Barcelona
-Proof Methods for European Software Systems-

## PROMETHEUSS GRUP

### Software unreliability and the legal system

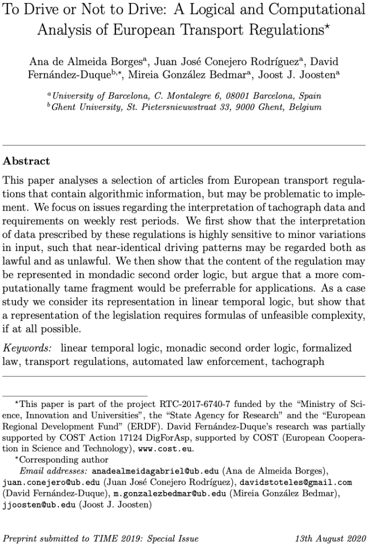
Software malfunction can appear in one or several layers of the software development cycle, including: natural language specifications, technical specifications, formal specifications, coding, compilation, installation, and execution. The consequences of software malfunction in legal and administrative settings arguably imply the violation of legal principles, loss of valuable resources, attacks on civil rights (such as well-documented cases of automated racial discrimination), and degradation of legal systems. Also, in the future as well as in the present, it may aggravate the societal loss of confidence in technology and in government alike. Legally binding decisions taken based on data produced by software, or even decisions which are automated outright, very rarely acknowledge the existence of several crucial potential problems inherent to the nature

WHO WE ARE

Members

Dr. Joost J. Joosten (mathematical logic, team leader)
Ana Borges (mathematical logic)
Joaquim Casals Buñuel (computer science)
Mireia González Bedmar

# Group Genesis: The result of over 7 years of research



## To Drive or Not to Drive: A Logical and Computational Analysis of European Transport Regulations*

Ana de Almeida Borges[a], Juan José Conejero Rodríguez[a], David Fernández-Duque[b,*], Mireia González Bedmar[a], Joost J. Joosten[a]

[a] *University of Barcelona, C. Montalegre 6, 08001 Barcelona, Spain*
[b] *Ghent University, St. Pietersnieuwstraat 33, 9000 Ghent, Belgium*

### Abstract

This paper analyses a selection of articles from European transport regulations that contain algorithmic information, but may be problematic to implement. We focus on issues regarding the interpretation of tachograph data and requirements on weekly rest periods. We first show that the interpretation of data prescribed by these regulations is highly sensitive to minor variations in input, such that near-identical driving patterns may be regarded both as lawful and as unlawful. We then show that the content of the regulation may be represented in mondadic second order logic, but argue that a more computationally tame fragment would be preferrable for applications. As a case study we consider its representation in linear temporal logic, but show that a representation of the legislation requires formulas of unfeasible complexity, if at all possible.

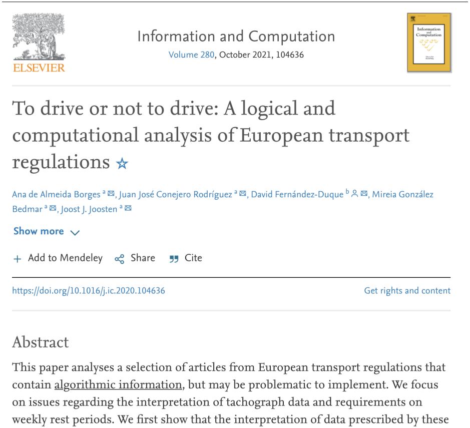
*Keywords:* linear temporal logic, monadic second order logic, formalized law, transport regulations, automated law enforcement, tachograph

*This paper is part of the project RTC-2017-6740-7 funded by the "Ministry of Science, Innovation and Universities", the "State Agency for Research" and the "European Regional Development Fund" (ERDF). David Fernández-Duque's research was partially supported by COST Action 17124 DigForAsp, supported by COST (European Cooperation in Science and Technology), www.cost.eu.

*Corresponding author

*Email addresses:* anadealmeidagabriel@ub.edu (Ana de Almeida Borges), juan.conejero@ub.edu (Juan José Conejero Rodríguez), davidstoteles@gmail.com (David Fernández-Duque), m.gonzalezbedmar@ub.edu (Mireia González Bedmar), jjoosten@ub.edu (Joost J. Joosten)

*Preprint submitted to TIME 2019: Special Issue* *13th August 2020*



ELSEVIER

Information and Computation
Volume 280, October 2021, 104636

## To drive or not to drive: A logical and computational analysis of European transport regulations ☆

Ana de Almeida Borges [a] ✉, Juan José Conejero Rodríguez [a] ✉, David Fernández-Duque [b] ✉, Mireia González Bedmar [a] ✉, Joost J. Joosten [a] ✉

https://doi.org/10.1016/j.ic.2020.104636

### Abstract

This paper analyses a selection of articles from European transport regulations that contain algorithmic information, but may be problematic to implement. We focus on issues regarding the interpretation of tachograph data and requirements on weekly rest periods. We first show that the interpretation of data prescribed by these

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NIT EUROPEA
DE LA RECERCA

27/09/2019

Cafès científics de la UB

**PODEM CONFIAR EN EL RAONAMENT?**
**...el nostre i el dels ordinadors**

**HORA: 17 h / LLOC: jardí Ferran Soldevila, Edifici Històric de la UB**

Moderador: Joost J. Joosten, Departament de Filosofia

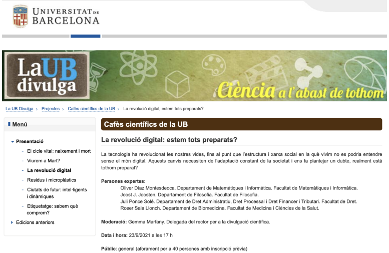
**EXPERTS CONVIDATS:**

Eric Sancho Adamson i Aleix Solé Sánchez, membres de Prometheuss Grup,
grup de recerca de programari formalment verificat aplicat a legislació europea

**http://www.ub.edu/laubdivulga/nitdelarecerca/confiarraonament.html**

UNIVERSITAT DE BARCELONA
Facultat de Filosofia

LaUB divulga



UNIVERSITAT DE BARCELONA

LaUB divulga

Ciència a l'abast de tothom

La UB Divulga › Projectes › Cafès científics de la UB › La revolució digital, estem tots preparats?

Menú
Presentació
- El cicle vital: naixement i mort
- Viurem a Mart?
- La revolució digital
- Residus i microplàstics
- Ciutats de futur: intel·ligents i dinàmiques
- Etiquetatge: sabem què comprem?
Edicions anteriors

**Cafès científics de la UB**

**La revolució digital: estem tots preparats?**

La tecnologia ha revolucionat les nostres vides, fins al punt que l'estructura i xarxa social en la què vivim no es podria entendre sense el món digital. Aquests canvis necessiten de l'adaptació constant de la societat i ens fa plantejar un dubte, realment està tothom preparat?

**Persones expertes:**

Oliver Díaz Montesdeoca. Departament de Matemàtiques i Informàtica. Facultat de Matemàtiques i Informàtica.
Joost J. Joosten. Departament de Filosofia. Facultat de Filosofia.
Juli Ponce Solé. Departament de Dret Administratiu, Dret Processal i Dret Financer i Tributari. Facultat de Dret.
Roser Sala Llonch. Departament de Biomedicina. Facultat de Medicina i Ciències de la Salut.

**Moderació:** Gemma Marfany. Delegada del rector per a la divulgació científica.

**Data i hora:** 23/9/2021 a les 17 h

**Públic**: general (aforament per a 40 persones amb inscripció prèvia)

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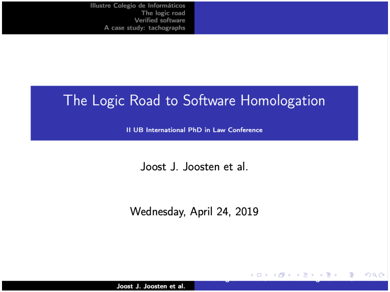


Illustre Colegio de Informáticos
The logic road
Verified software
A case study: tachographs

The Logic Road to Software Homologation

II UB International PhD in Law Conference

Joost J. Joosten et al.

Wednesday, April 24, 2019

Joost J. Joosten et al.

Control funcional y control cualitativo de los algoritmos en la administración pública:

a case study from European road transport regulations

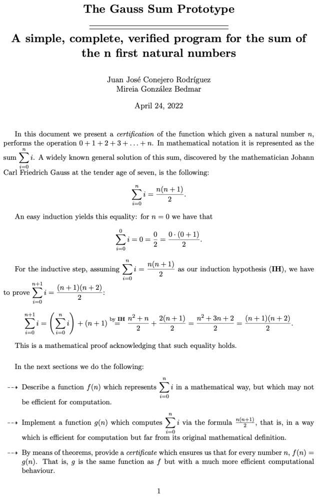
Joost J. Joosten

University of Barcelona

10 de octubre del 2019
II Seminario Internacional DAIA de Derecho público.
*Datos e inteligencia artificial en el sector público: la importancia de las garantías jurídicas*
Valencia, Spain

2019: two new Industrial Doctorate students: +- 100 K.

# Group Genesis: The result of over 7 years of research



**The Gauss Sum Prototype**

**A simple, complete, verified program for the sum of the n first natural numbers**

Juan José Conejero Rodríguez
Mireia González Bedmar

April 24, 2022

In this document we present a *certification* of the function which given a natural number $n$, performs the operation $0+1+2+3+\ldots+n$. In mathematical notation it is represented as the sum $\sum_{i=0}^{n} i$. A widely known general solution of this sum, discovered by the mathematician Johann Carl Friedrich Gauss at the tender age of seven, is the following:

$$\sum_{i=0}^{n} i = \frac{n(n+1)}{2}.$$

An easy induction yields this equality: for $n=0$ we have that

$$\sum_{i=0}^{0} i = 0 = \frac{0}{2} = \frac{0\cdot(0+1)}{2}.$$

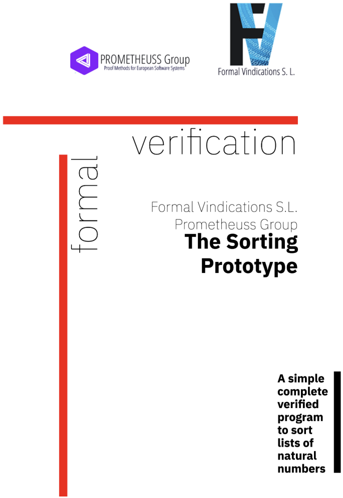
For the inductive step, assuming $\sum_{i=0}^{n} i = \frac{n(n+1)}{2}$ as our induction hypothesis (**IH**), we have to prove $\sum_{i=0}^{n+1} i = \frac{(n+1)(n+2)}{2}$:

$$\sum_{i=0}^{n+1} i = \left(\sum_{i=0}^{n} i\right) + (n+1) \overset{\text{by } \mathbf{IH}}{=} \frac{n^2+n}{2} + \frac{2(n+1)}{2} = \frac{n^2+3n+2}{2} = \frac{(n+1)(n+2)}{2}.$$

This is a mathematical proof acknowledging that such equality holds.

In the next sections we do the following:

- Describe a function $f(n)$ which represents $\sum_{i=0}^{n} i$ in a mathematical way, but which may not be efficient for computation.
- Implement a function $g(n)$ which computes $\sum_{i=0}^{n} i$ via the formula $\frac{n(n+1)}{2}$, that is, in a way which is efficient for computation but far from its original mathematical definition.
- By means of theorems, provide a *certificate* which ensures us that for every number $n$, $f(n) = g(n)$. That is, $g$ is the same function as $f$ but with a much more efficient computational behaviour.



PROMETHEUSS Group
Proof Methods for European Software Systems

Formal Vindications S. L.

formal verification

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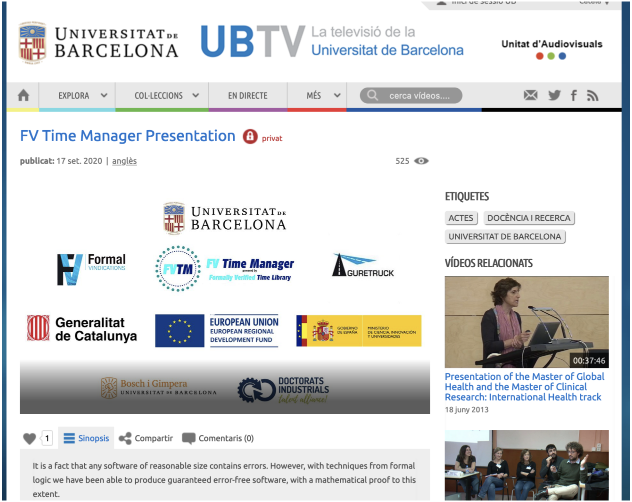
Prometheuss Group
**The Sorting Prototype**

**A simple complete verified program to sort lists of natural numbers**

Universitat de Barcelona

# Group Genesis: The result of over 7 years of research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FV Time Manager powered by Formally Verified Time Library
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## FV Time Manager Presentation

privat

**publicat:** 17 set. 2020 | anglès

525

ETIQUETES

ACTES | DOCÈNCIA I RECERCA | UNIVERSITAT DE BARCELONA

VÍDEOS RELACIONATS

Presentation of the Master of Global Health and the Master of Clinical Research: International Health track

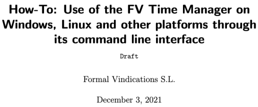
18 juny 2013

1 | Sinopsis | Compartir | Comentaris (0)

It is a fact that any software of reasonable size contains errors. However, with techniques from formal logic we have been able to produce guaranteed error-free software, with a mathematical proof to this extent.

UNIVERSITAT DE BARCELONA

# Group Genesis: The result of over 7 years of research

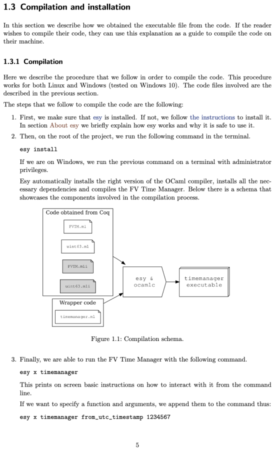


**How-To: Use of the FV Time Manager on Windows, Linux and other platforms through its command line interface**

Draft

Formal Vindications S.L.

December 3, 2021



### 1.3 Compilation and installation

In this section we describe how we obtained the executable file from the code. If the reader wishes to compile their code, they can use this explanation as a guide to compile the code on their machine.

#### 1.3.1 Compilation

Here we describe the procedure that we follow in order to compile the code. This procedure works for both Linux and Windows (tested on Windows 10). The code files involved are the described in the previous section.

The steps that we follow to compile the code are the following:

1. First, we make sure that esy is installed. If not, we follow the instructions to install it. In section About esy we briefly explain how esy works and why it is safe to use it.
2. Then, on the root of the project, we run the following command in the terminal.

   ```
   esy install
   ```

   If we are on Windows, we run the previous command on a terminal with administrator privileges.

   Esy automatically installs the right version of the OCaml compiler, installs all the necessary dependencies and compiles the FV Time Manager. Below there is a schema that showcases the components involved in the compilation process.

   Figure 1.1: Compilation schema.

3. Finally, we are able to run the FV Time Manager with the following command.

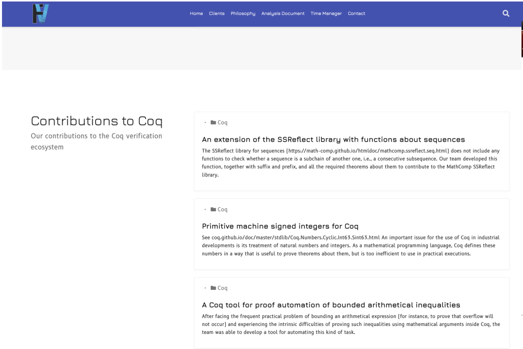
   ```
   esy x timemanager
   ```

   This prints on screen basic instructions on how to interact with it from the command line.

   If we want to specify a function and arguments, we append them to the command thus:

   ```
   esy x timemanager from_utc_timestamp 1234567
   ```

# Group Genesis: The result of over 7 years of research



## Contributions to Coq

Our contributions to the Coq verification ecosystem

- Coq

### An extension of the SSReflect library with functions about sequences

The SSReflect library for sequences [https://math-comp.github.io/htmldoc/mathcomp.ssreflect.seq.html] does not include any functions to check whether a sequence is a subchain of another one, i.e., a consecutive subsequence. Our team developed this function, together with suffix and prefix, and all the required theorems about them to contribute to the MathComp SSReflect library.

- Coq

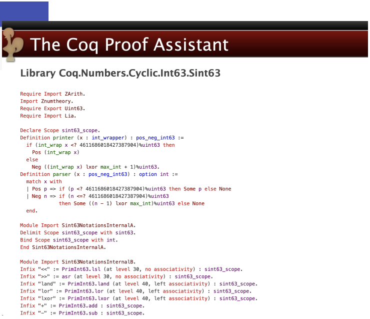
### Primitive machine signed integers for Coq

See coq.github.io/doc/master/stdlib/Coq.Numbers.Cyclic.Int63.Sint63.html An important issue for the use of Coq in industrial developments is its treatment of natural numbers and integers. As a mathematical programming language, Coq defines these numbers in a way that is useful to prove theorems about them, but is too inefficient to use in practical executions.

- Coq

### A Coq tool for proof automation of bounded arithmetical inequalities

After facing the frequent practical problem of bounding an arithmetical expression [for instance, to prove that overflow will not occur] and experiencing the intrinsic difficulties of proving such inequalities using mathematical arguments inside Coq, the team was able to develop a tool for automating this kind of task.



## The Coq Proof Assistant

### Library Coq.Numbers.Cyclic.Int63.Sint63

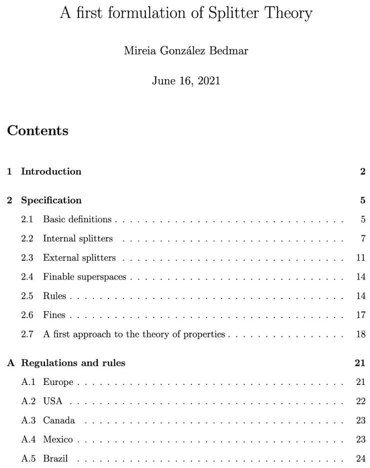
```
Require Import ZArith.
Import Znumtheory.
Require Export Uint63.
Require Import Lia.

Declare Scope sint63_scope.
Definition printer (x : int_wrapper) : pos_neg_int63 :=
  if (int_wrap x <? 4611686018427387904)%uint63 then
    Pos (int_wrap x)
  else
    Neg ((int_wrap x) lxor max_int + 1)%uint63.
Definition parser (x : pos_neg_int63) : option int :=
  match x with
  | Pos p => if (p <? 4611686018427387904)%uint63 then Some p else None
  | Neg n => if (n <=? 4611686018427387904)%uint63
             then Some ((n - 1) lxor max_int)%uint63 else None
  end.

Module Import Sint63NotationsInternalA.
Delimit Scope sint63_scope with sint63.
Bind Scope sint63_scope with int.
End Sint63NotationsInternalA.

Module Import Sint63NotationsInternalB.
Infix "<<" := PrimInt63.lsl (at level 30, no associativity) : sint63_scope.
Infix ">>" := asr (at level 30, no associativity) : sint63_scope.
Infix "land" := PrimInt63.land (at level 40, left associativity) : sint63_scope.
Infix "lor" := PrimInt63.lor (at level 40, left associativity) : sint63_scope.
Infix "lxor" := PrimInt63.lxor (at level 40, left associativity) : sint63_scope.
Infix "+" := PrimInt63.add : sint63_scope.
Infix "-" := PrimInt63.sub : sint63_scope.
```

# Group Genesis: The result of over 7 years of research

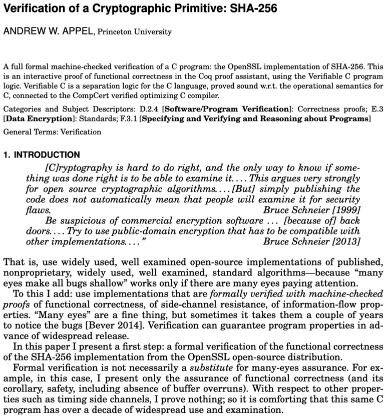


## A first formulation of Splitter Theory

Mireia González Bedmar

June 16, 2021

### Contents



## Verification of a Cryptographic Primitive: SHA-256

ANDREW W. APPEL, Princeton University

A full formal machine-checked verification of a C program: the OpenSSL implementation of SHA-256. This is an interactive proof of functional correctness in the Coq proof assistant, using the Verifiable C program logic. Verifiable C is a separation logic for the C language, proved sound w.r.t. the operational semantics for C, connected to the CompCert verified optimizing C compiler.

Categories and Subject Descriptors: D.2.4 [**Software/Program Verification**]: Correctness proofs; E.3 [**Data Encryption**]: Standards; F.3.1 [**Specifying and Verifying and Reasoning about Programs**]

General Terms: Verification

### 1. INTRODUCTION

> *[C]ryptography is hard to do right, and the only way to know if something was done right is to be able to examine it. . . . This argues very strongly for open source cryptographic algorithms. . . . [But] simply publishing the code does not automatically mean that people will examine it for security flaws.* Bruce Schneier [1999]
>
> *Be suspicious of commercial encryption software . . . [because of] back doors. . . . Try to use public-domain encryption that has to be compatible with other implementations. . . .”* Bruce Schneier [2013]

That is, use widely used, well examined open-source implementations of published, nonproprietary, widely used, well examined, standard algorithms—because “many eyes make all bugs shallow” works only if there are many eyes paying attention.

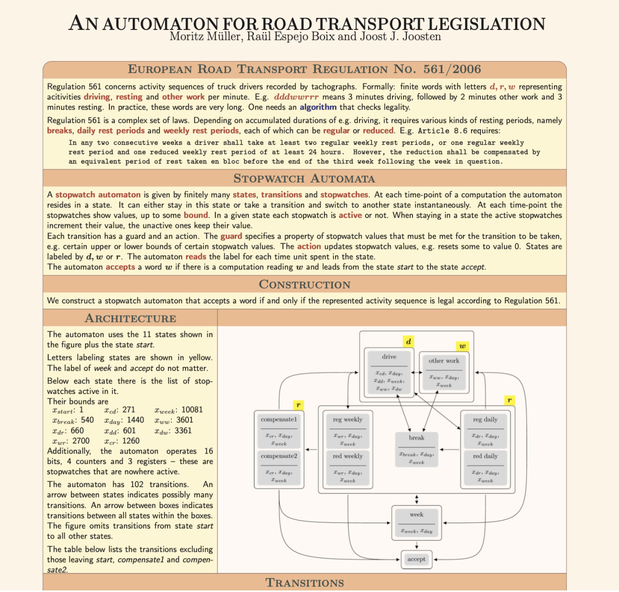
To this I add: use implementations that are *formally verified with machine-checked proofs* of functional correctness, of side-channel resistance, of information-flow properties. “Many eyes” are a fine thing, but sometimes it takes them a couple of years to notice the bugs [Bever 2014]. Verification can guarantee program properties in advance of widespread release.

In this paper I present a first step: a formal verification of the functional correctness of the SHA-256 implementation from the OpenSSL open-source distribution.

Formal verification is not necessarily a *substitute* for many-eyes assurance. For example, in this case, I present only the assurance of functional correctness (and its corollary, safety, including absence of buffer overruns). With respect to other properties such as timing side channels, I prove nothing; so it is comforting that this same C program has over a decade of widespread use and examination.

# Group Genesis: The result of over 7 years of research

# Group Genesis: The result of over 7 years of research



## An Automaton for Road Transport Legislation

Moritz Müller, Raül Espejo Boix and Joost J. Joosten

### European Road Transport Regulation No. 561/2006

Regulation 561 concerns activity sequences of truck drivers recorded by tachographs. Formally: finite words with letters $d, r, w$ representing acitivities **driving**, **resting** and **other work** per minute. E.g. $dddwwrrr$ means 3 minutes driving, followed by 2 minutes other work and 3 minutes resting. In practice, these words are very long. One needs an **algorithm** that checks legality.

Regulation 561 is a complex set of laws. Depending on accumulated durations of e.g. driving, it requires various kinds of resting periods, namely **breaks**, **daily rest periods** and **weekly rest periods**, each of which can be **regular** or **reduced**. E.g. `Article 8.6` requires:

```
In any two consecutive weeks a driver shall take at least two regular weekly rest periods, or one regular weekly
rest period and one reduced weekly rest period of at least 24 hours.  However, the reduction shall be compensated by
an equivalent period of rest taken en bloc before the end of the third week following the week in question.
```

### Stopwatch Automata

A **stopwatch automaton** is given by finitely many **states**, **transitions** and **stopwatches**. At each time-point of a computation the automaton resides in a state. It can either stay in this state or take a transition and switch to another state instantaneously. At each time-point the stopwatches show values, up to some **bound**. In a given state each stopwatch is **active** or not. When staying in a state the active stopwatches increment their value, the unactive ones keep their value.

Each transition has a guard and an action. The **guard** specifies a property of stopwatch values that must be met for the transition to be taken, e.g. certain upper or lower bounds of certain stopwatch values. The **action** updates stopwatch values, e.g. resets some to value 0. States are labeled by $d, w$ or $r$. The automaton **reads** the label for each time unit spent in the state.

The automaton **accepts** a word $w$ if there is a computation reading $w$ and leads from the state *start* to the state *accept*.

### Construction

We construct a stopwatch automaton that accepts a word if and only if the represented activity sequence is legal according to Regulation 561.

### Architecture

The automaton uses the 11 states shown in the figure plus the state *start*.

Letters labeling states are shown in yellow. The label of *week* and *accept* do not matter.

Below each state there is the list of stopwatches active in it.

Their bounds are

| | | |
|---|---|---|
| $x_{start}$: 1 | $x_{cd}$: 271 | $x_{week}$: 10081 |
| $x_{break}$: 540 | $x_{day}$: 1440 | $x_{ww}$: 3601 |
| $x_{dr}$: 660 | $x_{dd}$: 601 | $x_{dw}$: 3361 |
| $x_{wr}$: 2700 | $x_{cr}$: 1260 | |

Additionally, the automaton operates 16 bits, 4 counters and 3 registers – these are stopwatches that are nowhere active.

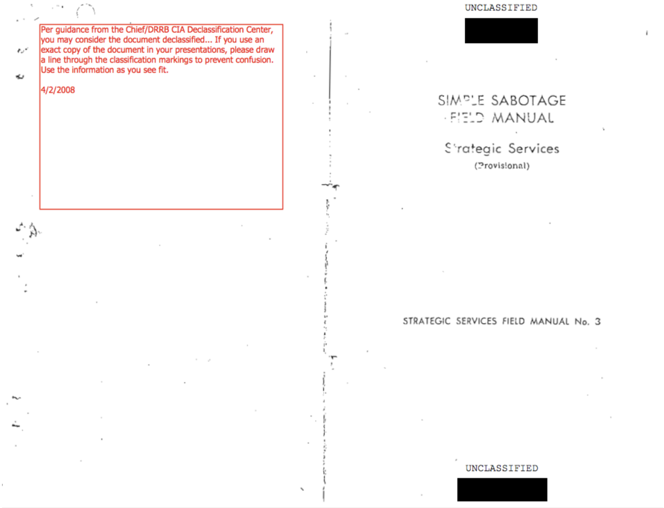
The automaton has 102 transitions. An arrow between states indicates possibly many transitions. An arrow between boxes indicates transitions between all states within the boxes. The figure omits transitions from state *start* to all other states.

The table below lists the transitions excluding those leaving *start*, *compensate1* and *compensate2*.

d
w
drive
$x_{cd}, x_{day}, x_{dd}, x_{week}, x_{ww}, x_{dw}$
other work
$x_{ww}, x_{day}, x_{week}$
r
compensate1
$x_{cr}, x_{day}, x_{week}$
compensate2
$x_{cr}, x_{day}, x_{week}$
reg weekly
$x_{wr}, x_{day}, x_{week}$
red weekly
$x_{wr}, x_{day}, x_{week}$
break
$x_{break}, x_{day}, x_{week}$
r
reg daily
$x_{dr}, x_{day}, x_{week}$
red daily
$x_{dr}, x_{day}, x_{week}$
week
$x_{week}, x_{day}$
accept

### Transitions

# The conference: A one-night stand?



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4/2/2008

UNCLASSIFIED

[redacted]

SIMPLE SABOTAGE
FIELD MANUAL

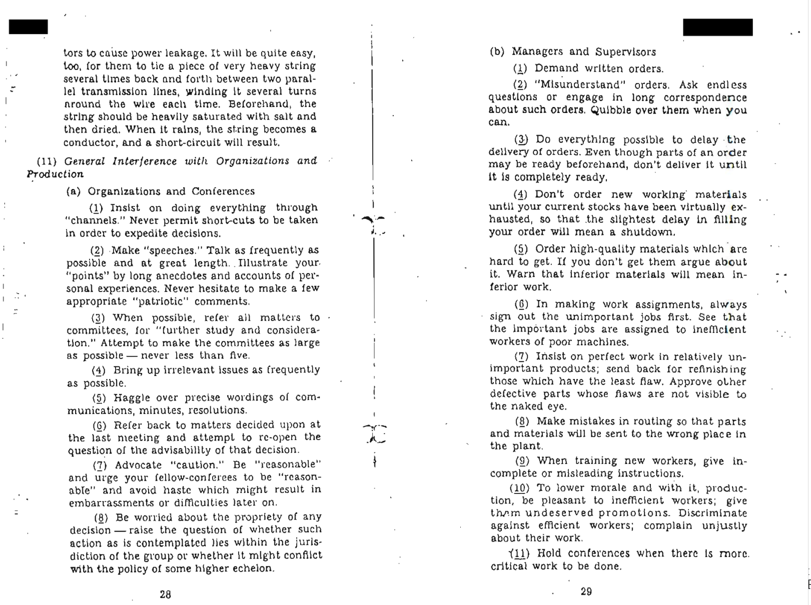
Strategic Services
(Provisional)

STRATEGIC SERVICES FIELD MANUAL No. 3

UNCLASSIFIED

[redacted]

# The conference: A one-night stand?



[redacted]

tors to cause power leakage. It will be quite easy, too, for them to tie a piece of very heavy string several times back and forth between two parallel transmission lines, winding it several turns around the wire each time. Beforehand, the string should be heavily saturated with salt and then dried. When it rains, the string becomes a conductor, and a short-circuit will result.

(11) *General Interference with Organizations and Production*

(a) Organizations and Conferences

(1) Insist on doing everything through "channels." Never permit short-cuts to be taken in order to expedite decisions.

(2) Make "speeches." Talk as frequently as possible and at great length. Illustrate your "points" by long anecdotes and accounts of personal experiences. Never hesitate to make a few appropriate "patriotic" comments.

(3) When possible, refer all matters to committees, for "further study and consideration." Attempt to make the committees as large as possible — never less than five.

(4) Bring up irrelevant issues as frequently as possible.

(5) Haggle over precise wordings of communications, minutes, resolutions.

(6) Refer back to matters decided upon at the last meeting and attempt to re-open the question of the advisability of that decision.

(7) Advocate "caution." Be "reasonable" and urge your fellow-conferees to be "reasonable" and avoid haste which might result in embarrassments or difficulties later on.

(8) Be worried about the propriety of any decision — raise the question of whether such action as is contemplated lies within the jurisdiction of the group or whether it might conflict with the policy of some higher echelon.

[redacted]

(b) Managers and Supervisors

(1) Demand written orders.

(2) "Misunderstand" orders. Ask endless questions or engage in long correspondence about such orders. Quibble over them when you can.

(3) Do everything possible to delay the delivery of orders. Even though parts of an order may be ready beforehand, don't deliver it until it is completely ready.

(4) Don't order new working materials until your current stocks have been virtually exhausted, so that the slightest delay in filling your order will mean a shutdown.

(5) Order high-quality materials which are hard to get. If you don't get them argue about it. Warn that inferior materials will mean inferior work.

(6) In making work assignments, always sign out the unimportant jobs first. See that the important jobs are assigned to inefficient workers of poor machines.

(7) Insist on perfect work in relatively unimportant products; send back for refinishing those which have the least flaw. Approve other defective parts whose flaws are not visible to the naked eye.

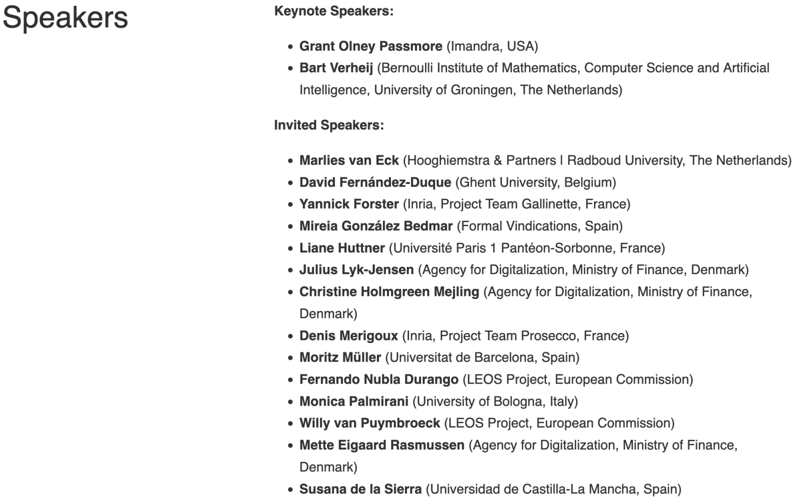
(8) Make mistakes in routing so that parts and materials will be sent to the wrong place in the plant.

(9) When training new workers, give incomplete or misleading instructions.

(10) To lower morale and with it, production, be pleasant to inefficient workers; give them undeserved promotions. Discriminate against efficient workers; complain unjustly about their work.

(11) Hold conferences when there is more critical work to be done.

# The conference: A one-night stand?



## Speakers

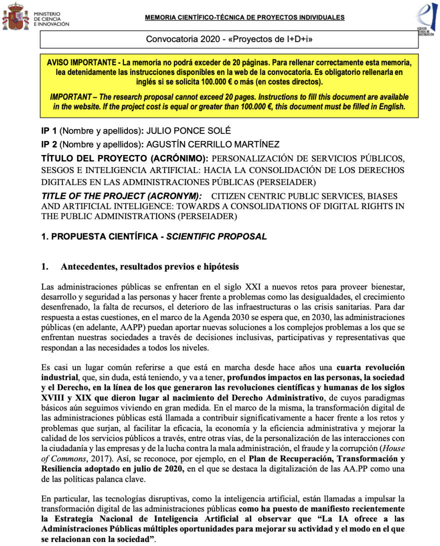
**Keynote Speakers:**

- **Grant Olney Passmore** (Imandra, USA)
- **Bart Verheij** (Bernoulli Institute of Mathematics, Computer Science and Artificial Intelligence, University of Groningen, The Netherlands)

**Invited Speakers:**

- **Marlies van Eck** (Hooghiemstra & Partners I Radboud University, The Netherlands)
- **David Fernández-Duque** (Ghent University, Belgium)
- **Yannick Forster** (Inria, Project Team Gallinette, France)
- **Mireia González Bedmar** (Formal Vindications, Spain)
- **Liane Huttner** (Université Paris 1 Pantéon-Sorbonne, France)
- **Julius Lyk-Jensen** (Agency for Digitalization, Ministry of Finance, Denmark)
- **Christine Holmgreen Mejling** (Agency for Digitalization, Ministry of Finance, Denmark)
- **Denis Merigoux** (Inria, Project Team Prosecco, France)
- **Moritz Müller** (Universitat de Barcelona, Spain)
- **Fernando Nubla Durango** (LEOS Project, European Commission)
- **Monica Palmirani** (University of Bologna, Italy)
- **Willy van Puymbroeck** (LEOS Project, European Commission)
- **Mette Eigaard Rasmussen** (Agency for Digitalization, Ministry of Finance, Denmark)
- **Susana de la Sierra** (Universidad de Castilla-La Mancha, Spain)

# Cradle: Future projects



MINISTERIO DE CIENCIA E INNOVACIÓN

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Convocatoria 2020 - «Proyectos de I+D+i»

**AVISO IMPORTANTE - La memoria no podrá exceder de 20 páginas. Para rellenar correctamente esta memoria, lea detenidamente las instrucciones disponibles en la web de la convocatoria. Es obligatorio rellenarla en inglés si se solicita 100.000 € o más (en costes directos).**

***IMPORTANT – The research proposal cannot exceed 20 pages. Instructions to fill this document are available in the website. If the project cost is equal or greater than 100.000 €, this document must be filled in English.***

**IP 1** (Nombre y apellidos): JULIO PONCE SOLÉ

**IP 2** (Nombre y apellidos): AGUSTÍN CERRILLO MARTÍNEZ

**TÍTULO DEL PROYECTO (ACRÓNIMO):** PERSONALIZACIÓN DE SERVICIOS PÚBLICOS, SESGOS E INTELIGENCIA ARTIFICIAL: HACIA LA CONSOLIDACIÓN DE LOS DERECHOS DIGITALES EN LAS ADMINISTRACIONES PÚBLICAS (PERSEIADER)

***TITLE OF THE PROJECT (ACRONYM):*** CITIZEN CENTRIC PUBLIC SERVICES, BIASES AND ARTIFICIAL INTELIGENCE: TOWARDS A CONSOLIDATIONS OF DIGITAL RIGHTS IN THE PUBLIC ADMINISTRATIONS (PERSEIADER)

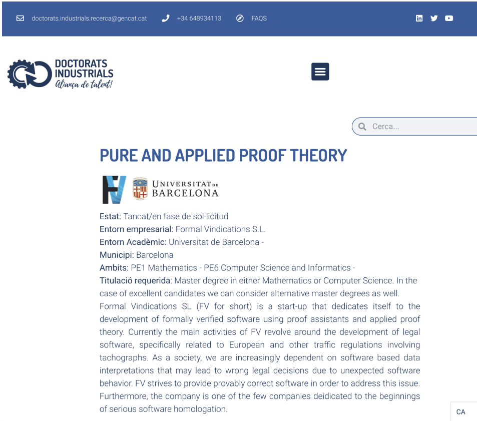
**1. PROPUESTA CIENTÍFICA - *SCIENTIFIC PROPOSAL***

**1. Antecedentes, resultados previos e hipótesis**

Las administraciones públicas se enfrentan en el siglo XXI a nuevos retos para proveer bienestar, desarrollo y seguridad a las personas y hacer frente a problemas como las desigualdades, el crecimiento desenfrenado, la falta de recursos, el deterioro de las infraestructuras o las crisis sanitarias. Para dar respuesta a estas cuestiones, en el marco de la Agenda 2030 se espera que, en 2030, las administraciones públicas (en adelante, AAPP) puedan aportar nuevas soluciones a los complejos problemas a los que se enfrentan nuestras sociedades a través de decisiones inclusivas, participativas y representativas que respondan a las necesidades a todos los niveles.

Es casi un lugar común referirse a que está en marcha desde hace años una **cuarta revolución industrial**, que, sin duda, está teniendo, y va a tener, **profundos impactos en las personas, la sociedad y el Derecho, en la línea de los que generaron las revoluciones científicas y humanas de los siglos XVIII y XIX que dieron lugar al nacimiento del Derecho Administrativo**, de cuyos paradigmas básicos aún seguimos viviendo en gran medida. En el marco de la misma, la transformación digital de las administraciones públicas está llamada a contribuir significativamente a hacer frente a los retos y problemas que surjan, al facilitar la eficacia, la economía y la eficiencia administrativa y mejorar la calidad de los servicios públicos a través, entre otras vías, de la personalización de las interacciones con la ciudadanía y las empresas y de la lucha contra la mala administración, el fraude y la corrupción (*House of Commons*, 2017). Así, se reconoce, por ejemplo, en el **Plan de Recuperación, Transformación y Resiliencia adoptado en julio de 2020,** en el que se destaca la digitalización de las AA.PP como una de las políticas palanca clave.

En particular, las tecnologías disruptivas, como la inteligencia artificial, están llamadas a impulsar la transformación digital de las administraciones públicas **como ha puesto de manifiesto recientemente la Estrategia Nacional de Inteligencia Artificial al observar que "La IA ofrece a las Administraciones Públicas múltiples oportunidades para mejorar su actividad y el modo en el que se relacionan con la sociedad".**



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## PURE AND APPLIED PROOF THEORY

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Estat: Tancat/en fase de sol·licitud
Entorn empresarial: Formal Vindications S.L.
Entorn Acadèmic: Universitat de Barcelona -
Municipi: Barcelona
Ambits: PE1 Mathematics - PE6 Computer Science and Informatics -
Titulació requerida: Master degree in either Mathematics or Computer Science. In the case of excellent candidates we can consider alternative master degrees as well.

Formal Vindications SL (FV for short) is a start-up that dedicates itself to the development of formally verified software using proof assistants and applied proof theory. Currently the main activities of FV revolve around the development of legal software, specifically related to European and other traffic regulations involving tachographs. As a society, we are increasingly dependent on software based data interpretations that may lead to wrong legal decisions due to unexpected software behavior. FV strives to provide provably correct software in order to address this issue. Furthermore, the company is one of the few companies deidicated to the beginnings of serious software homologation.

CA

# Cradle: Future projects

*Guretruck S.L., (Consortium Leader)*
*Universitat de Barcelona (Technical Coordinator)*
*Formal Vindications S.L.,*

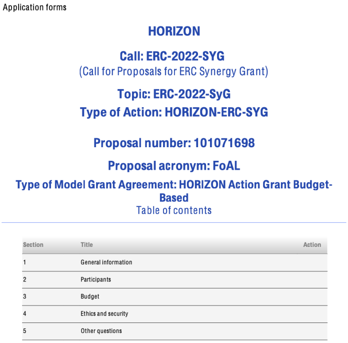
**Algorithmic Law Design and Implementation**

**Ensuring civil rights in legal software**

RETOS 2021: Proyectos en colaboración público-privada 2021

GURETRUCK

UNIVERSITAT DE BARCELONA



Application forms

**HORIZON**

**Call: ERC-2022-SYG**
(Call for Proposals for ERC Synergy Grant)

**Topic: ERC-2022-SyG**
**Type of Action: HORIZON-ERC-SYG**

**Proposal number: 101071698**

**Proposal acronym: FoAL**

**Type of Model Grant Agreement: HORIZON Action Grant Budget-Based**
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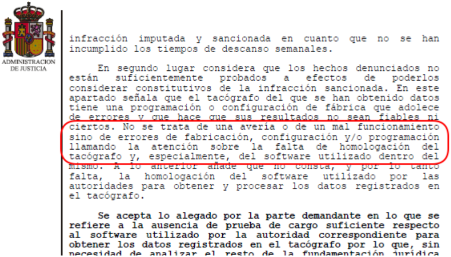
| 4 | Ethics and security | |
| 5 | Other questions | |

# Cradle: Future projects



ADMINISTRACION
DE JUSTICIA

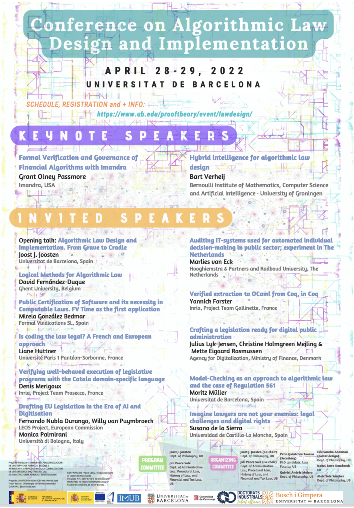
infracción imputada y sancionada en cuanto que no se han incumplido los tiempos de descanso semanales.

En segundo lugar considera que los hechos denunciados no están suficientemente probados a efectos de poderlos considerar constitutivos de la infracción sancionada. En este apartado señala que el tacógrafo del que se han obtenido datos tiene una programación o configuración de fábrica que adolece de errores y que hace que sus resultados no sean fiables ni ciertos. No se trata de una avería o de un mal funcionamiento sino de errores de fabricación, configuración y/o programación llamando la atención sobre la falta de homologación del tacógrafo y, especialmente, del software utilizado dentro del mismo. A lo anterior añade que no consta, y por lo tanto falta, la homologación del software utilizado por las autoridades para obtener y procesar los datos registrados en el tacógrafo.

**Se acepta lo alegado por la parte demandante en lo que se refiere a la ausencia de prueba de cargo suficiente respecto al software utilizado por la autoridad correspondiente para obtener los datos registrados en el tacógrafo por lo que, sin necesidad de analizar el resto de la fundamentación jurídica**

N. Sentence: 30/2019, CONTENCIOSO/ADMTVO court. N. 4 of Valladolid (Spain)

# The present: Our conference



## Conference on Algorithmic Law Design and Implementation

APRIL 28-29, 2022
UNIVERSITAT DE BARCELONA

SCHEDULE, REGISTRATION and + INFO:
https://www.ub.edu/prooftheory/event/lawdesign/

### KEYNOTE SPEAKERS

**Formal Verification and Governance of Financial Algorithms with Imandra**
Grant Olney Passmore
Imandra, USA

**Hybrid intelligence for algorithmic law design**
Bart Verheij
Bernoulli Institute of Mathematics, Computer Science and Artificial Intelligence · University of Groningen

### INVITED SPEAKERS

Opening talk: **Algorithmic Law Design and Implementation. From Grave to Cradle**
Joost J. Joosten
Universitat de Barcelona, Spain

**Logical Methods for Algorithmic Law**
David Fernández-Duque
Ghent University, Belgium

**Public Certification of Software and its necessity in Computable Laws. FV Time as the first application**
Mireia González Bedmar
Formal Vindications SL, Spain

**Is coding the law legal? A French and European approach**
Liane Huttner
Université Paris 1 Panthéon-Sorbonne, France

**Verifying well-behaved execution of legislative programs with the Catala domain-specific language**
Denis Merigoux
Inria, Project Team Prosecco, France

**Drafting EU Legislation in the Era of AI and Digitisation**
Fernando Nubla Durango, Willy van Puymbroeck
LEOS Project, European Commission
Monica Palmirani
Università di Bologna, Italy

**Auditing IT-systems used for automated individual decision-making in public sector; experiment in The Netherlands**
Marlies van Eck
Hooghiemstra & Partners and Radboud University, The Netherlands

**Verified extraction to OCaml from Coq, in Coq**
Yannick Forster
Inria, Project Team Gallinette, France

**Crafting a legislation ready for digital public administration**
Julius Lyk-Jensen, Christine Holmgreen Mejling & Mette Eigaard Rasmussen
Agency for Digitalization, Ministry of Finance, Denmark

**Model-Checking as an approach to algorithmic law and the case of Regulation 561**
Moritz Müller
Universitat de Barcelona, Spain

**Imagine lawyers are not your enemies: legal challenges and digital rights**
Susana de la Sierra
Universidad de Castilla-La Mancha, Spain

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Isabel Serra Domènech
UB

Aleix Solé Sánchez
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Proyecto PID2020-[illegible]: PERSONALIZACIÓN DE LOS SERVICIOS PÚBLICOS, SESGOS E INTELIGENCIA ARTIFICIAL: HACIA LA CONSOLIDACIÓN DE LOS DERECHOS DIGITALES EN LAS ADMINISTRACIONES PÚBLICAS, financiado por:

Proyecto [illegible]: Worlds and Truth Values: Challenges to Formal Semantics ([illegible]) financiado por:

SOFTWARE DE FALLO CERO. Innovación para el sector del transporte
Proyecto RTC-2017-6740-7 financiado por MCIN/AEI/ 10.13039/501100011033 y por FEDER Una manera de hacer Europa

Thank you for your contributions!
Enjoy the conference!