Artificial Intelligence to calibrate traffic models

ERASMUS+ Mobility

Prof. PhD. André Luiz Cunha

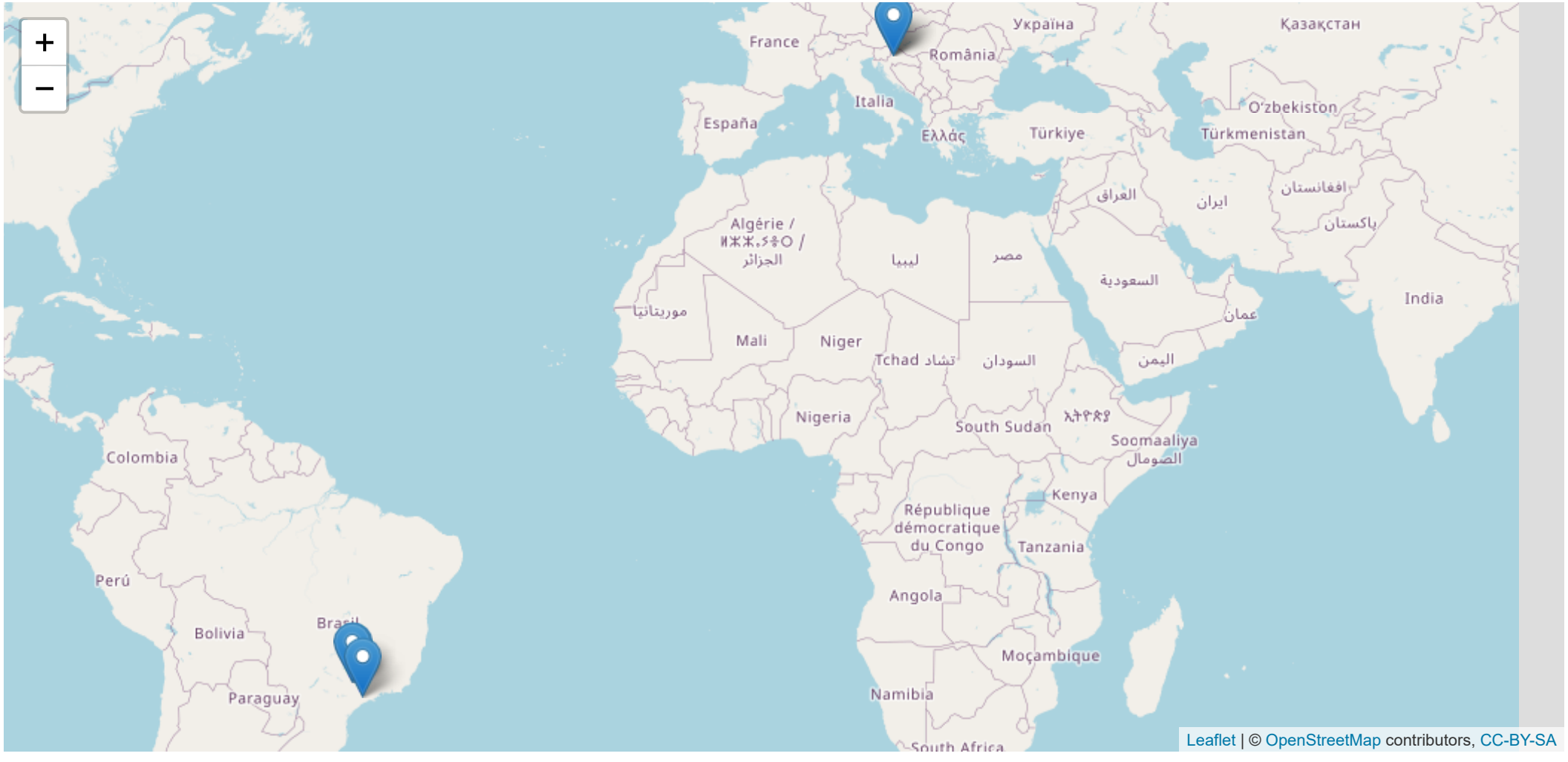
USP | EESC

2022-04-21

University of Zagreb
Faculty of Transport and Traffic Sciences

São Carlos School of Engineering
University of São Paulo

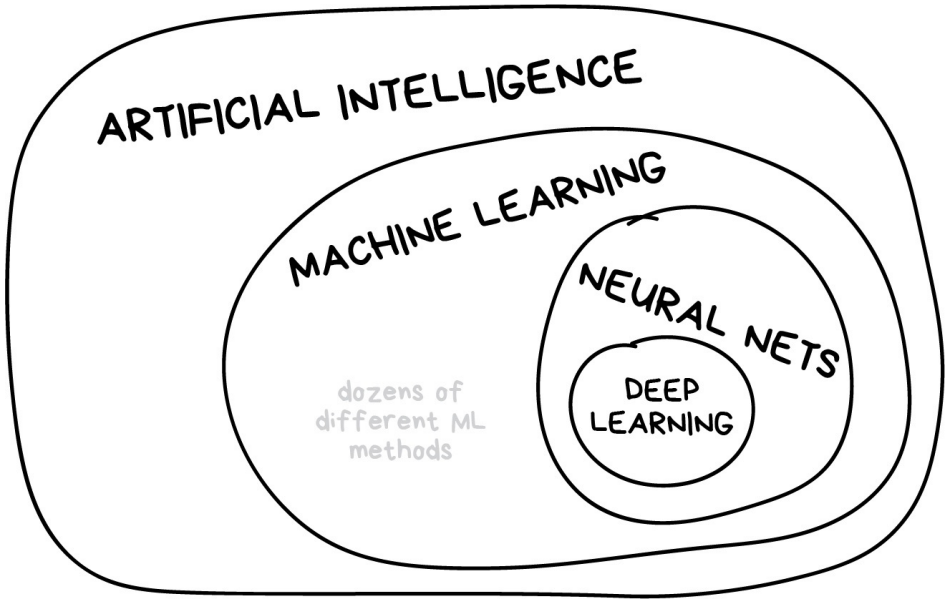
Virtual Mobility


+
−
France
România
Україна
Қазақстан
Italia
España
Ελλάς
Türkiye
O'zbekiston
Türkmenistan
العراق
ایران
افغانستان
پاکستان
Algérie / ⵍⵣⵣⴰⵢⴻⵔ / الجزائر
ليبيا
مصر
السعودية
India
عمان
موريتانيا
Mali
Niger
Tchad تشاد
السودان
اليمن
Nigeria
South Sudan
ኢትዮጵያ
Soomaaliya الصومال
Kenya
Colombia
République démocratique du Congo
Tanzania
Perú
Angola
Bolivia
Brasil
Moçambique
Paraguay
Namibia
South Africa
Leaflet | © OpenStreetMap contributors, CC-BY-SA

website: USP

Get Started

Concepts



- **|AI| Artificial Intelligence**:
  a whole knowledge field
- **|ML| Machine Learning**:
  is a part of AI, but not the only one
- **|NN| Neural Networks**:
  one of the machine learning types
- **|DP| Deep Learning**:
  a modern method of building, training and using NN (a new architecture)

Image credit: vask3

Methods & Algorithms

Image credit: vask3

Genetic Algorithm [GA]

Genetic Algorithm

Concept | Algorithm | Elements | Operators

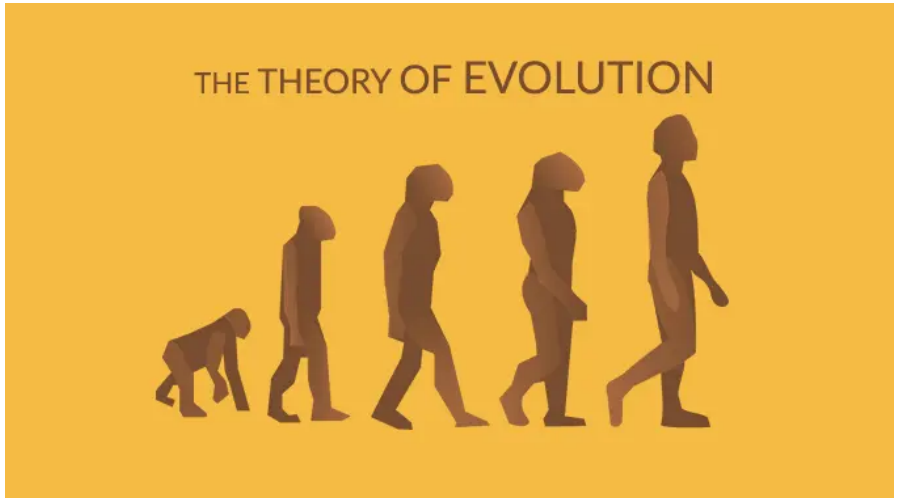


Image credit: EarthHow

> GAs are stochastic search algorithms inspired by principles of biological and natural selection.
>
> --*John H. Holland* (1984)

> GAs simulate the evolution of living organisms, where the fittest individuals dominate over the weaker ones, by mimicking the biological mechanisms of evolution, such as selection, crossover and mutation.
>
> -- [STRUCCA, 2021]

Genetic Algorithm

Concept | Algorithm | Elements | Operators

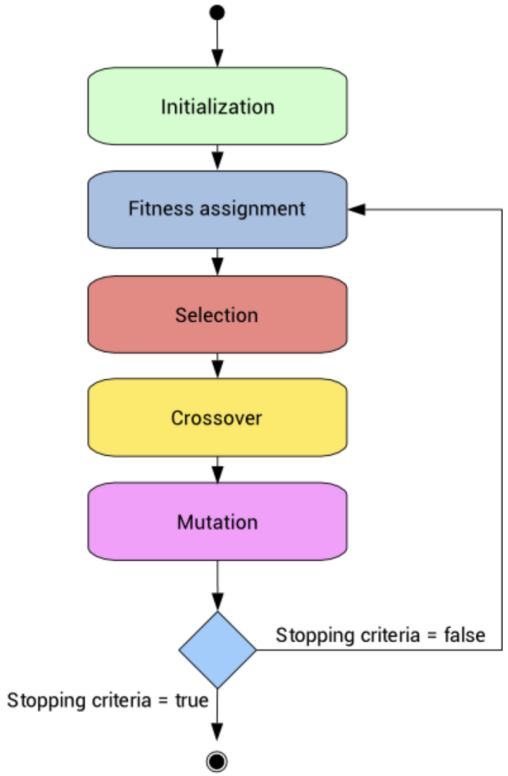


Image credit: RPubs

- Free for any kind of model:

$$y = f(\alpha_n, X_m)$$

$$model = f(parameters, variables)$$

$$min(Error) = g(model, data)$$

- Dataset:

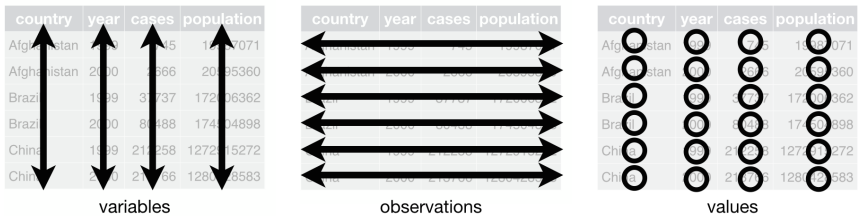
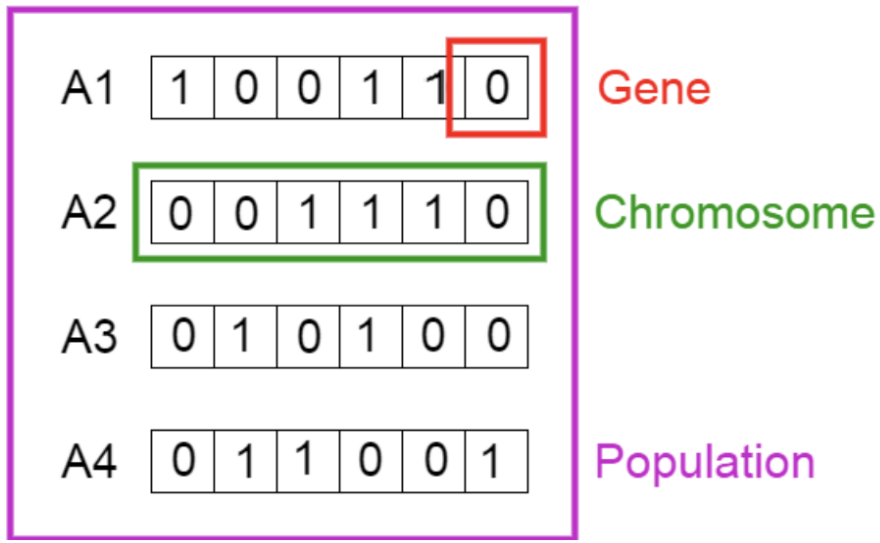


Image credit: R4DS

Genetic Algorithm

Concept | Algorithm | **Elements** | Operators



$$chromosome = \left[\underbrace{1110101}_{gen\ 1}\ \underbrace{1001}_{gen\ 2}\ \ldots\ \underbrace{10101}_{gen\ N}\right]$$

$$chromosome = \left[\underbrace{11}_{gen\ 1}\ \underbrace{32}_{gen\ 2}\ \underbrace{5}_{gen\ 2}\ \ldots\ \underbrace{10}_{gen\ N}\right]$$

Genetic Algorithm

Concept | Algorithm | Elements | **Operators**

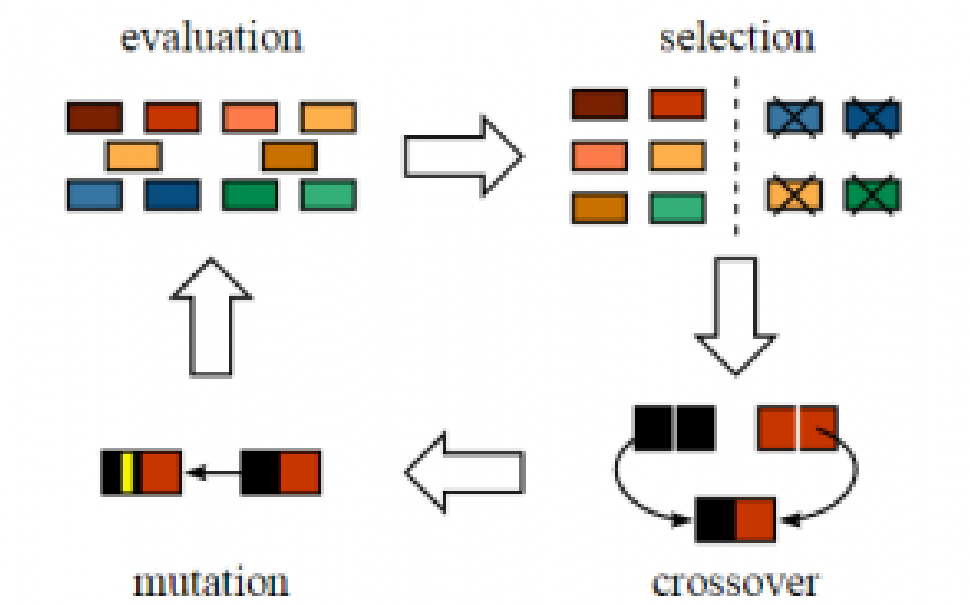


Image credit: PapersWithCode

Parameters to set:

- **Evaluation**:
  'fitness function' - rank of the individuals
  Hollander & Liu, 2008
- **Selection/Eletism**:
  preserve the *n*-th best solutions
- **Crossover**:
  mix the solutions
- **Mutation**:
  change part of a solution
- **Predation**:
  "diversity", eliminate *k* worst solutions and generate new ones randomly

Aplications of GA

Examples in Transport Engineering

Research Team | Brazilian road transport

Prof. J.R. Setti
[USP-EESC]

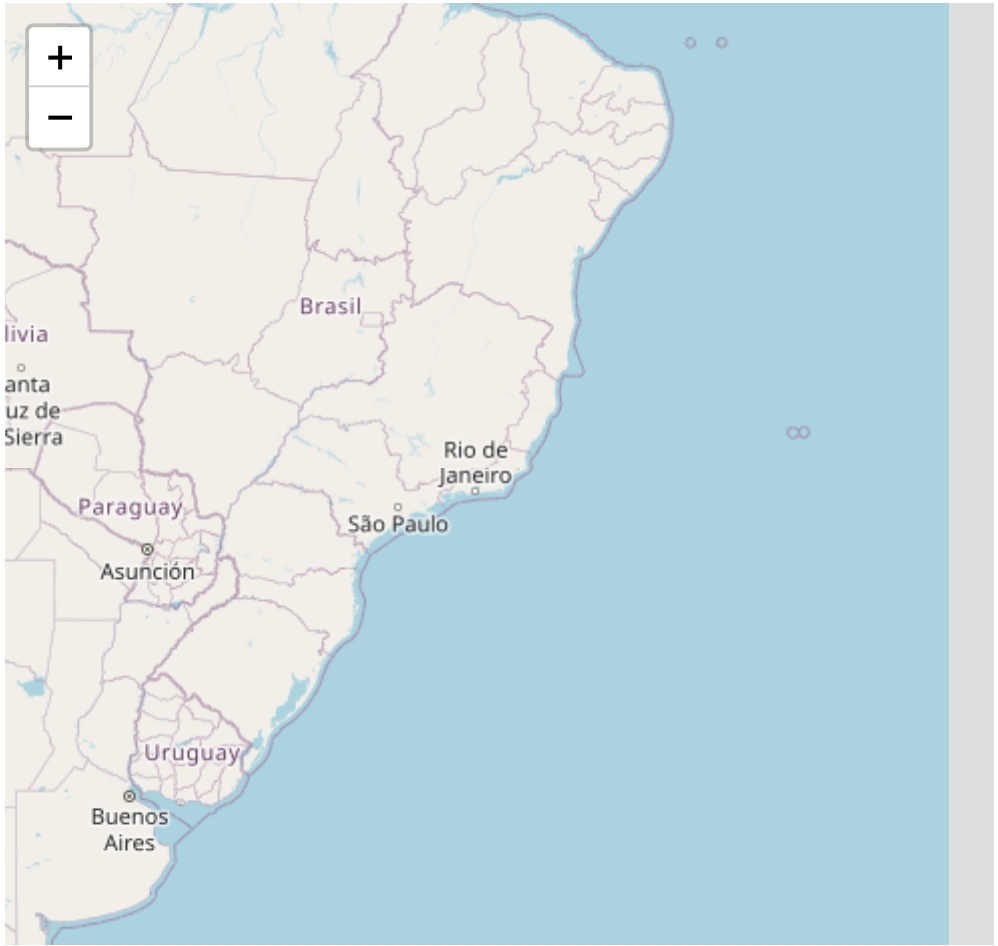
Prof. A.L. Cunha
[USP-EESC]

Prof. J.E. Bessa Jr.
[UFMG]

Gustavo Riente
McTrans Center, UFL

Examples in Transport Engineering

Research Team | Brazilian road transport



- ~80% of the roads are Two-lane Highways
- ~60% of Brazilian cargo is transported by road
- Need for *Highway Capacity Manual* for Brazil

Microscopic models calibration

PREMISSES:

> Microscopic models are essential tools to the Transport engineer, however he/she needs specialized knowledge to specify how well the simulation is reproduced.

> The use of simulation models without proper calibration results in planning and design errors.

MODELS:

Driver behavior:

- Car-following logic
- Lane change logic

Vehicle performance:

- Acceleration \ Deceleration
- Emergency stop

TRARR (TRAffic on Rural Roads)

Details | GA | Result | Publication

Developed by *Australian Road Research Board* (ARRB), Transport Research Ltd, Australia.

- Simulation time step: 1.0s
- 7 fleet composition
- 18 different vehicles
- 18 driver profiles

TRARR (TRAffic on Rural Roads)

Details | GA | Result | Publication

- coded in Perl
- **25 parameters** calibrated
- Vehicle performance:
  - used 7 vehicles in 3 classes
    (car, unit truck, articulated truck)
  - Weight
  - Lenght
  - Weight/Power ratio
- Driver behavior:
  - 7 drivers profile
  - Free Flow Speed
  - Speed factor reduction in auxiliary lanes

TRARR (TRAffic on Rural Roads)

- Error drops from 9% to 6% using calibrated parameters
- Method to estimate traffic parameters from video camera (manually).

TRARR (TRAffic on Rural Roads)

Details GA Result **Publication**

- Egami, C.Y. [2000] (Master)
- Egami, C.Y. [2006] (PhD thesis)

TWOPAS (TWO-lane with PASsing)

Details | GA | Result | Publication

developed by *Midwest Research Institute* (MRI), *Federal Highway Administration* (FHWA), in USA.

- Simulation time step: 1.0s
- 13 different vehicles
- 10 driver profiles

TWOPAS (TWO-lane with PASsing)

Details | GA | Result | Publication

- coded in Perl and Lua
- **35 parameters** calibrated
- Vehicle performance:
  - used 4 vehicles
  - Weight/Power ratio
- Driver behavior:
  - 10 drivers profile
  - Free Flow Speed
  - Probability distribution of overtaking
  - Car-following factor

TWOPAS (TWO-lane with PASsing)

Details GA Result Publication

- Error drops from 9.5% to 6% using calibrated parameters
- Method to estimate traffic parameters from video camera (manually/automatic).

TWOPAS (TWO-lane with PASsing)

Details GA Result **Publication**

- [2006] Automatic Calibration of Two-Lane Highway Traffic Simulation Models Using Genetic Algorithm.
- [2008] Mon-Ma, M.L. (PhD thesis)
- [2011] Derivation of ATS and PTS function for Two-lane, Rural Highways in Brazil.

INTEGRATION Dynamic Traffic Assignment and Simulation Software

Details | GA | Truck model | Result

developed by **Michael Van Aerde** and **Dr. Hesham Rakha**, at *Virginia Tech Transportation Institute* (VTTI), in USA. Simulate any type of highway (two-lane, multilane and freeway).

- Simulation time step: 0.1s
- 7 different vehicles
- 10 driver profiles
- Small version is available for download: https://sites.google.com/a/vt.edu/hrakha/software

INTEGRATION Dynamic Traffic Assignment and Simulation Software

Details | GA | Truck model | Result

- Coded in VBA-Excel and Lua
- **8 parameters** calibrated
- Vehicle performance:
  - 4 different vehicles
  - Weight/Power ratio
- Fitness function:
  - MAER (Mean Absolute Error)

INTEGRATION Dynamic Traffic Assignment and Simulation Software

- Collect data:
  - GPS position of trucks at 10Hz (0.1s) travelling 10km on road
  - 62 trucks (5 light, 13 medium, 22 heavy, and 22 extra-heavy)
- Model:

$$F = m \cdot a$$

$$F_t = min(\eta \cdot 3600 \cdot \frac{P}{V}; W_{ta} \cdot \mu)$$

$$R_t = R_a + R_r + R_g$$

$$R_a = c_1 \cdot C_D \cdot C_h \cdot A \cdot V^2$$

$$R_r = C_r \cdot (c_2 \cdot V + c_3) \cdot \frac{W}{1000}$$

$$R_g = W \cdot i$$

INTEGRATION Dynamic Traffic Assignment and Simulation Software

- The GA was able to find parameters to represent the average performance of four different trucks
- The MAER for truck classes ranged from 4.0% to 6.5%
- The MAER for individual trucks was 2.2%

TSIS-CORSIM (CORridor traffic SIMulation model)

developed by *Federal Highway Administration* (FHWA), in USA. It is capable to simulate freeways, two-lane highways, street in an integrated system.

- Simulation time step: 1.0s
- 7 different vehicles
- 10 driver profiles

TSIS-CORSIM (CORridor traffic SIMulation model)

- **31 parameters** in TSIS-CORSIM
- **Models were calibrated separately**
- Vehicle performance:
  - 4 different vehicles
  - Weight/Power ratio
- Driver behavior:
  - 10 drivers profile
  - Car-following logic
  - Lane-changing logic
- Fitness function:
  - MAER (Mean Absolute Error)

TSIS-CORSIM (CORridor traffic SIMulation model)

- Collect data:
  - GPS position of trucks at 10Hz (0.1s) travelling 10km on road
  - 62 trucks (5 light, 13 medium, 22 heavy, and 22 extra-heavy)
- Model:

TSIS-CORSIM (CORridor traffic SIMulation model)

- Collect data:
  - Speed and Flow data on a 10km of multilane highway
  - Speed and Flow data on 16 segments of two-lane highways
- Model:

TSIS-CORSIM (CORridor traffic SIMulation model)

- The AG was able to calibrate parameter to four different trucks and 10 different drivers profile.
- The MAER for truck classes ranged from 4.5% to 7.5%
- The MAER for individual trucks was 2.2%
- The error ratio dropped by almost 50% using the parameter calibrated for driver behaviour
- The method reveals how to estimate percentage time spent following (PTSF) with a calibrated model

TSIS-CORSIM (CORridor traffic SIMulation model)

- [2007] Araújo, J.J. (PhD thesis)
- [2007] Cunha, A.L. (Master's)
- [2009] Genetic Algorithm for the calibration of vehicle performance models of microscopic traffic simulators.
- [2011] Truck equivalence factors for divided, multilane highways in Brazil.
- [2017] Evaluation of Models to Estimate Percent Time Spent Following on Two-Lane Highways.

VISSIM Traffic Simulation Software

Details | GA | Truck model | Driver model | Publication

Developed by PTV Group in Karlsruhe, Germany. It is a microscopic multi-modal traffic flow simulation package.

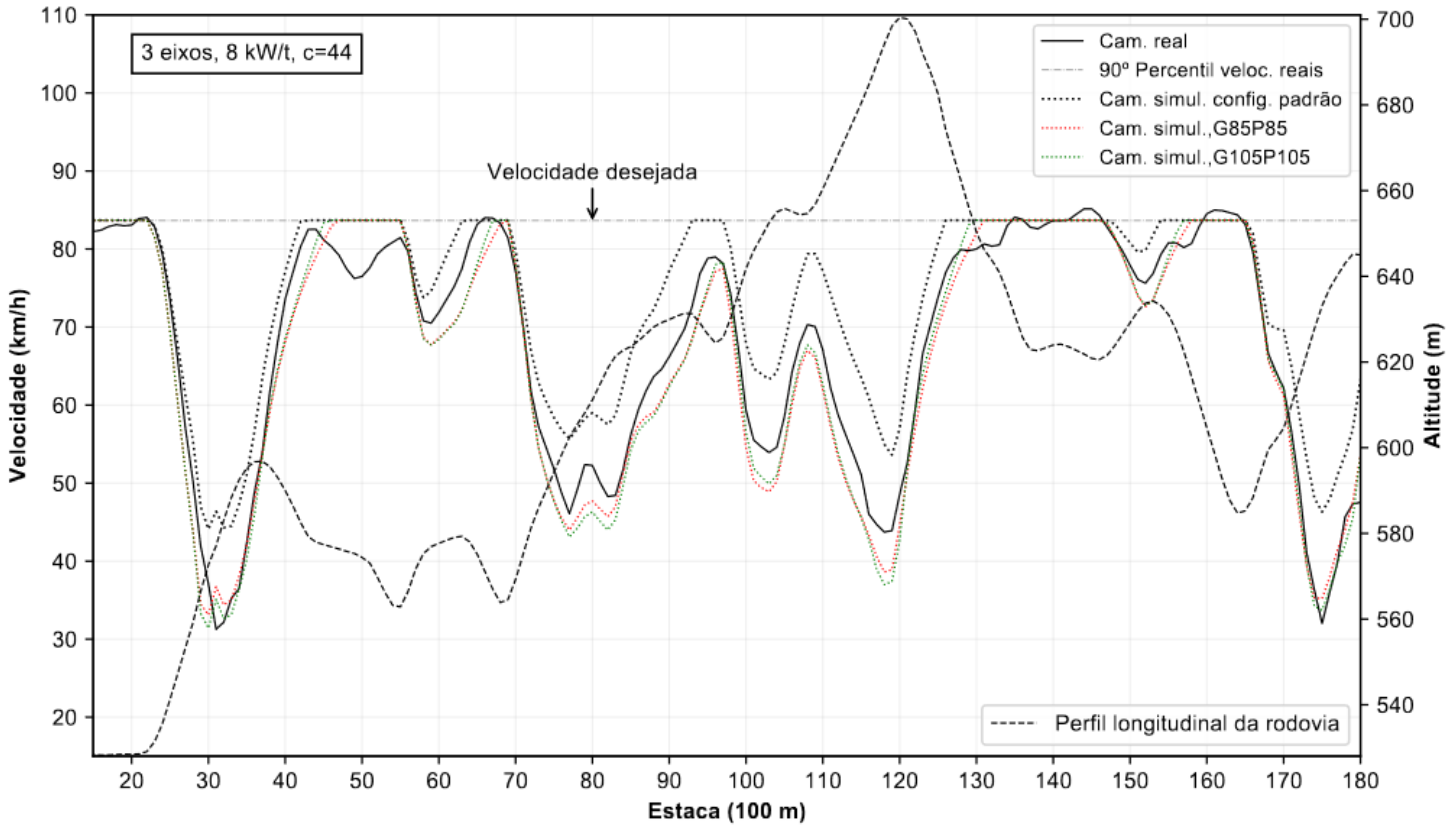
- Simulation time step: 0.1s
- unlimited vehicles
- 10 driver profiles

VISSIM Traffic Simulation Software

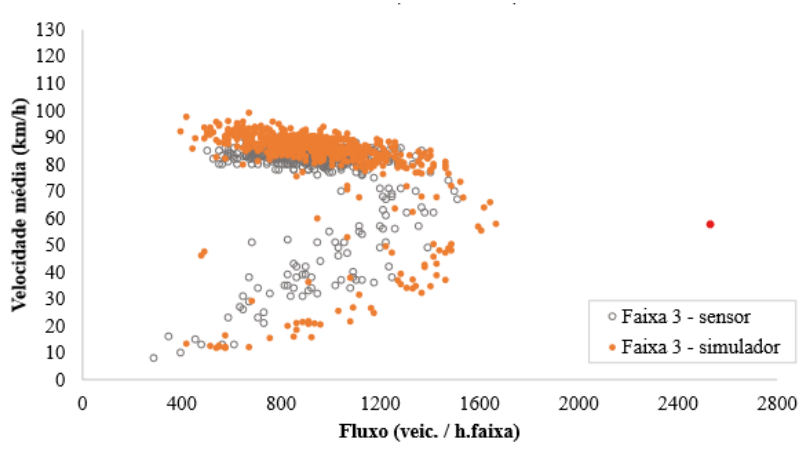
- Coded in Python
- **30 parameters** for each truck class
- **10 parameters** for each driver profile
- Vehicle performance
  - used 4 truck classes
  - distribution of acceleration, power and weight
- Driver behavior
  - 10 drivers profile
  - Car-following logic
  - Lane-changing logic
- Fitness function
  - MAER (Mean Absolute Error)

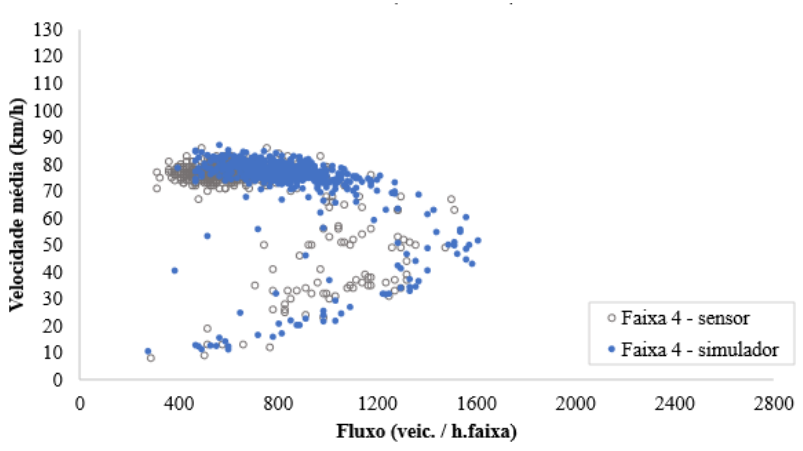
VISSIM Traffic Simulation Software

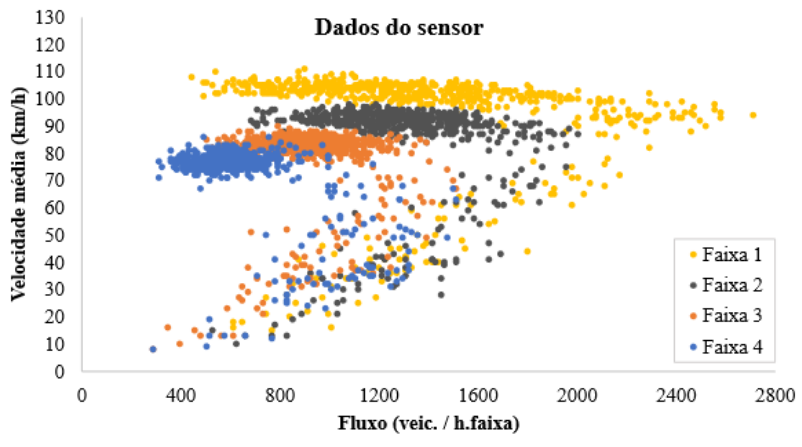
Details | GA | **Truck model** | Driver model | Publication

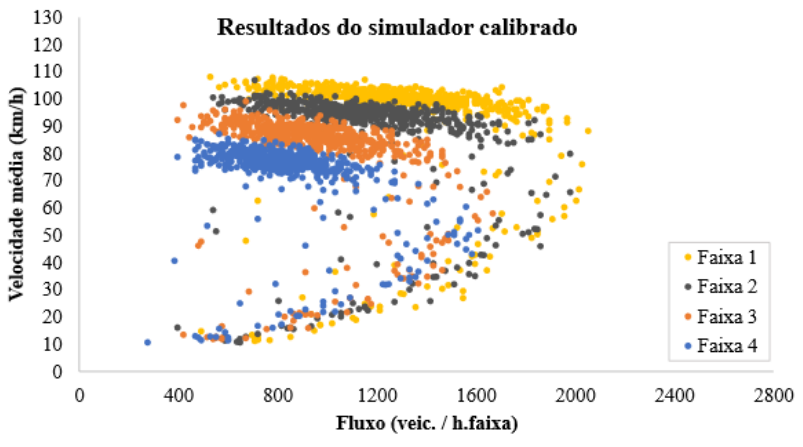


VISSIM Traffic Simulation Software









VISSIM Traffic Simulation Software

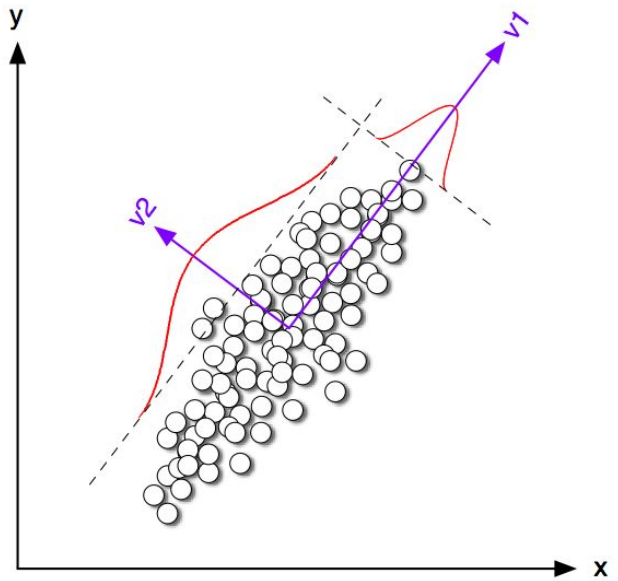
- [2016] Calibration of microscopic traffic simulators using macroscopic measures
- [2018] Calibration of Vissim's truck acceleration model

Principal Component Analysis (PCA)

Principal Component Analysis

Concept | Application

- Reducing dimensionality of data
- Preserve as much as possible the information contained in original data
- Emphasizes variation and highlights patterns in dataset



Principal Component Analysis

Concept | Application

- [2016] A Model for Estimating Free-Flow Speed on Brazilian Expressways
- Models for estimation of FFS
  - HCM:

$$FFS = BFFS - f_1 - f_2 - \ldots - f_n$$

  - HDM-4:

$$FFS = f(V_{drive}, V_{brake}, V_{curve})$$

  - Proposed:

$$FFS = f(PostSpeed, NumLanes, HwyType, AdjLandUse, HorzAlign, AccessDen)$$

Bayesian Inference

Bayesian Inference

Concept | Application

- Specify how one should update one's belief upon observing data
- A method of statistical inference used to update the probability for a hypothesis as more evidence or information become available.

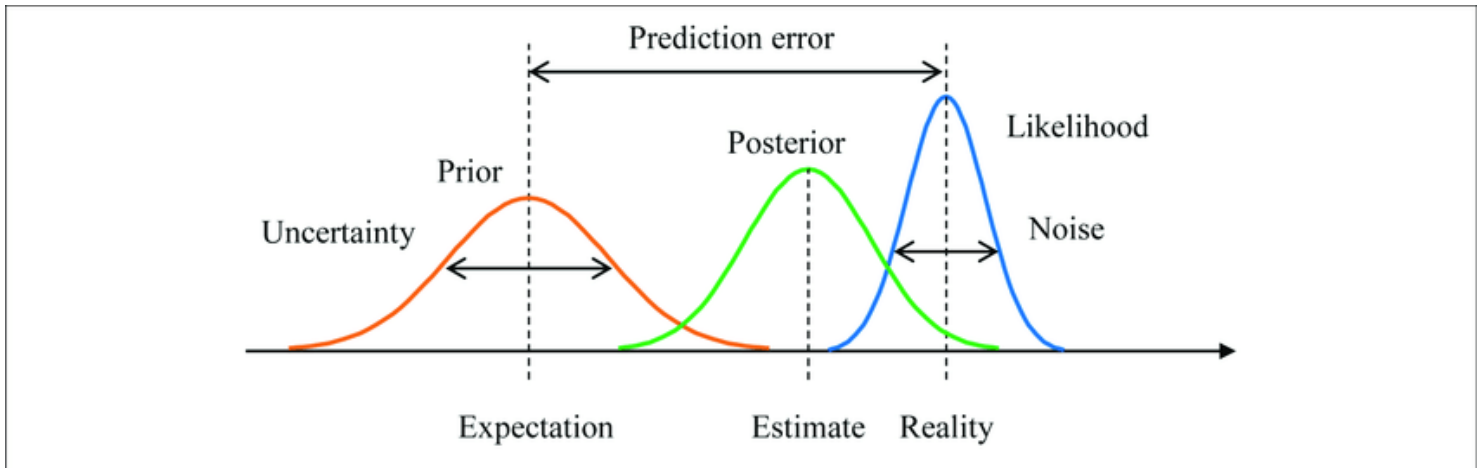


Image credit: Yanagisawa

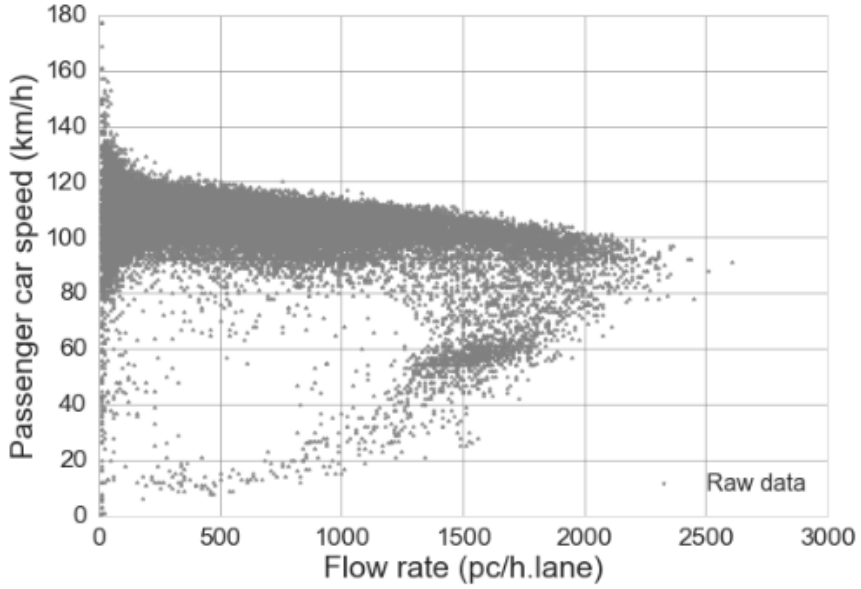
Bayesian Inference

Concept | Application

- [2019] A calibration method structured on Bayesian Inference of the HCM speed-flow relationship for freeways and multilane highways and a temporal analysis of traffic behavior

- HCM Speed-flow model:

$$u = u_f - ((u_f - \frac{q_c}{k_c}) \cdot (\frac{q - bp}{q_c - bp})^{\alpha}) \cdot (q \geq bp)$$



Thanks!

alcunha@usp.br

https://github.com/albnc