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BY INTELLITECH

XTRACTIS®
The General Reasoning AI for Trusted Decisions

Automatic Discovery of Robust, Intelligible & Auditable Predictive Knowledge for High-Risk Applications
by Collective & Evolving AI with Continuous Logics
[Augmented Fuzzy Symbolic AI]

École Polytechnique Conference (short version)
January 18, 2024
v1.0

Prof. Dr. Zyed ZALILA
Chairman & CEO | Founder

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XTRACTIS AI Technology

General Reasoning AI for Trusted Decisions, by design

General AI

- MULTI-PURPOSE for any business/scientific field
- Suitable for **HIGH-RISK APPLICATIONS**
  when AI-driven decisions impact human lives or the environment or cause economic losses.

Reasoning AI

Exobrain augmenting the 3 human reasoning modes with an infinite plasticity (learns to reason better)

1. **INDUCTION**: automatically extracts knowledge-based models from data, as do scientists applying the Experimental Scientific Method
2. **DEDUCTION**: instantly predicts the outputs for a new case
3. **ABDUCTION**: discovers the most optimal solutions satisfying a fuzzy multi-objective request

Trusted Decisions

- Produces the most **ROBUST** and **INTELLIGIBLE** models = AI-driven decision systems having the highest predictive capacity AND understandable by humans
- Auditable by experts and can be certified by the regulator before deployment to end-users
- Decisions are instantly computed **RATIONALLY** & **DETERMINISTICALLY**

by design

All specificities are natively derived from the scientific foundation of our algorithms

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Trustworthy AI for High-Risk Applications

when AI-driven Decisions Impact Human Lives or the Environment or Cause Economic Losses

HEALTH / PHARMA

Automated diagnoses for Personalized Medicine
(from metabolic, epigenetic, physiological & anatomopathological data),
Optimal Formulations & Drug Discovery, Monitoring,
Virtual Screening, Protein Homology, Toxicity.

INDUSTRY / R&D

Product Design & Ergonomics, Sensory Marketing & Engineering, Smart Industry, Quality Control, Maintenance & Diagnosis, Logistics, Risk Analysis, Environment, Geomatics, Optimization, ADAS, Autonomous Vehicles.

DEFENSE / CYBER / SECURITY

Command & Control, Autonomous Systems & Devices, Malicious Activities, Crime & Surveillance, Cybersecurity, Operational Research.

FINANCE / BUSINESS

Scoring & Risk Analysis, Econometrics, Malicious Activities, Venture Capital, Behavioral Finance, Wealth Management, Real Estate Finance, Strategy, Marketing & CRM, Legal, HR & Administration, Operational Research.

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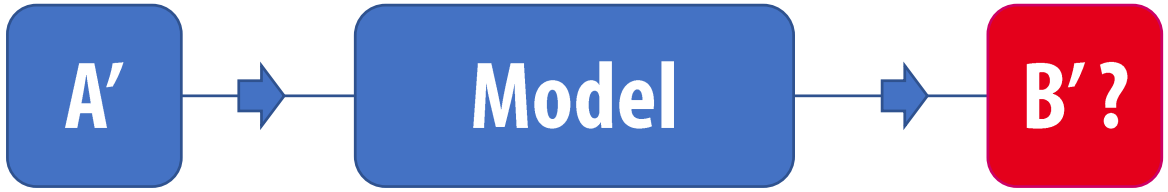
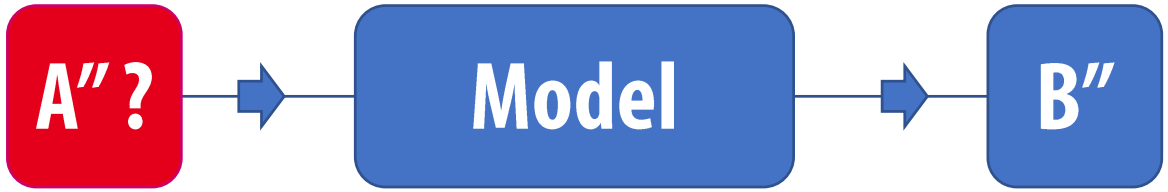
Reasoning modes – *Human or Artificial*

INDUCTION (11th c.)

DEDUCTION (-4th c.)



ABDUCTION (20th c.)



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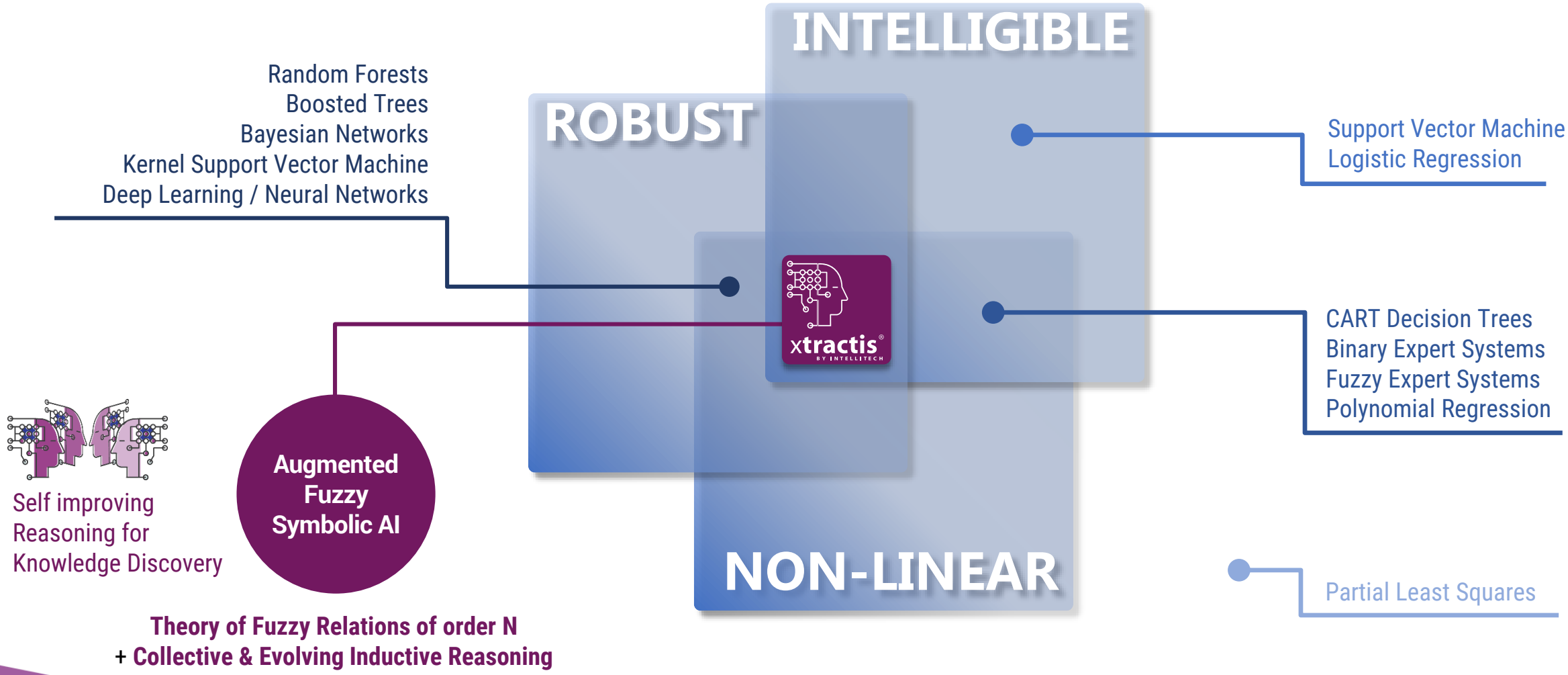
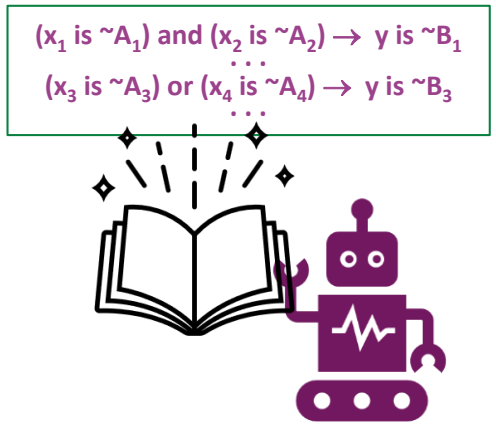
12 AIs & Data-Driven Modeling Techniques

for Complex Processes and Phenomena

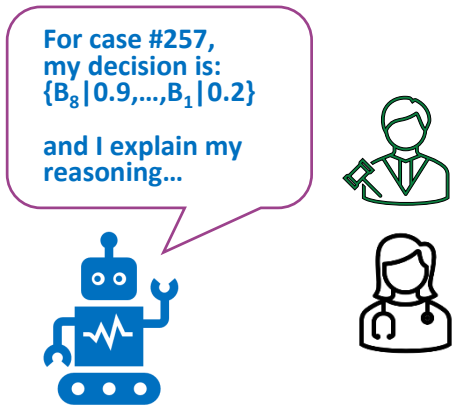


Robust = high predictive capacity
Intelligible = transparent model, revealing all its internal decision-logic

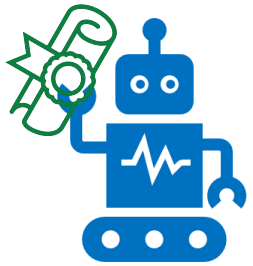
Trusted AI – *Intelligibility & Explainability, mandatory for critical decisions*



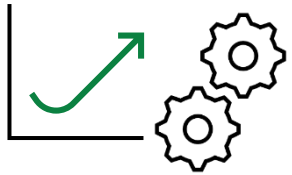
Intelligibility of the internal logic of the decision system
(transparent models)



Explainability of each decision-making
(using the model already induced)

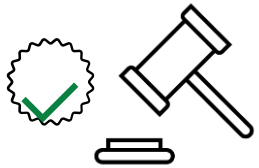


Audit & Certification of AI systems
(Building trust)



Quick generation of IP assets
(models belong to licensee)

Consolidation of decision-making processes
(automated, transparent and reliable decisions)



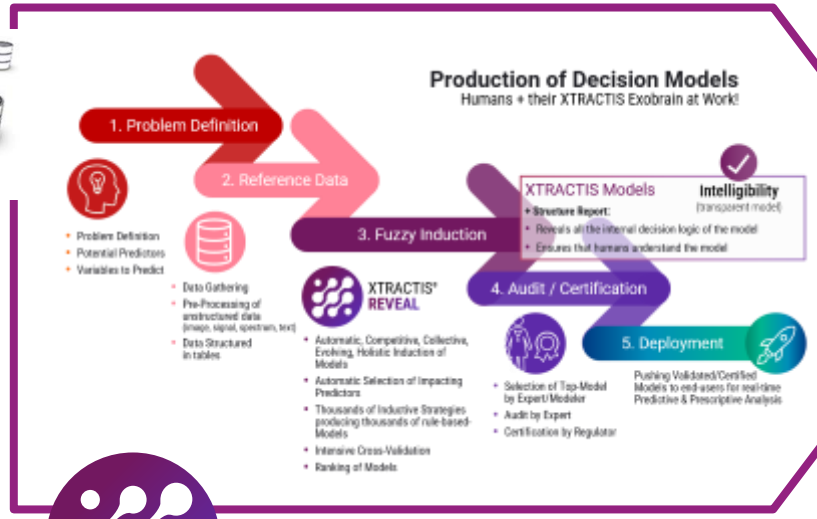
Reduction of ethical and moral biases
(responsible AI by design)

Compliance with the new regulations for high-risk AI applications
(EU AI Act, WHO guiding principles)

XTRACTIS® – *Software Robots implementing human reasoning*

❶ INDUCTION Robots
Discover rule-based knowledge from data
Reveal & Validate Predictive Models

Reference Dataset



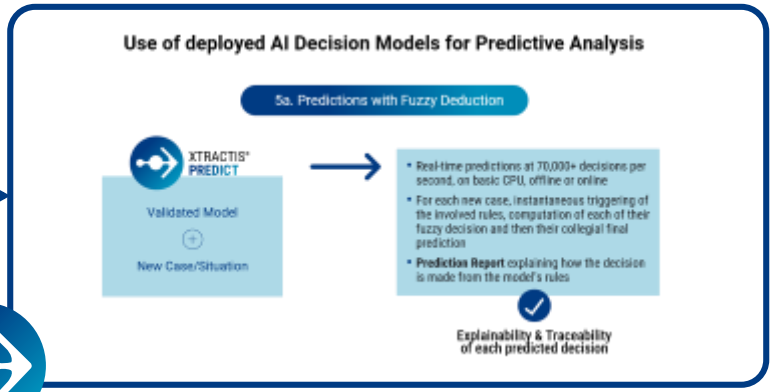
XTRACTIS® **REVEAL**

Update Models with new data

Validated Decision Models

+ new cases

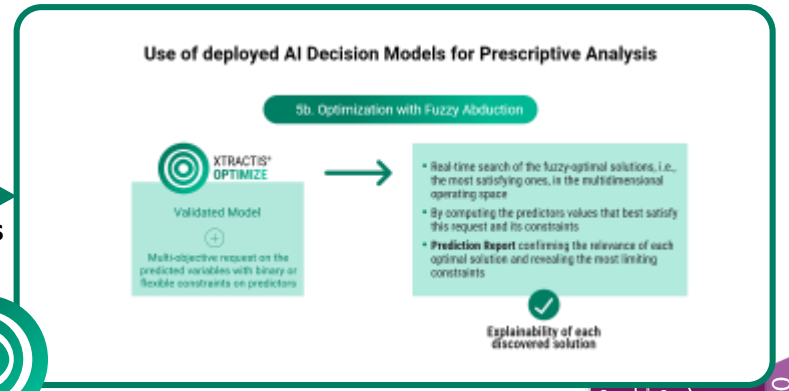
❷ DEDUCTION Robots
Predict in real-time & very high frequency



XTRACTIS® **PREDICT**

+ new requests

❸ ABDUCTION Robots
Compute the most optimal solutions



XTRACTIS® **OPTIMIZE**

❹ SUPERVISION Engine
Oversee quality of deployed models
Detect changes in process behavior
Monitor models' maintenance

XTRACTIS® **MONITOR**

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Data for XTRACTIS® – *Structured, Quantitative/Qualitative*

Variables to predict

Intelligible potential predictors

Regression | *Scoring / Binomial Classification* | *Multinomial Classification*

Label	Binary Variable	Nominal Variable	Numerical Variable	…	Var 1 to predict	Var 2 to predict	Var 3 to predict
Observation 1	0	Modality A	1.2558	…	2.35	1	D
Observation 2	1	Modality C	0.2356	…	1.256	0	A
Observation 3		Modality D	4.568	…	12.03	1	C
…	1		125.36	…	1.002	1	A
Observation n	0	Modality A		…	7.056	0	F

Observations

Missing values allowed

Production of Decision Models

Humans + their XTRACTIS Exobrain at Work!

1. Problem Definition

- Problem Definition
- Potential Predictors
- Variables to Predict

2. Reference Data

- Data Gathering
- Pre-Processing of unstructured data (image, signal, spectrum, text)
- Data Structured in tables

3. Fuzzy Induction

XTRACTIS® REVEAL

- Automatic, Competitive, Collective, Evolving, Holistic Induction of Models
- Automatic Selection of Impacting Predictors
- Thousands of Inductive Strategies producing thousands of rule-based-Models
- Intensive Cross-Validation
- Ranking of Models

XTRACTIS Models

Intelligibility
(transparent model)

+ Structure Report:

- Reveals all the internal decision logic of the model
- Ensures that humans understand the model

4. Audit / Certification

- Selection of Top-Model by Expert/Modeler
- Audit by Expert
- Certification by Regulator

5. Deployment

Pushing Validated/Certified Models to end-users for real-time Predictive & Prescriptive Analysis

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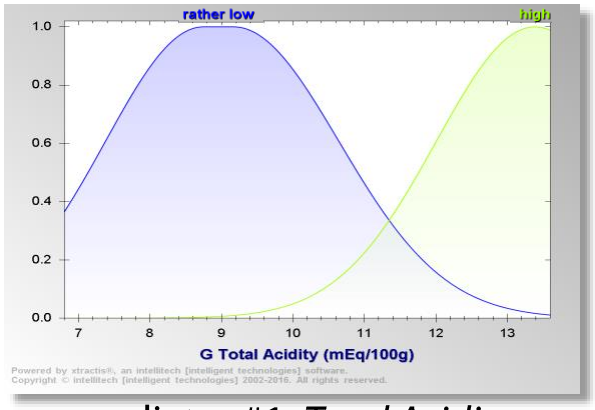
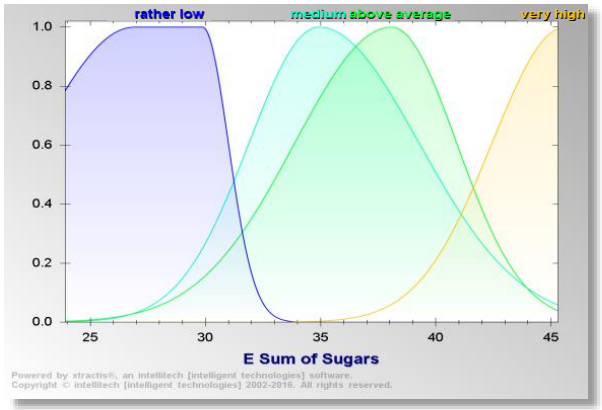
XTRACTIS® Model – *Making explicit an implicit decision*

Sweet perception of a fresh tomato: 2 variables, 6 classes, 4 rules (complexity 33.0)

>> Classes



predictor #1: *Total Acidity*



predictor #2: *Sum of Sugars*

>> Rules

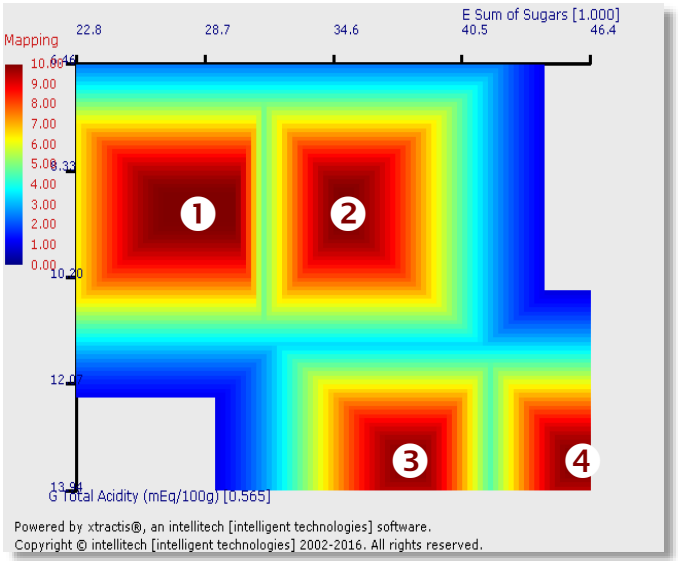
Rule ❶
If *Total Acidity* is *rather low*
And *Sum of Sugars* is *rather low*
Then *Sweet* equals *3.39*

Rule ❷
If *Total Acidity* is *rather low*
And *Sum of Sugars* is *medium*
Then *Sweet* equals *7.19*

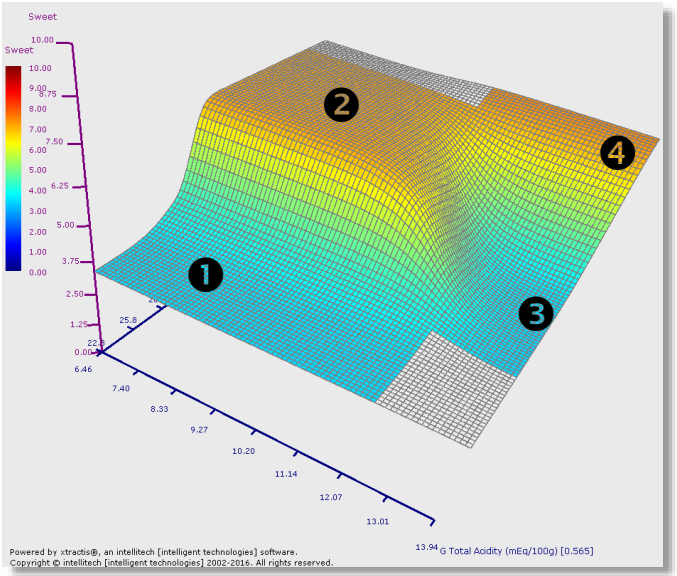
Rule ❸
If *Total Acidity* is *high*
And *Sum of Sugars* is *above average*
Then *Sweet* equals *3.30*

Rule ❹
If *Total Acidity* is *high*
And *Sum of Sugars* is *very high*
Then *Sweet* equals *7.49*

>> Inference



Mapping



Decision Surface

Data Source:
INRA (Institut National de la Recherche Agronomique) et CTIFL (Centre Technique Interprofessionnel des Fruits et Légumes) - 7th Sensometrics Conf., July 2004, Davis, CA, USA

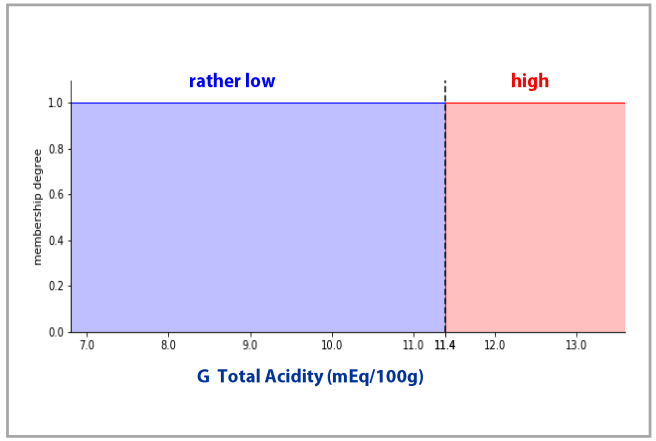
Scoring | Binomial Classification | Multinomial Classification | Regression

Results from XTRACTIS® REVEAL 9.1.16325

Binary rule-based model – *intelligible model, but not efficient*

Sweet perception of a fresh tomato: 2 variables , 6 classes, 4 rules

>> Classes



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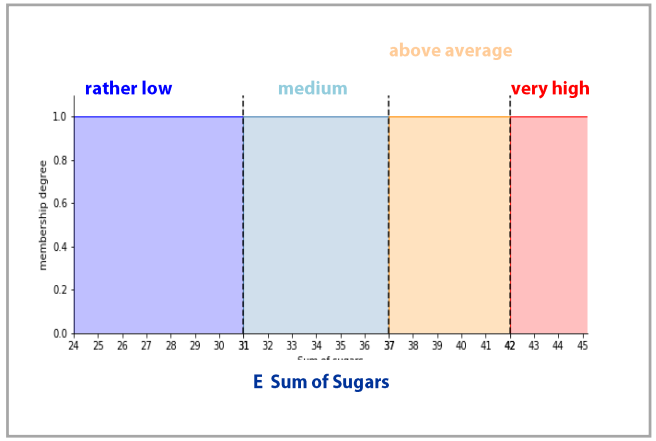

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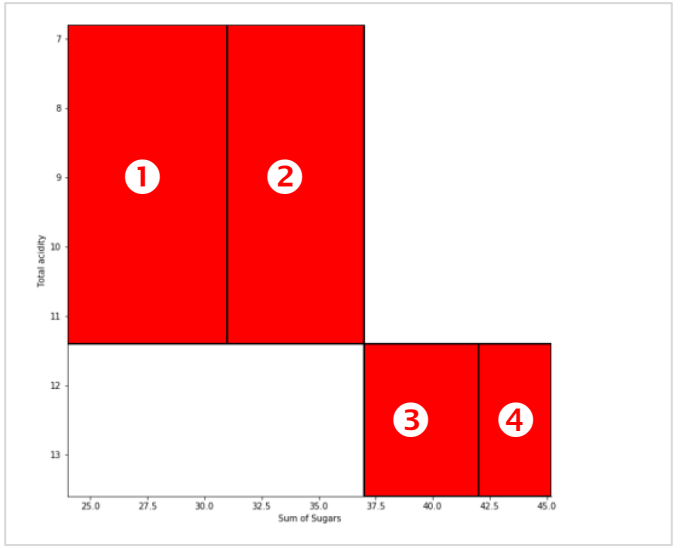
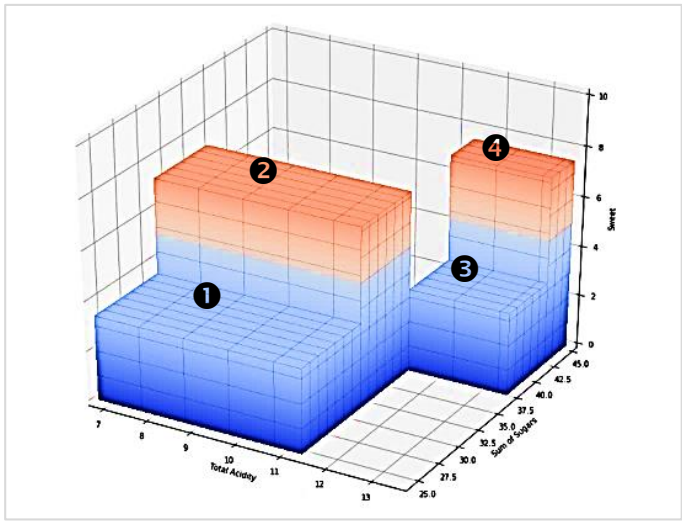
>> Inference

Mapping



Decision Surface



Data Source:
INRA (Institut National de la Recherche Agronomique) et CTIFL (Centre Technique Interprofessionnel des Fruits et Légumes) - 7th Sensometrics Conf., July 2004, Davis, CA, USA

Scoring
Binomial Classification
Multinomial Classification
Regression

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Use of deployed AI Decision Models for Predictive Analysis

5a. Predictions with Fuzzy Deduction

XTRACTIS®
PREDICT

Validated Model

+

New Case/Situation

- Real-time predictions at 70,000+ decisions per second, on basic CPU, offline or online
- For each new case, instantaneous triggering of the involved rules, computation of each of their fuzzy decision and then their collegial final prediction
- **Prediction Report** explaining how the decision is made from the model's rules

Explainability & Traceability of each predicted decision

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Fuzzy Deductive Inference System – *Approximate reasoning*

Gradual reasoning / by analogy (Fuzzy Modus Ponens [Zadeh 1975])

⊥–T and T–⊥ Composition by anchoring of Fuzzy Relations of order *N* (Generalized Fuzzy Modus Ponens [Zalila 1993])

IF the tomato is red **AND** the tomato is soft **THEN** the tomato is ripe

This tomato is very red **AND** soft

This tomato is very ripe

$$(A_1 \text{ AND } A_2) \rightarrow B$$

$$\frac{A_1' \text{ AND } A_2'}{B'}$$

$$B'(y) = A_1' \times_{T'} A_2'(x_1,x_2) \circ_{\perp-T} R_{(A_1 \times_{T'} A_2) \rightarrow B}(x_1,x_2,y)$$

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Use of deployed AI Decision Models for Prescriptive Analysis

5b. Optimization with Fuzzy Abduction

XTRACTIS®
OPTIMIZE

Validated Model

+

Multi-objective request on the predicted variables with binary or flexible constraints on predictors

- Real-time search of the fuzzy-optimal solutions, i.e., the most satisfying ones, in the multidimensional operating space
- By computing the predictors values that best satisfy this request and its constraints
- **Prediction Report** confirming the relevance of each optimal solution and revealing the most limiting constraints

Explainability of each discovered solution

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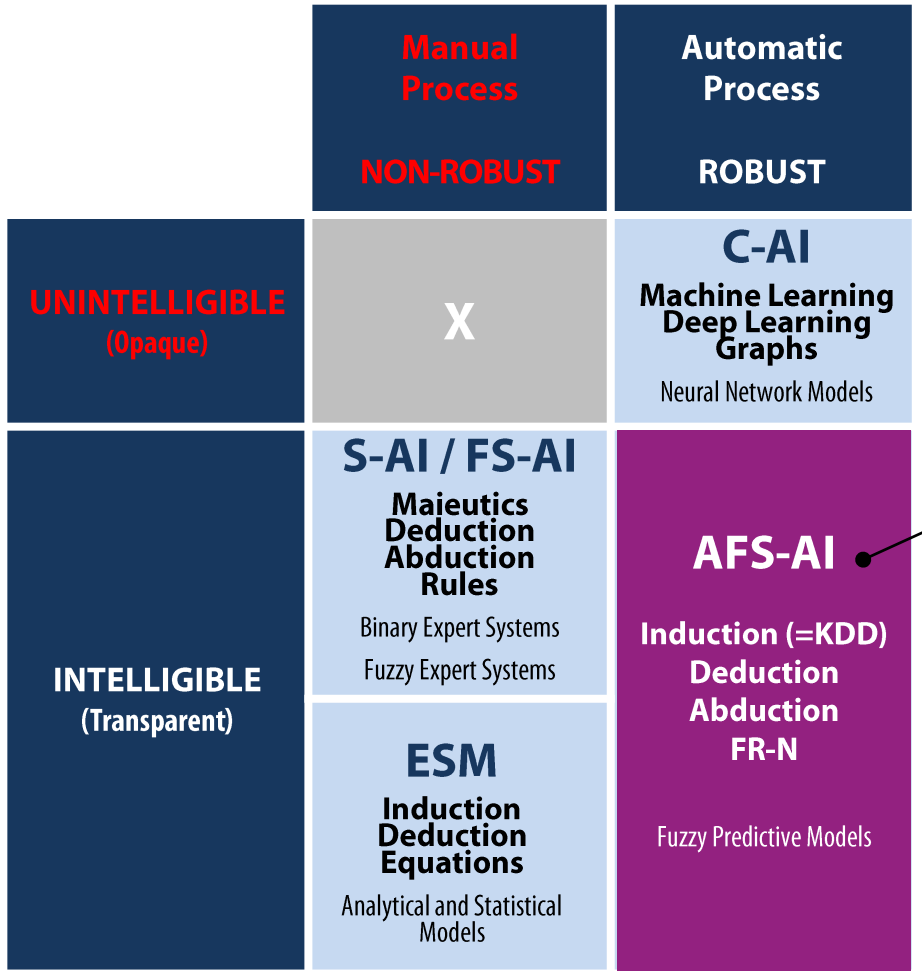
XTRACTIS® Augmented Fuzzy Symbolic AI – *the best of 3 worlds*



***C-AI**: Connectionnist AI*
***S-AI**: Binary Symbolic AI*
***FS-AI**: Fuzzy Symbolic AI*
***ESM**: Experimental Scientific Method*
***AFS-AI**: Augmented Fuzzy Symbolic AI*

Augmented Fuzzy Symbolic AI

Symbolic, ∝-valent,
∝- relational, ∝-operable,
∝-measurable, ordinal, non-additive AI
with Holistic, Inductive, Abductive, Deductive, Collective, Competitive, Reflexive, Cooperative and Evolving Reasoning.

➡ **robust symbolic universal approximator**
of non-linear, non-monotonic multidimensional functions, and of non-convex, disconnected, non-decomposable sets.

➡ Proposal for a New **Intelligence Test** for Automatons [Zalila 2017]:
It designs, with no supervision, its most efficient inductive strategies to automatically discover the most robust & intelligible decision system, and the most optimal multi-objective prescriptions

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Examples of XTRACTIS® Use Cases – *with benchmarks vs. LoR, RFo, BT & NN*

HEALTH / PHARMA

Anatomopathological Diagnosis of Breast Cancer (2022)

Genetic Diagnosis of Prostate Cancer (2022)

Cardiotocographic Identification of Fetal Heart Conditions (2022)

Spectrometric Diagnosis of Ovarian Cancer (2022)

Serological Diagnosis of Chronic Kidney Disease (2023)

Voice-based Diagnosis of Parkinson's Disease (2023)

FINANCE / BUSINESS

Prediction of Loan Reimbursement Default (2018)

Recognition of Facial Expressions (2018)

Nonlinear Multi-Objective Optimization of a Supply Chain Under Flexible Constraints (2023)

Detection of Fraudulent Credit Card Transactions (2023)

Prediction of Telecom Customer Churning (2023)

INDUSTRY / R&D

Prediction of the Degradation of a Naval Propulsion Unit (2022)

Emergency Detection for an Automatic Braking System (2021)

Prediction of the Toxicity of Chemical Molecule Residues & Discovery of New Nontoxic Herbicides (2023)

Prediction of the Compressive Strength of Concrete (2023)

Identification of the Longitudinal Action Required when Approaching Traffic Lights (2023)

Prediction of the Rupture of Flexible Underwater Pipe (2023)

DEFENSE/CYBER /SECURITY

Log-based Detection & Identification of Cyber Intrusions (2022)

Acoustic Detection of Underwater Mines (2022)

Identification of an UAV Intrusion Based on Wi-Fi Analysis (2023)

Temporal Identification of Criminal Profiles and Action Phases from Communications Metadata (2023)

Passive Magnetic Identification of Land Mines (2023)

Temporal Identification of Aircraft based on Trajectory (soon)

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Temporal Identification of Criminal Profiles and Action Phases from Communications Metadata

Problem Definition and Reference Data

Design an AI-based decision system which **accurately** identifies risky behavior linked to criminal activities by analyzing communication metadata from surveillance investigations -without accessing the content of phone calls- and **rationally** predicts dangerous Homeland Security situations.

Source:
ATOS-BDS-MCS
(EVIDEN)

Variable to Predict among 10 possible classes

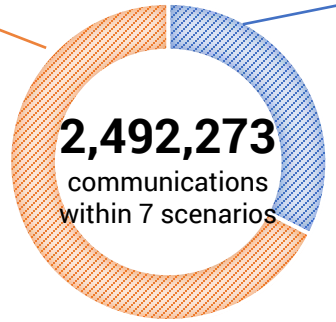
Sender Profile among 4 types	+	the **associated Temporal Phase** among 4 phases
Banal, Support, Executant, Chief		P1 Initialization, P2 Gathering, P3 Planning, P4 Execution

1. BANAL	2. SUP_P2	5. EXEC_P2	8. CHIEF_P2
	3. SUP_P3	6. EXEC_P3	9. CHIEF_P3
	4. SUP_P4	7. EXEC_P4	10.CHIEF_P4

321 Potential Predictors: Each communication is described by 29 to 37 metadata combined and aggregated over time to obtain the predictors: Number of SMS-type communications over the last 2 days, Duration of the call...

67.5%
External Test

1,682,719 cases (no duplicates)									
BNL	SUP_P2	SUP_P3	SUP_P4	EXEC_P2	EXEC_P3	EXEC_P4	CH_P2	CH_P3	CH_P4
47.10%	16.23%	0.98%	0.12%	28.72%	1.87%	0.37%	4.26%	0.31%	0.04%



32.5% from 6 scenarios
Training 53.6% | Validation 19.8% | Test 26.6%

809,554 cases (no duplicates)									
BNL	SUP_P2	SUP_P3	SUP_P4	EXEC_P2	EXEC_P3	EXEC_P4	CH_P2	CH_P3	CH_P4
57.84%	11.83%	0.95%	0.16%	23.15%	2.19%	0.37%	3.17%	0.30%	0.04%

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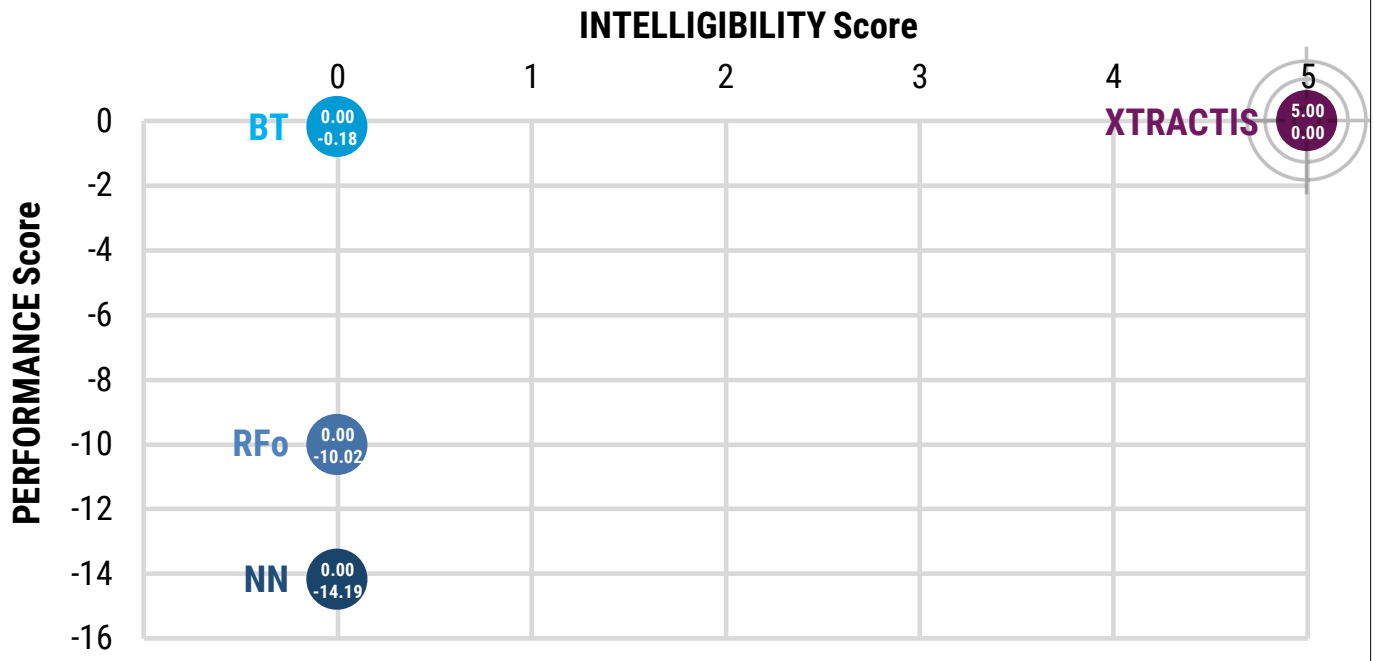
Benchmark XTRACTIS vs. its Challengers

XTRACTIS[1]	24 predictors | 12 gradual rules without chaining aggregated into 10 disjunctive rules | Each unitary rule uses 6.3 predictors on average | A few rules triggered at a time
Logistic Regression	Not available for this Use Case
Random Forest[2]	299 predictors | 500 trees | 20,216 binary rules | Each rule uses 8.3 predictors on average
Boosted Trees[2]	313 predictors | 10 chains of 309 trees each | 49,797 binary rules | Each rule uses 6.1 predictors on average | Tree #N corrects the error of the N-1 previous trees
Neural Network[2]	321 predictors | 2 hidden layers | 22 hidden nodes | Unintelligible synthetic variables

Average F_2-Score calculated on all unknown cases. Leader performance is 88.53%.



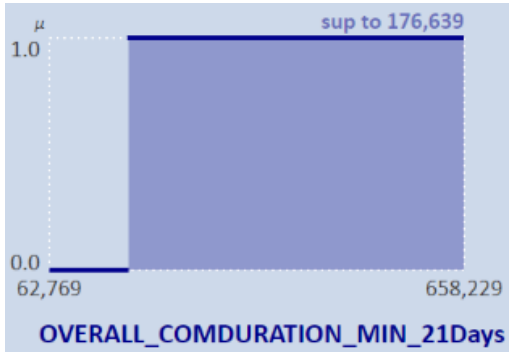
[1] Results from XTRACTIS® REVEAL v12.2.44349 [2] Results from Python 3.9 package: LightGBM 3.3.2 | TensorFlow 2.10.0 Keras 2.10.0

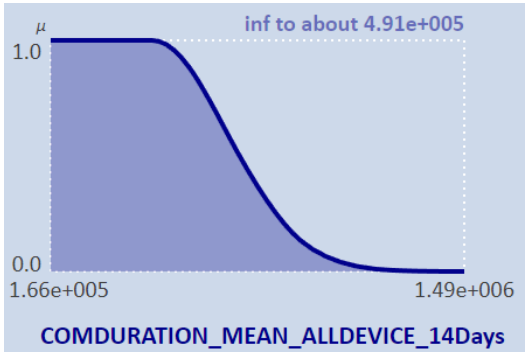
XTRACTIS top-model: Intelligible Decision System

464 inductive reasoning strategies explored, Induction optimization on Average F_2-Score,
Top-model selection on validation Average F_2-Score

PREDICTORS

- **24 metadata selected out of 321**
  (continuous variables)
- Ranked by impact significance:
  7 strong signals, 4 medium & 13 weak
- Labeled by fuzzy & binary classes
  Examples: binary interval "**superior to 176,639**";
  fuzzy interval "**inferior to about 4.91e+005**"





RULES

- **12 connective fuzzy rules without chaining**
  (aggregated into 10 disjunctive fuzzy rules)
- 3 to 12 predictors per rule (on average, 6.3 / rule)

R1

R6

IF	COMDURATION_MEAN_ALLDEVICE_14D	IS	inf to ~8'11''
AND	NUM_UNIQUE_USED_DEVICE_1D	IS	sup to ~2 devices
AND	OVERALL_COMDURATION_MIN_21D	IS	sup to 2'57"
AND	VARPRC_OVERALL_NUM_SMS_3_7D	IS	sup to ~-57%
THEN	Sender Profile_Phase	IS	EXEC_P2

R12

Explained Prediction for a Case from the External Test Set

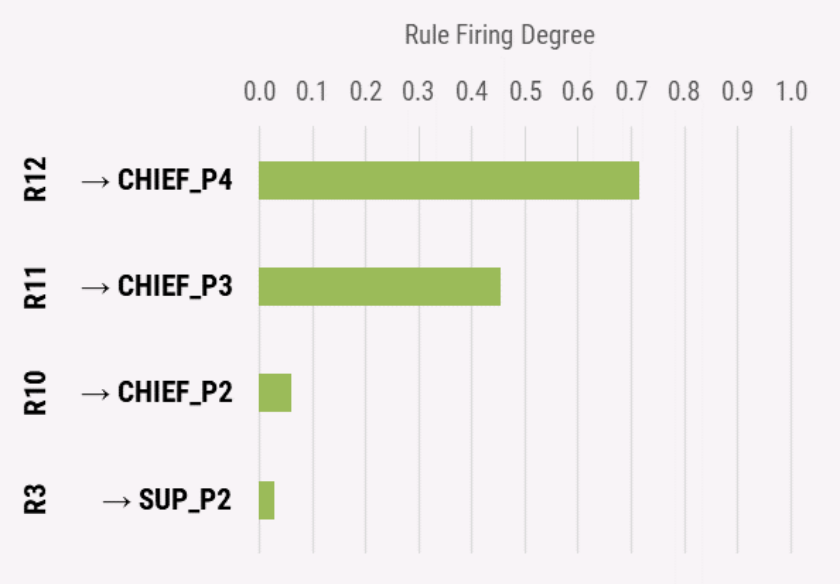
CASE

ihfgwmqida_2014-05-23 16:17:47.166
(actual value = CHIEF_P4)

COMDURATION_MEAN_7D	1.83e+005
NUM_UNIQUE_TMSI_RECEIVER_SMS_3D	Missing Value
NUM_UNIQUE_USED_DEVICE_SMS_14D	6.00
NUM_VOICE_ALLDEVICE_1D	4.0
...	...
OVERALL_COMDURATION_MIN_21D	80,186
VARPRC_NUM_UNIQUE_TMSI_RECEIVER_1_2D	0.0
VARPRC_NUM_VOICE_ALLDEVICE_7_14D	-61.2
VARPRC_OVERALL_NUM_SMS_1_2D	-49.7
VARPRC_OVERALL_NUM_VOICE_7_14D	-50.7

Real Time Deductive Inference of the model's rules

Number of triggered rules: **4 / 12**



FUZZY PREDICTION

{ CHIEF_P4 | 0.715,
CHIEF_P3 | 0.453,
CHIEF_P2 | 0.061,
SUP_P2 | 0.027 }

FINAL PREDICTION

{ CHIEF_P4 }

The system delivers a correct decision of the situation vs. the intelligence expert

Profile CHIEF, Phase EXECUTION

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Chairman & CEO | Founder

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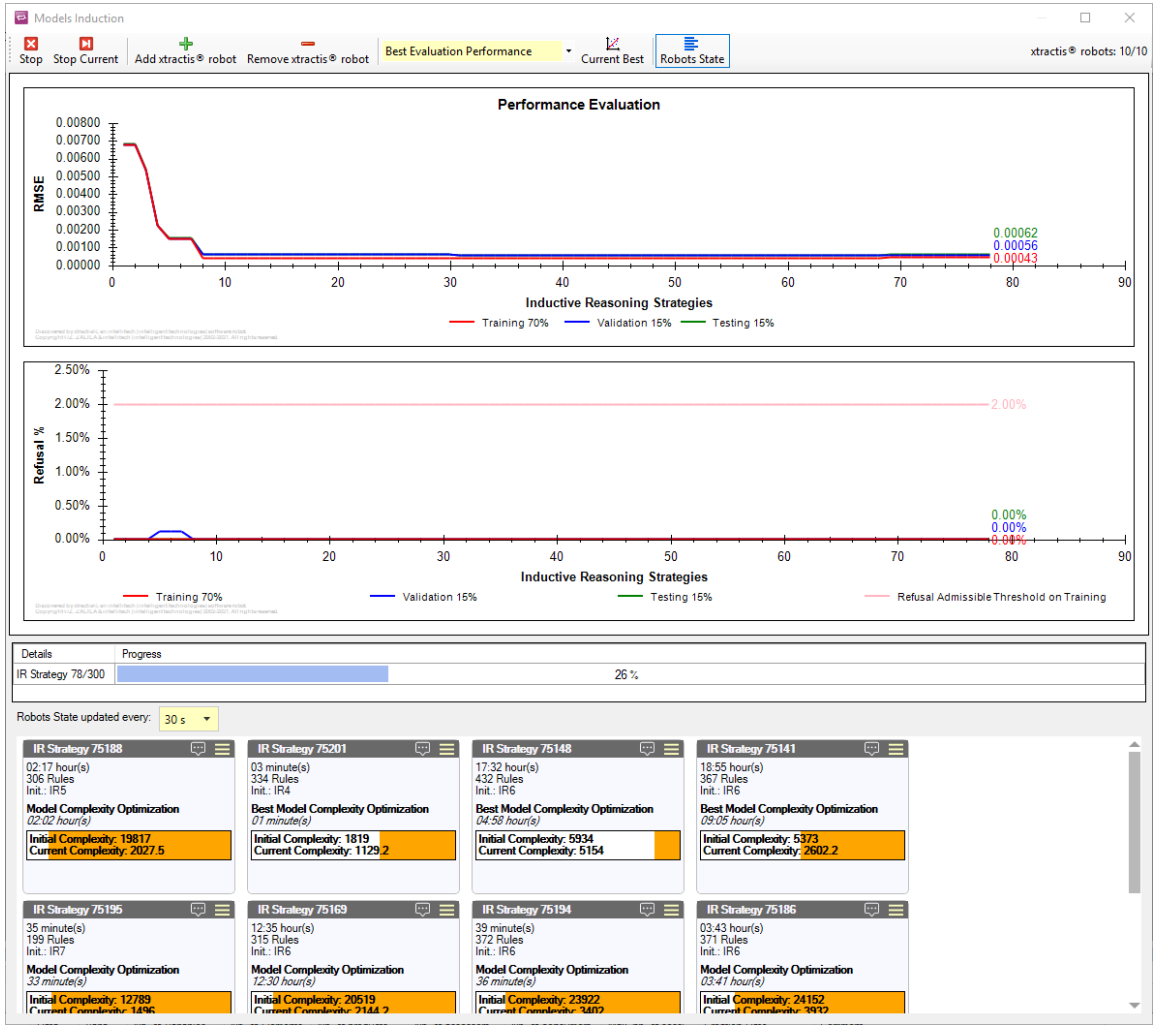
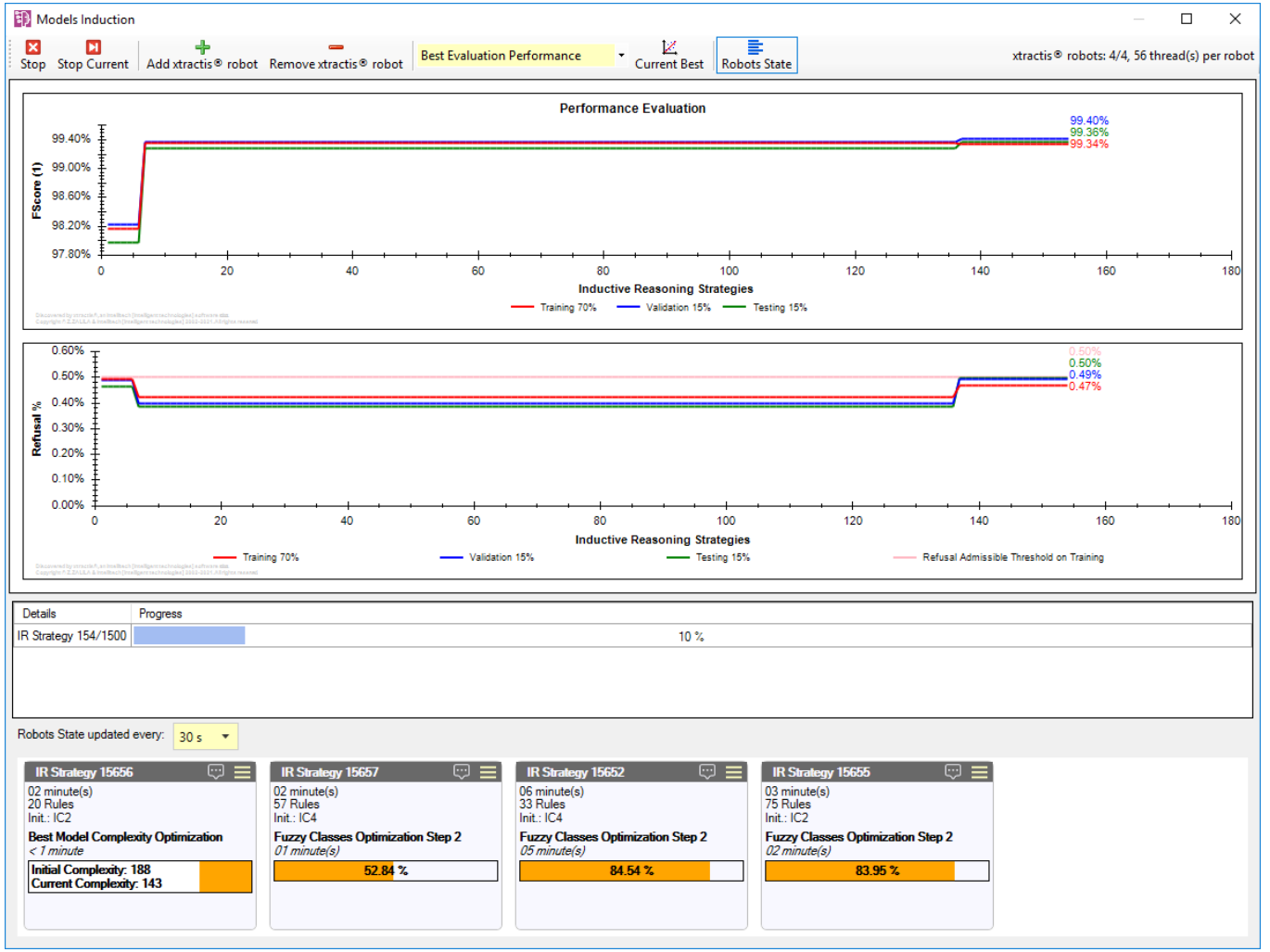
Screenshots – *Induction Convergence (1/2)*





Screenshots – *The most optimal solutions (2/2)*