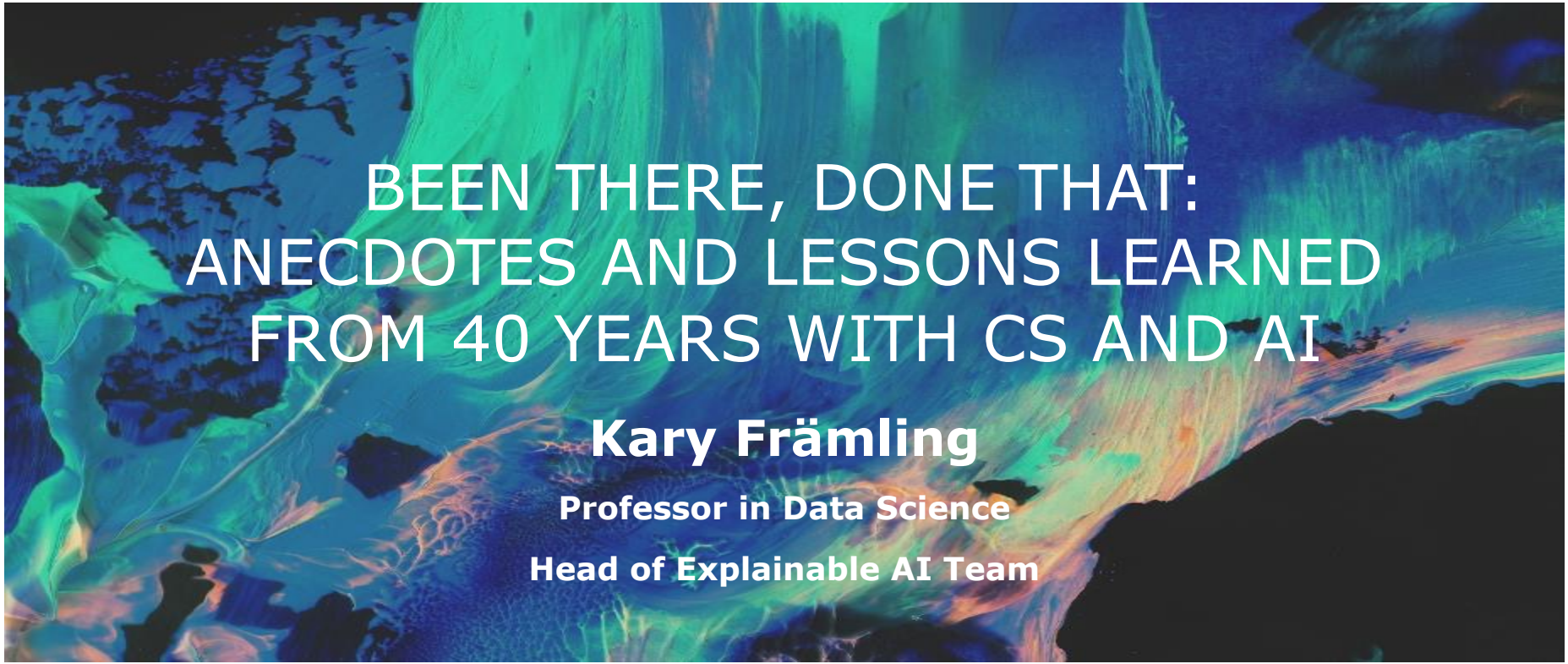


# BEEN THERE, DONE THAT: ANECDOTES AND LESSONS LEARNED FROM 40 YEARS WITH CS AND AI

**Kary Främling**

**Professor in Data Science**

**Head of Explainable AI Team**

UMEÅ UNIVERSITY

# KARY FRÄMLING IN A NUTSHELL

Born in Borgå (Porvoo), Finland 1965

M.Sc. in CS, Helsinki University of Technology, 1990
- Computers in Industry
- Artificial Intelligence (AI)
- Mechatronics

PhD, Saint-Etienne, France 1996
- Decision Support Systems
- Neural Networks
- Explainable AI

Professor of Practice in Building Information Modeling, Aalto University, Finland 2013-2018

Adjunct Professor in Computer Science, Aalto university 2018-

Research Director, Louhe Oy 2020-

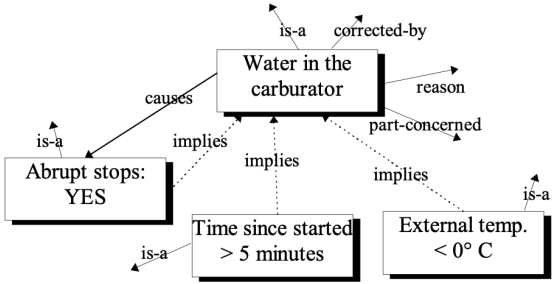
Professor, Umeå Universitet, 2017-

# THE WORLD IN THE 1980'S

- **"AI will take all jobs"** already in the 1980's
- **Big things** in the 1980's:
  - **Rule-based** systems (also called "expert systems")
  - **Semantic nets**
  - **Certainty factors**, **probabilities** for managing uncertainty
  - **Machine learning**:
    - Induction, deduction, abduction learning
    - Case-based reasoning
    - Decision trees
    - Bayesian reasoning
- **Neural Nets** had been "killed" in 1969
- The era of **GOFAI** (Good Old-Fashioned AI)

# WHAT DID KARY DO IN (END OF) 1980'S?

- M.Sc. thesis in 1990: "**Digital Twin**" of phenol plant
  - Used **Smalltalk**, **Prolog** programming languages
  - Production scheduling using **plant model**, **rule-based AI** and **"real-life" information**
- Kary still says "*the evolution of programming languages could have finished with Smalltalk*" (because Java, Python etc. mainly imitate it)
- Weighted **Semantic Nets** for heuristic search, fault diagnosis etc.
  - Semantic nets are now gaining in popularity again, under the name **Knowledge Graphs**
  - An **almost identical example used in a recent (2024)** paper as in Kary's M.Sc. Thesis, below (which was inspired from elsewhere)
  - **Certainty factors** could be propagated and indicated for the result



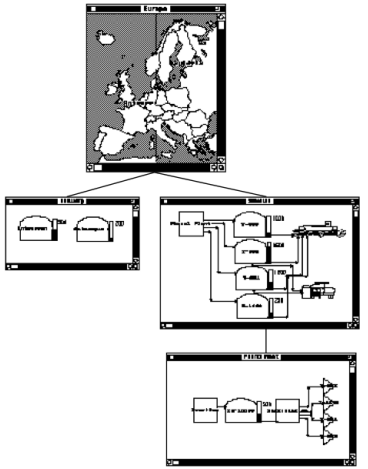



Figure 4. Hierarchical model of a phenol plant and storage places.

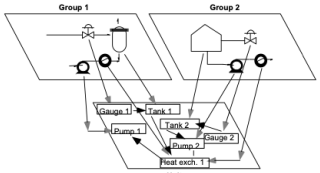



Figure 5. Relation between unit groups, icons, model and units.

# NOKIA CELLULAR SYSTEMS AND TN-SDL

- Kary implemented a (very small) part of the **GSM system** for Nokia Cellular Systems 1990-1991
- Core tool **TN-SDL** (TeleNokia Specification and Description Language (SDL)):
  - Formal, graphical language for defining event-driven systems, such as communication protocols
  - Used especially in the telecommunications industry for designing complex, reactive and concurrent distributed systems like switching systems and mobile networks
  - Graphical Representation: Uses a block-diagram approach to represent processes, signals, and communication paths
  - Often used in combination with UML (Unified Modeling Language) and other tools for the formal verification and validation of system designs
- GSM specification was modeled in TN-SDL tool, which generated most of the needed code in C, as well as test scripts and documentation
  - Verification and validation tests were first run locally and/or sent to a dedicated server
  - When everything had passed, a final test was run on a mobile mini-switch with the actual hardware
- Generating code, test scripts and documentation is efficient and correct when it's based on **formal specifications**!

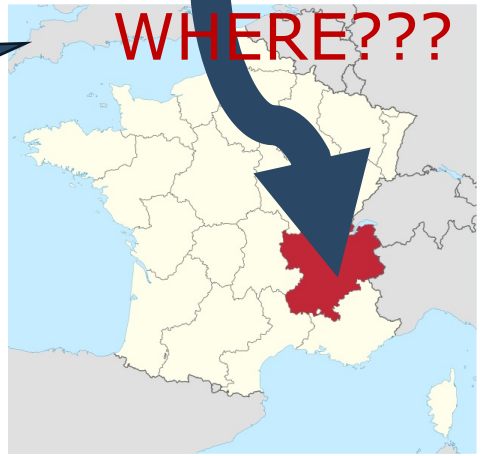
# THE WORLD IN THE 1990'S

- **GOFAI winter starts**, including "symbolic machine learning" methods to a large extent
- **Neural Networks** is the big thing, and there are many types:
  - Hopfield, Boltzmann, Radial Basis Function (RFB), self-organizing map, Neural Gas, ART (Adaptive Resonance Theory network), …
  - Obviously: Multi-layer, gradient descent network
    - Strange "accepted truth": *you never need or want more than one hidden layer*
    - Convolutional Neural Networks (CNN), Long Short-Term Memory (LSTM) etc. published in ~1997 but didn't prevent AI winter from kicking in a few years later
- **Also**: Fuzzy sets and logic, Genetic algorithms, Reinforcement learning (RL)

# WHAT DID KARY DO IN 1990'S?

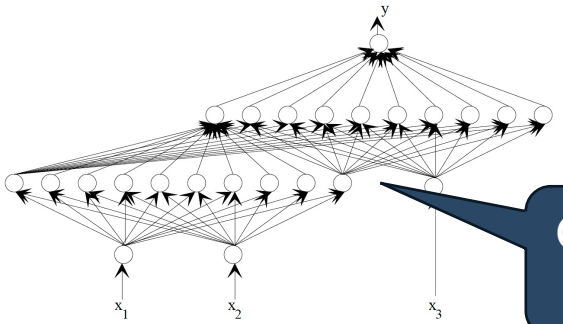
- PhD Thesis:
  - **Decision support systems**

- Select site for disposal of ultimate industrial waste
- Multiple Criteria Decision Making
- Conflicting goals -> Pareto optimality
- Necessary to justify decisions (explainability)



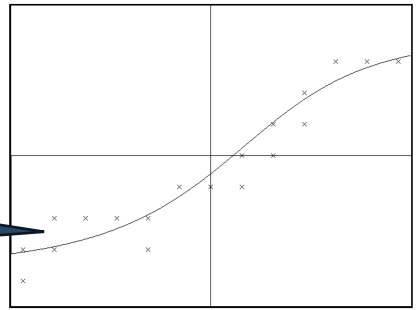
# WHAT DID KARY DO IN 1990'S?

- PhD Thesis:
  - Decision support systems
  - **Neural networks (implemented own ones, in C++ and Matlab)**



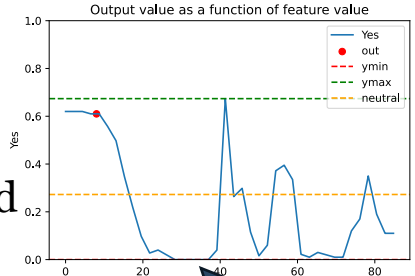

Could also be deep

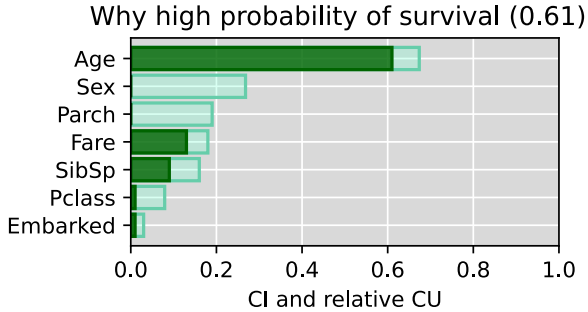
Behaves nicely when interpolating but often chaotic when extrapolating even a little
(good target for adversarial attacks)



# WHAT DID KARY DO IN 1990'S?

- PhD Thesis:
  - Decision support systems
  - Neural networks (implemented own ones, in C++ and Matlab)
  - **Explainable AI (XAI)**

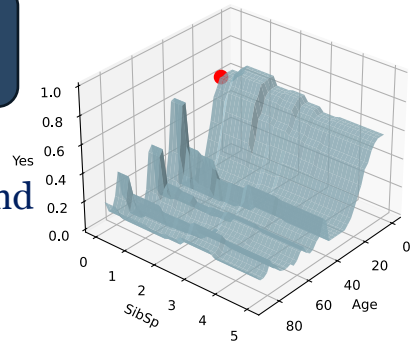



Explanations can reveal errors, inconsistencies, bias, …

The explained value is ***Yes*** with the value 0.61 (CU=0.61), which
Feature *Pclass* has **very low importance (CI=0.08)** and has val
Feature *Sex* has **low importance (CI=0.27)** and has value(s) 1.0, which is **low utility (CU=0.00)**
Feature *Age* has **high importance (CI=0.67)** and has value(s) 8.0, which is **high utility (CU=0.91)**
Feature *SibSp* has **very low importance (CI=0.16)** and has value(s) 0.0, which is **higher than average utility (CU=0.56)**
Feature *Parch* has **very low importance (CI=0.19)** and has value(s) 0.0, which is **low utility (CU=0.00)**
Feature *Fare* has **very low importance (CI=0.18)** and has value(s) 72.0, which is **higher than average utility (CU=0.72)**
Feature *Embarked* has **very low importance (CI=0.03)** and has value(s) 3.0, which is **lower than average utility (CU=0.33)**

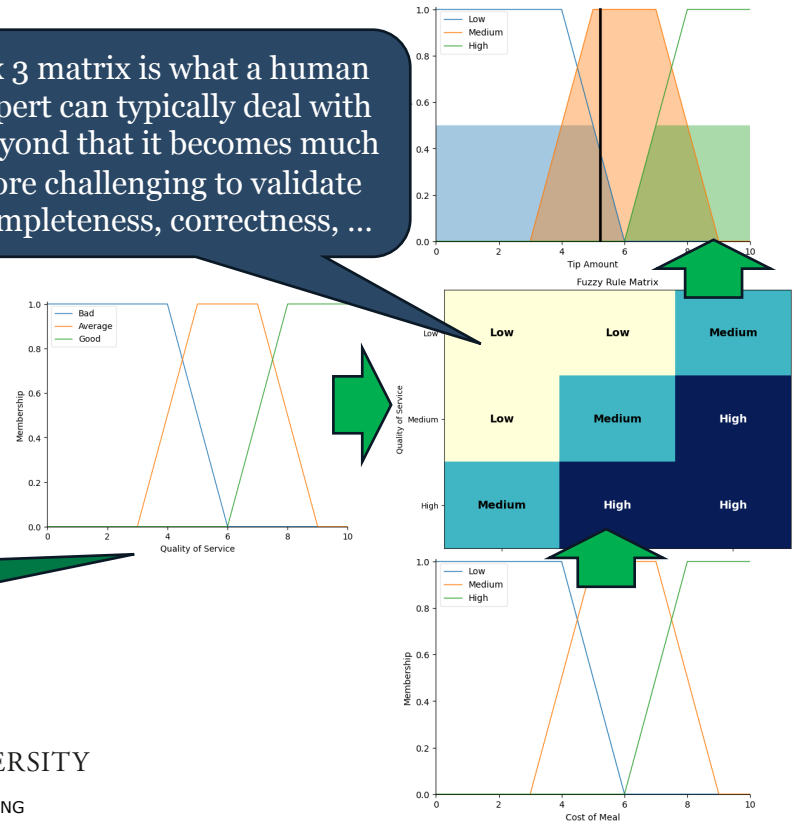
Contextual Importance and Utility (CIU) XAI method



# WHAT DID KARY DO IN 1990'S?

- PhD Thesis:
  - Decision support systems
  - Neural networks (implemented own ones, in C++ and Matlab)
  - Explainable AI (XAI)
- Some **fuzzy logic**

- 3 x 3 matrix is what a human expert can typically deal with
- Beyond that it becomes much more challenging to validate completeness, correctness, …




- Created example controller, visualisations in less than two hours, using Mistral AI LLM
- Required several iterations with error correction, improvements, …
- Still, 50-95% gain in time!

# THE WORLD FROM 2000 UNTIL NOW

- **AI winter** more or less 2000-2014(?), then:
- **CNN**s made a major breakthrough in 2012 when achieving outstanding recognition performance with ImageNet dataset
- **AlphaGo** (2015-2016) is a cornerstone achievement
  - Combines deep learning and reinforcement learning
- **Reinforcement Learning (RL)** becomes big topic in academia
  - But posters and papers look quite similar as they have since 1990's…
- **Explainable AI (XAI)** became hot after ~2017
- **Large Language Models (LLM)** are the star of the moment

# WHAT DID KARY DO FROM 2000 UNTIL NOW?

- **IoT**: First paper (in the world) in 2002, describing an operational implementation
  - Kary was very alone with IoT until about 2010, then IoT took off seriously
  - EU launched IoT program around 2006, more or less shut down a few years later
- **Digital Twin**: Described in paper(s) since 2003 with concepts such as “virtual counterpart”, “product agent”, etc.
  - Became popular at about the same time a IoT, presumably for similar reasons
  - Name “Digital Twin” was first used in 2010 by NASA. By the way: do not believe what ChatGPT, Wikipedia etc. tell you about the origins, it seems to have been heavily politicized
- **Intelligent Products**: Digital Twins (Product Agents) with an AI part that allows them to take actions
- **Systems of Systems** since about 2008, with a big emphasis on data and communication standards
- **Implemented** using many technologies over time and used in **real-life applications**, with:
  - CORBA, Java RMI, SOAP, UDDI, ebXML, REST …
  - Before Cloud, Edge, Fog, Python, etc. existed
- **Reinforcement learning** 2002-2008
- Back to **Explainable AI (XAI)** since 2018

# SOME OBSERVATIONS OF 2000 UNTIL NOW

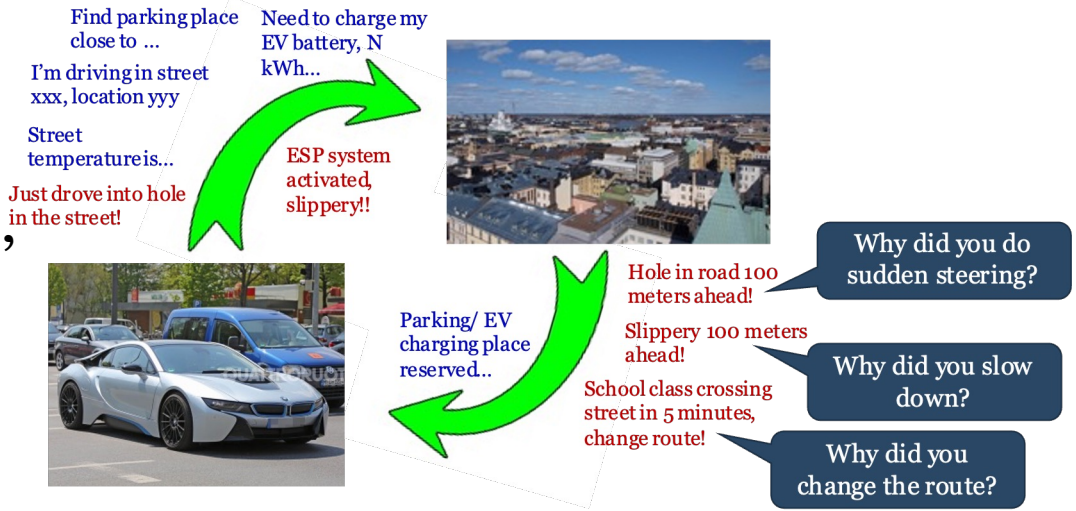
- **New programming languages** keep on taking over – Why?
- **REST-based**: is that smart, when and why?
  - Simple to implement, gives light-weight systems
- **What did we lose** when skipping SOAP etc?
  - Well-declared web service interfaces with validation and verification of types, automatic handling of intermittent connectivity, standardized lookup of services on the web, …
- **Machine Learning** has made huge progress – but why are many ”new” researchers turning back to GOFAI? And more importantly: All the old methods and lessons seem forgotten
- **XAI** not invented in around 2016, it’s only a new name that gained popularity
  - Kary’s **Contextual Importance and Utility (CIU)** method from 1992 outperforms current SOTA methods such as SHAP and LIME
- Seems like many academics believe that everything that is **older than 5 years is obsolete**, based on reviewer comments

# WHAT WILL THE WORLD DO NEXT?

- **LLMs** – will they take over everything?
  - Humanity seems to have a tendency or need to get “over-excited” about new technology
  - There will be other great new things
- For what are **LLMs great**?
  - Help in programming, especially for gaining time
    - Example: Implementing interoperability standards based on formal specifications
  - For looking up well-known facts on which there is some consensus
  - Summarizing text, generating images, …
- However: **LLMs give even bigger robustness challenges than ever before**
  - Wild extrapolation is possible, resulting in very convincing hallucinations
    - Try asking “Who invented Contextual Importance and Utility method?”, for instance
  - LLMs don’t seem to have any metric about the validity, certainty or robustness of their responses
  - These and other challenges are not new or specific to LLMs but most people seem to be unaware of them
- Conclusion: **Never trust an LLM unless you have reliable means of validating the output!**

# WHAT WILL KARY DO NEXT (SHORT-TERM)?

- Social XAI, better XAI in general
- Smart X
- Louhe.ai: (X)AI based cyber-physical security
- **Robustness, trustworthiness, explainability are more crucial than ever!**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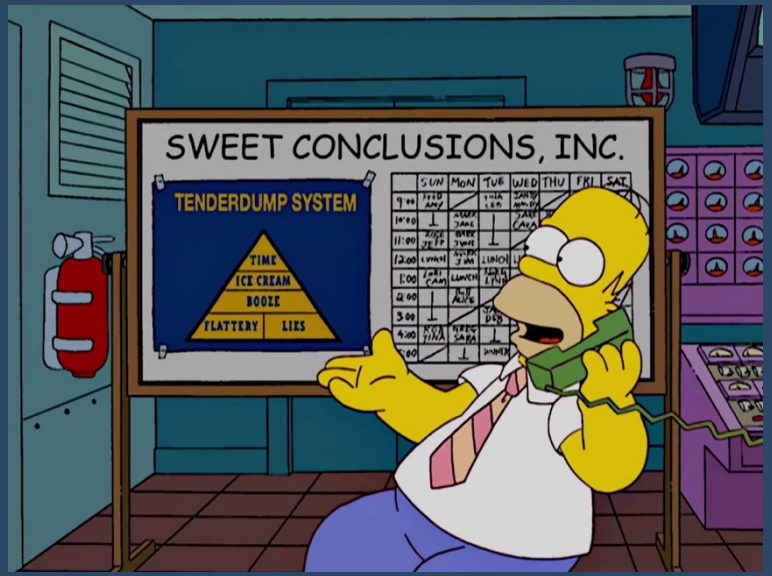
# THANK YOU!

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