Demystifying Machine Learning Sorcery

(Part 1: Fuzzy Logic & Neural Networks)[a]

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[a]Available @ https://github.com/a-mhamdi/isetbz/

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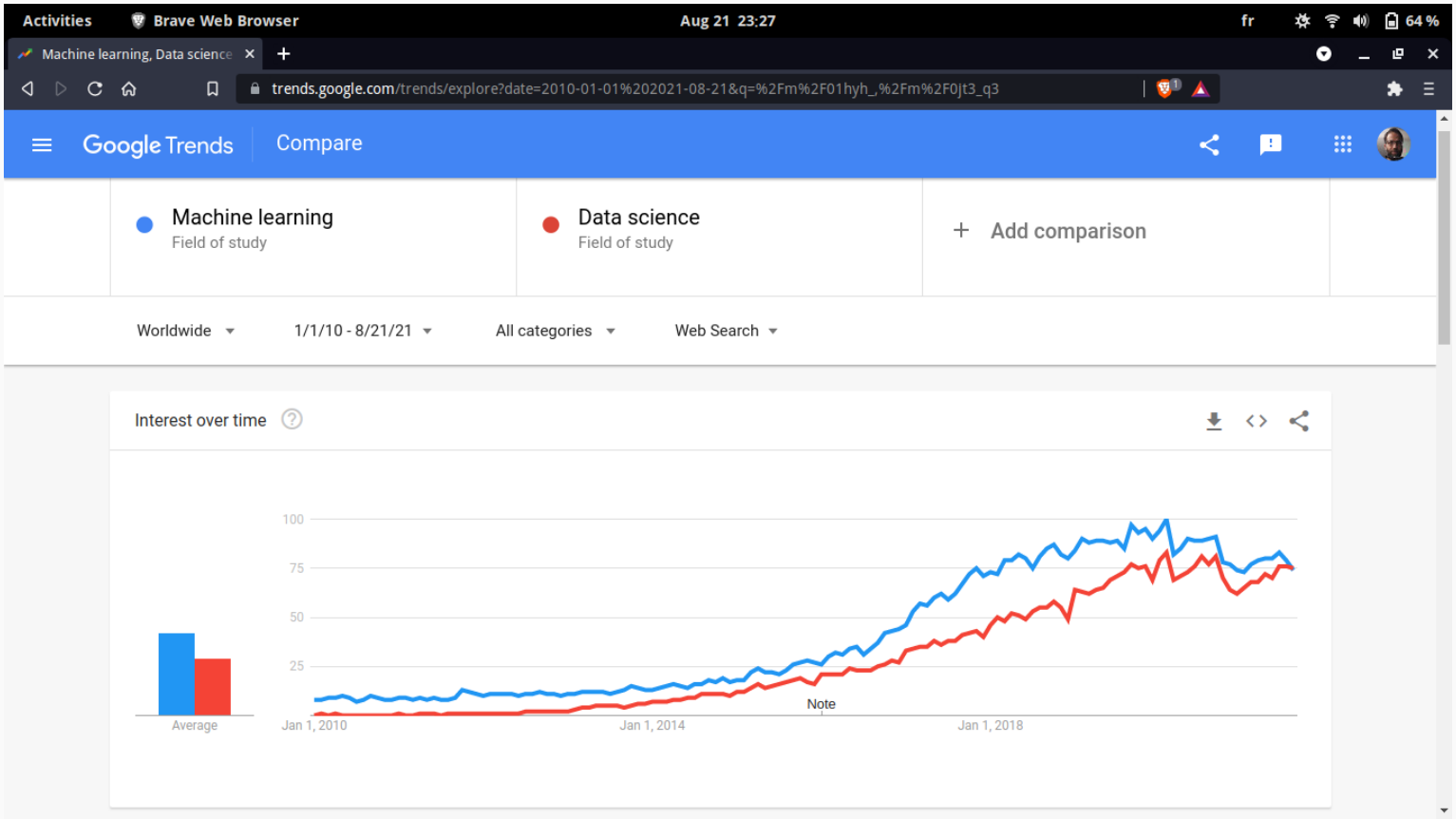
Roadmap

1. An overview
2. Fuzzy Logic
3. Neural Networks

An overview

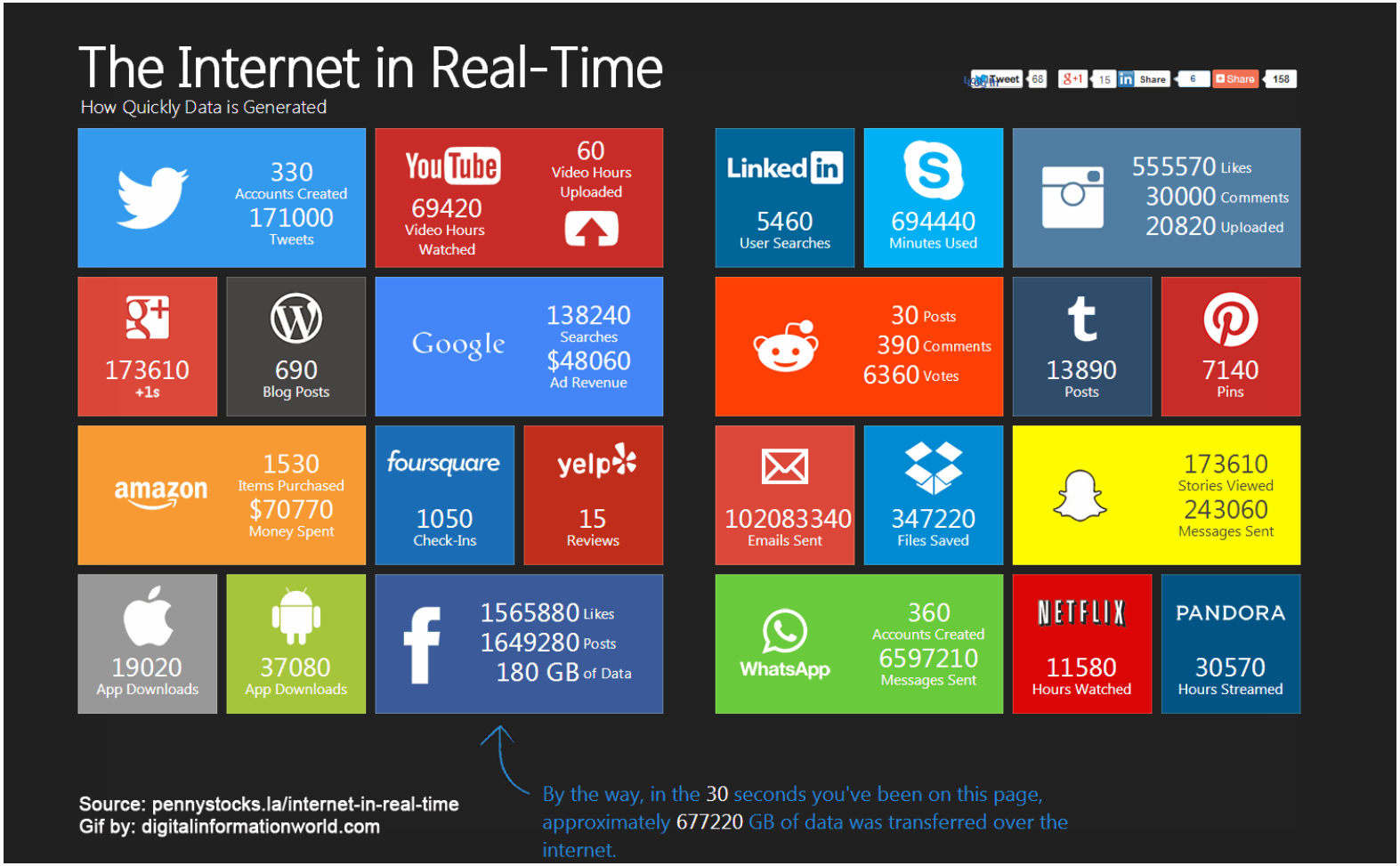
Trends



"Numbers represent search interest relative to the highest point on the chart for the given region and time.

- A value of 100 is the peak popularity for the term;
- A value of 50 means that the term is half as popular;
- A score of 0 means there was not enough data for this term."

Global Data Traffic



Update on the internet in real time is available here.

Top Uses


YouTube


Gboard


Google
Translate


amazon


Hi, how can I help?


amazon
alexa


Hi, I'm Cortana.

Literature Review (1/3)

[Mit97]

> "The field of machine learning is concerned with the question of how to construct computer programs that automatically improve with experience."

Mitchell, T. (1997) *Machine Learning*. **McGraw-Hill International Editions. McGraw-Hill.**

Literature Review (2/3)

[Woj12]

"Machine learning (ML) is a scientific discipline that concerns developing learning capabilities in computer systems. Machine learning is one of central areas of Artificial Intelligence (AI). It is an interdisciplinary area that combines results from statistics, logic, robotics, computer science, computational intelligence, pattern recognition, data mining, cognitive science, and more."

Wojtusiak, J. (2012) Machine learning. **In *Encyclopedia of the Sciences of Learning*, pages 2082–2083. Springer US.**

Literature Review (3/3)

[ENM15]

"Machine learning is an evolving branch of computational algorithms that are designed to emulate human intelligence by learning from the surrounding environment. They are considered the working horse in the new era of the so-called big data. Techniques based on machine learning have been applied successfully in diverse fields ranging from pattern recognition, computer vision, spacecraft engineering, finance, entertainment, and computational biology to biomedical and medical applications. [...] The ability of machine learning algorithms to learn from current context and generalize into unseen tasks would allow improvements in both the safety and efficacy of radiotherapy practice leading to better outcomes."

El Naqa, I. and Murphy, M. J. (2015) *What Is Machine Learning?*, pages 3–11. **Springer International Publishing.**

Debrief

Machine Learning is a branch of computer science which focuses on automation of intelligent behavior.

Some definitions can be categorized into four frames.

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Systems that think like humans

[Bel78]

> "[The automation of] activities that we associate with human thinking, activities such as decision-making, problem-solving, learning..."

Bellman, R. E. *An Introduction to Artificial Intelligence: Can Computers Think?* **Boyd & Fraser Publishing Company.**

[Hau89]

> "The exciting new effort to make computers think[...] *machines with minds*, in the full and literal sense"

Haugeland, J. (1989). *Artificial Intelligence: The Very Idea*. **A Bradford book. MIT Press.**

Systems that think rationally

[CMM85]

> "The study of mental faculties through the use of computational models."

Charniak, E., McDermott, D., and McDermott, D. V. (1985). *Introduction to Artificial Intelligence*. **Addison-Wesley series in computer science and information processing. Addison-Wesley.**

[Win92]

> "The study of the computations that make it possible to perceive, reason, and act."

Winston, P. H. (1992). *Artificial Intelligence*. **A-W Series in Computer Science. Addison-Wesley Publishing Company.**

Systems that act like humans

[Kur92]

> "The art of creating machines that perform functions that require intelligence when performed by people."

Kurzweil, R. (1992). *The Age of Intelligent Machines*. **Viking.**

[RK91]

> "The study of how to make computers do things at which, at the moment, people are better."

Rich, E. and Knight, K. (1991). *Artificial Intelligence*. **Artificial Intelligence Series. McGraw-Hill.**

Systems that act rationally

[Sch90]

> "A field of study that seeks to explain and emulate intelligent behavior in terms of computational processes."

Schalkoff, R. J. (1990). *Artificial Intelligence: An Engineering Approach*. **McGraw-Hill Computer science series. McGraw-Hill.**

[LS93]

> "The branch of computer science that is concerned with the automation of intelligent behavior."

Luger, G. F. and Stubblefield, W. A. *Artificial Intelligence: Structures and Strategies for Complex Problem Solving*. **Artificial intelligence. Benjamin/Cummings Publishing Company.**

Thought-Provoking Questions

How to achieve intelligence on a computer system

What do we mean by "Intelligence"?

- Single faculty or gathering of abilities
- Learned or existing
- What happens when we learn
- Are creativity and intuition measurable
- Does observable behavior infer to intelligence
- How knowledge is routed in the human brain

Thought-Provoking Questions

How to achieve intelligence on a computer system

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Turing Test

Alan Turing (1950)
The ability to achieve human level performance in all cognitive tasks, sufficient to fool an interrogator.

- ✓ Natural Language Processing (NLP) *(Communicate in human language)*
- ✓ Knowledge Representation *(Store information)*
- ✓ Automated Reasoning *(Answer questions & draw conclusions)*
- ✓ Machine Learning (ML) *(Adapt to new circumstances, detect & extrapolate patterns)*

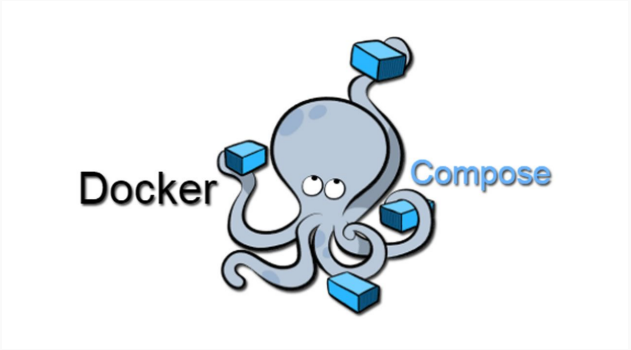
Forms of AI

- ☆ Expert Systems *(Based on knowledge or rule settings)*
- ☆ Fuzzy Systems *(Based on fuzzy set theory)*
- ☆ Artificial Neural Networks
- ☆ Genetic Algorithms
- ☆ Belief Networks
- ☆ Hybrid Systems *(Combine two or more approaches)*

Programming Language

julialang.org/

Development Environments

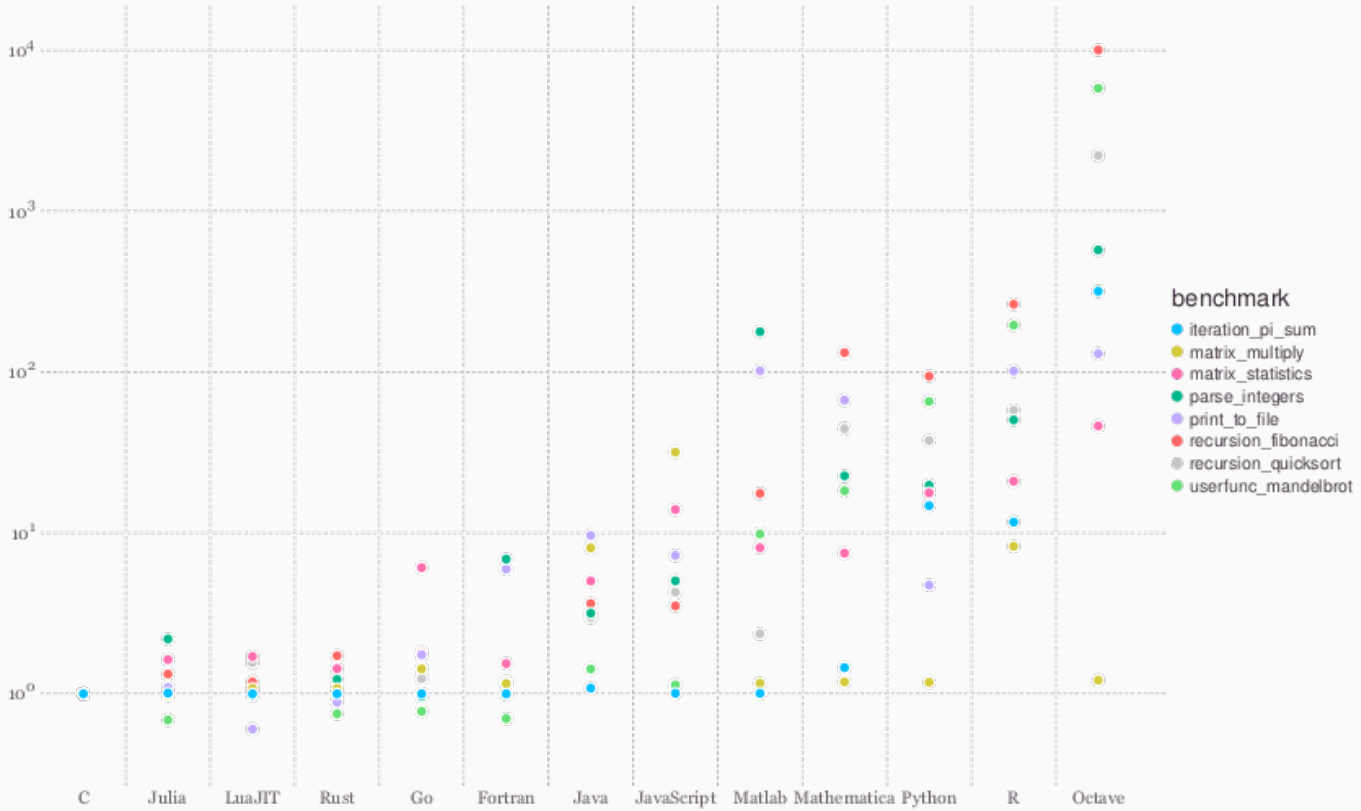


- ▲ $ docker compose up
- ▼ $ docker compose down

Julia in a Nutshell

- Fast
- Dynamic
- Reproducible
- Composable
- General
- Open Source

Julia Micro-Benchmarks (1/2)



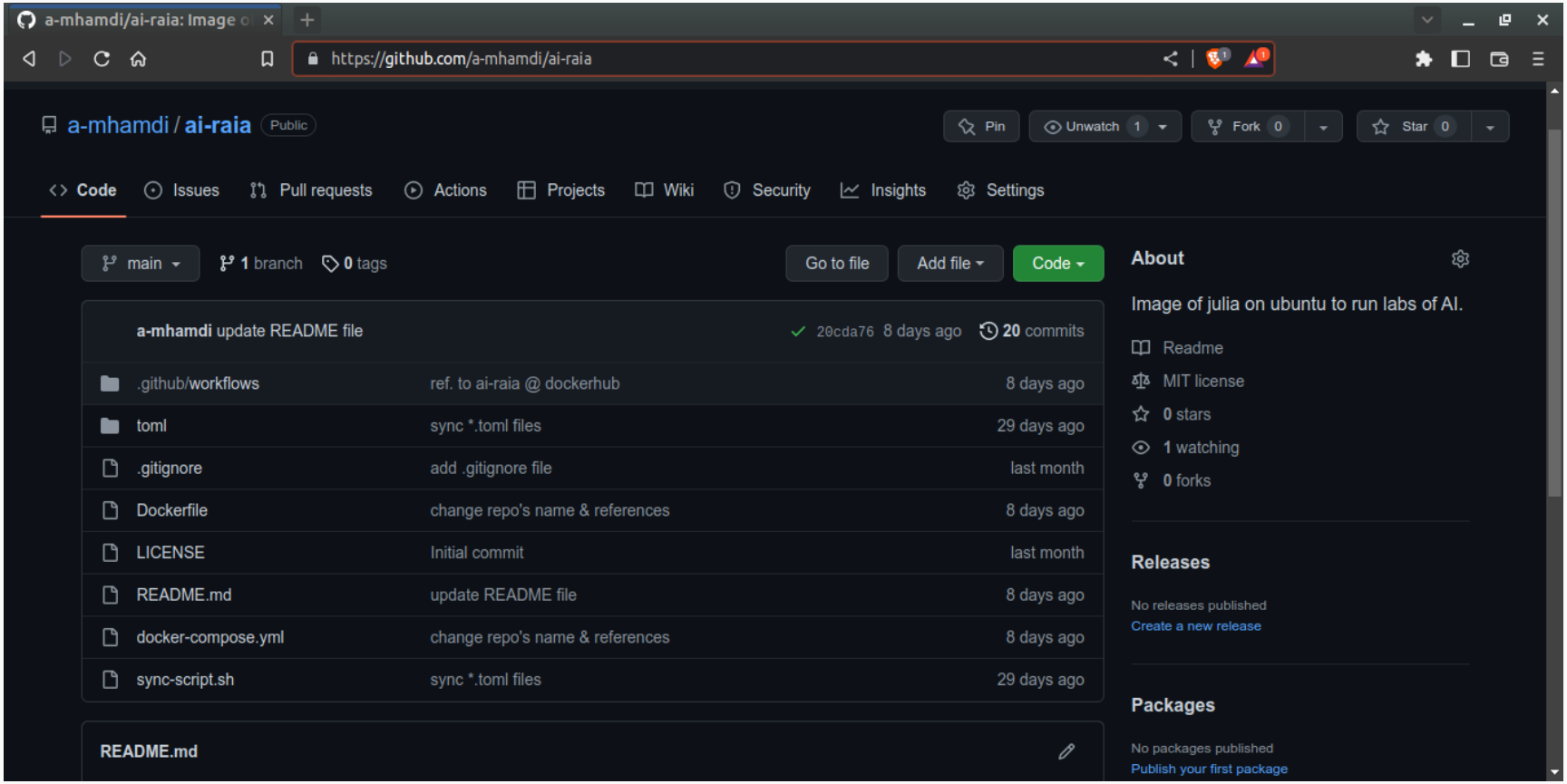
https://julialang.org/benchmarks

Julia Micro-Benchmarks (2/2)

Geometric Means of Micro-Benchmarks by Language

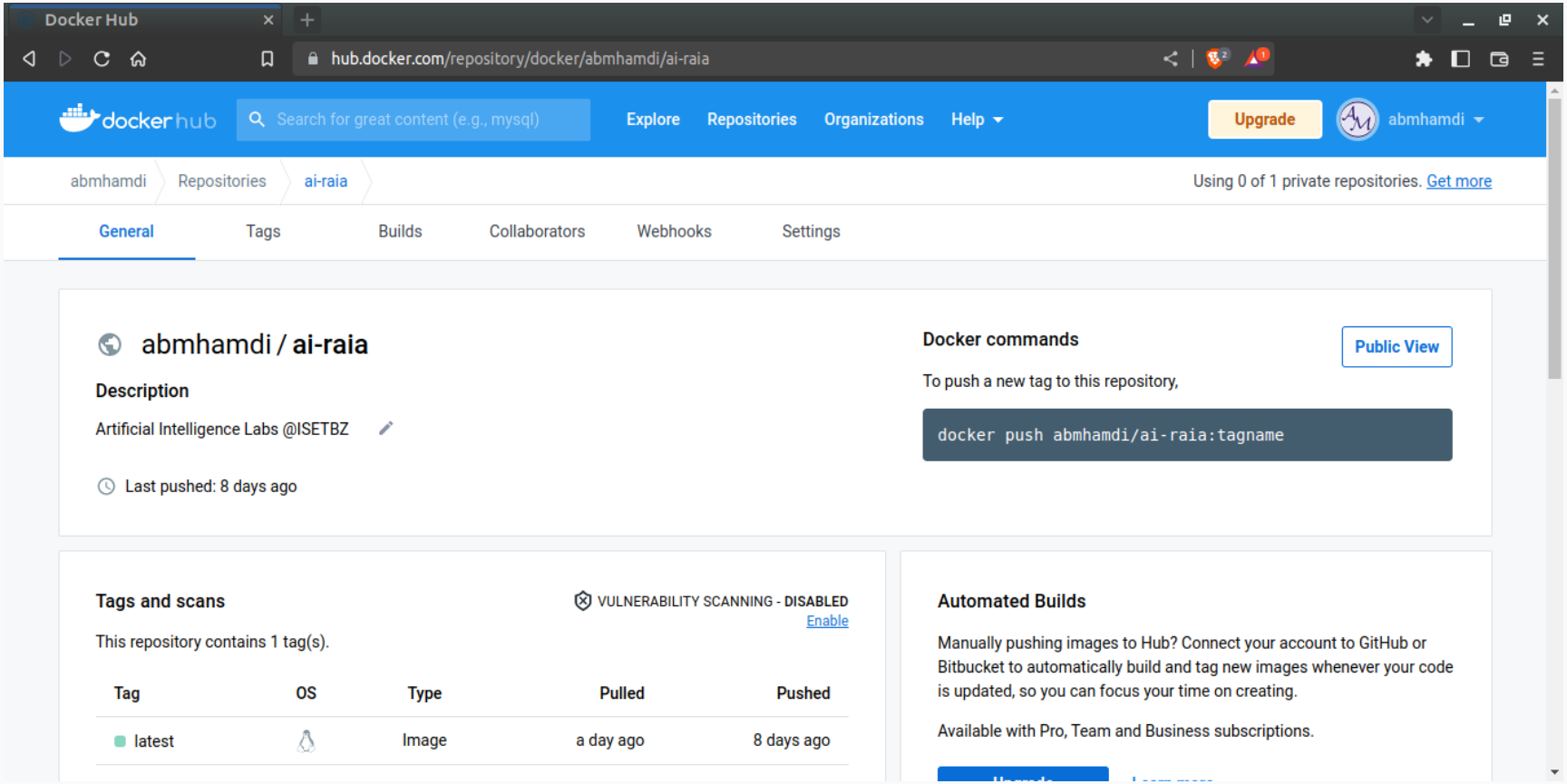
1	C	1.0
2	Julia	1.17006
3	LuaJIT	1.02931
4	Rust	1.0999
5	Go	1.49917
6	Fortran	1.67022
7	Java	3.46773
8	JavaScript	4.79602
9	Matlab	9.57235
10	Mathematica	14.6387
11	Python	16.9262
12	R	48.5796
13	Octave	338.704

Source Control Management (SCM)



https://github.com/a-mhamdi/ai-raia

Continuous Integration (CI)



https://hub.docker.com/r/abmhamdi/ai-raia

Fuzzy Logic

What is Fuzzy Logic?

"There are many misconceptions about fuzzy logic. To begin with, fuzzy logic is not fuzzy. Basically, fuzzy logic is a precise logic of imprecision. [...] fuzzy logic is designed to deal with imperfect information. Imperfect information is information which in one or more aspects is imprecise, uncertain, incomplete, unreliable, vague or partially true. In the real world, such information is the norm rather than exception."

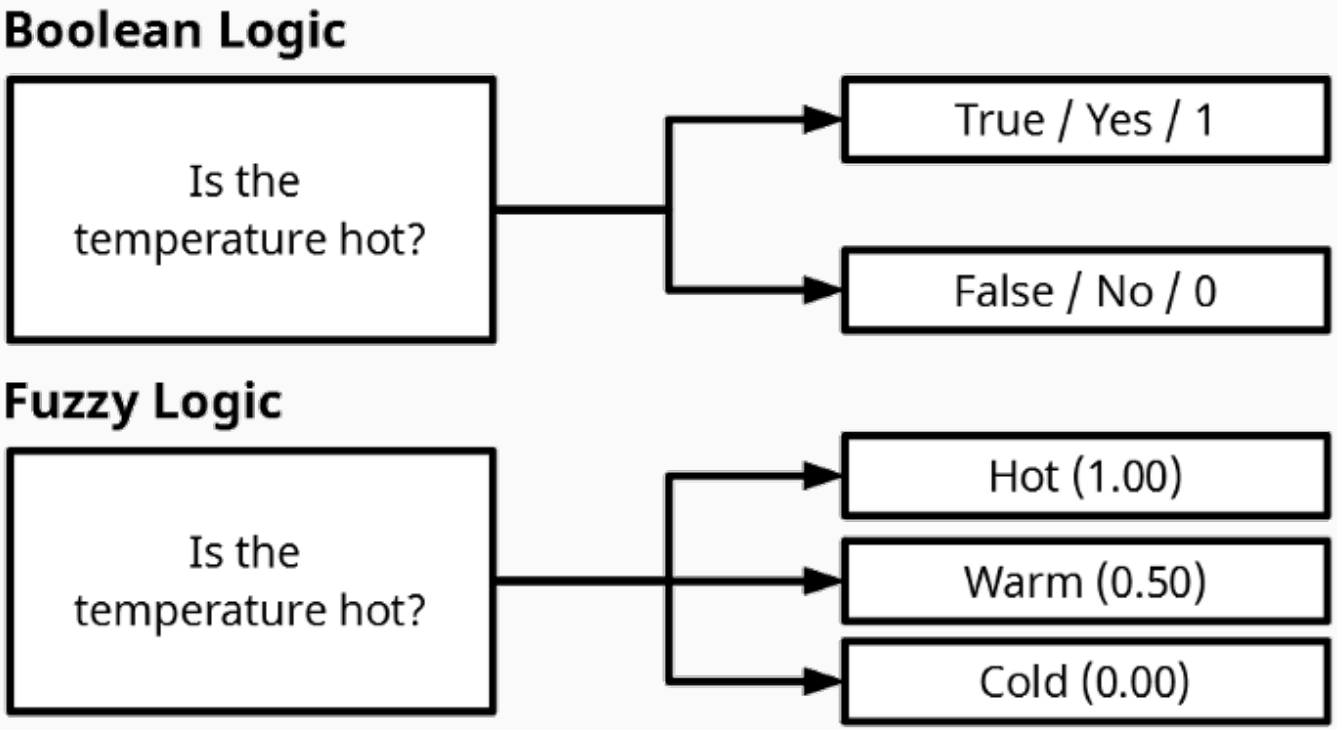
Lotfi Zadeh, *WCECS 2014*

What does Fuzzy Logic have to offer?

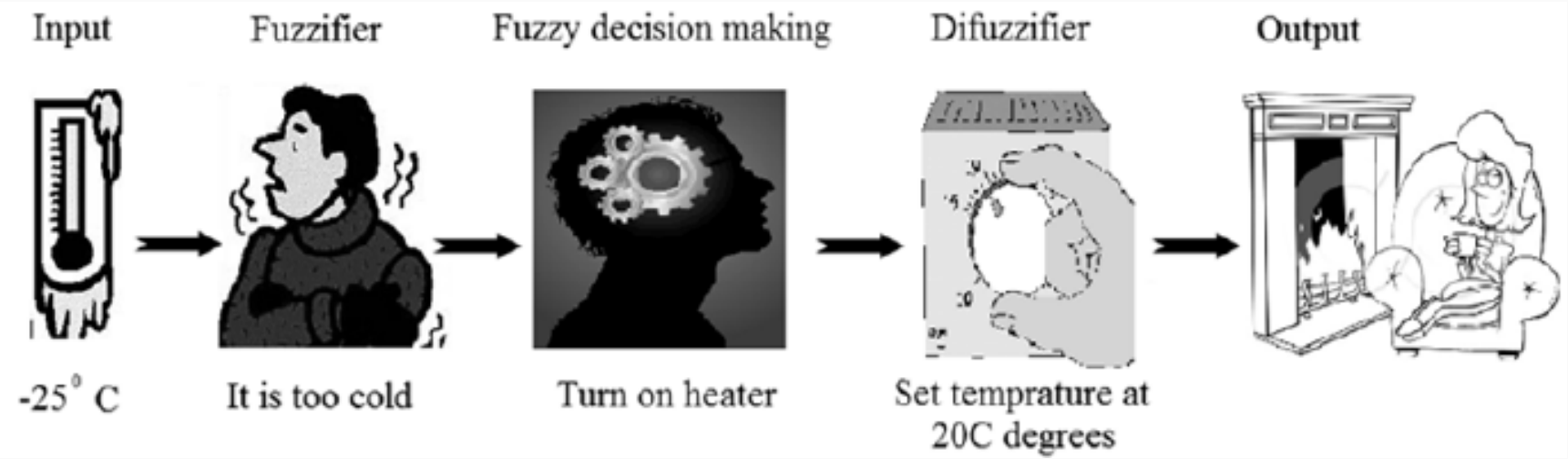
Fuzzy Logic aims at formalizing/mechanizing two noticeable human capabilities:

1. communicating, reasoning and rational decision making
   (in presence of imprecision, uncertainty & partiality of truth)
2. performing a wide variety of tasks
   (w/o measurements or computations)

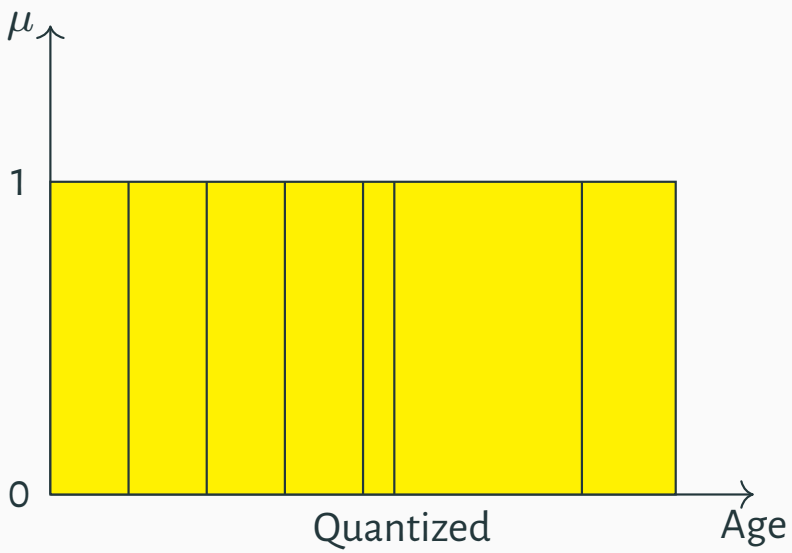
Fuzzy logic as an extension of the Boolean Logic

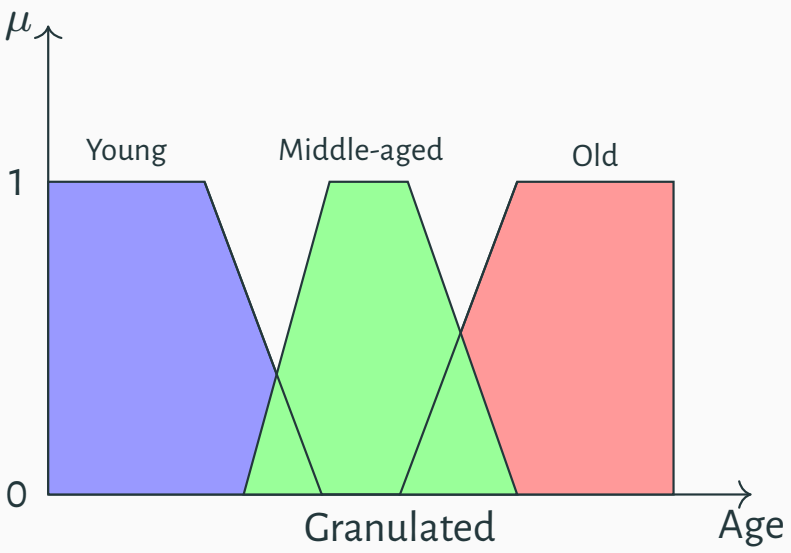


Example of a Fuzzy Control System



Continuous $\longrightarrow$ Quantized $\longrightarrow$ Granulated





Architecture

Rule Base is provided by experts. It contains the set of rules to govern the decision making.

Fuzzification converts crisp numbers to fuzzy sets.

Inference Engine decides which rules to be fired matching degree of the current fuzzy inputs.

Defuzzification converts the fuzzy sets delivered by the inference engine into some crisp value

Defuzzification

A fuzzy value can be defuzzified through multiple ways.

1. Center of Sums
2. Centroid Method
3. Center of Area
4. Weighted Average Method
5. Max-Membership Principal

Tipping Problem

What should be the TIP at a restaurant, given the quality of FOOD and of SERVICE. Theses latter are represented by some scores ranging from 0 *(poor)* to 10 *(excellent)*.

Rules Base

1. FOOD is rancid || SERVICE is poor $\Longrightarrow$ TIP is cheap;
2. SERVICE is good $\Longrightarrow$ TIP is average;
3. FOOD is delicious || SERVICE is excellent $\Longrightarrow$ TIP is generous.

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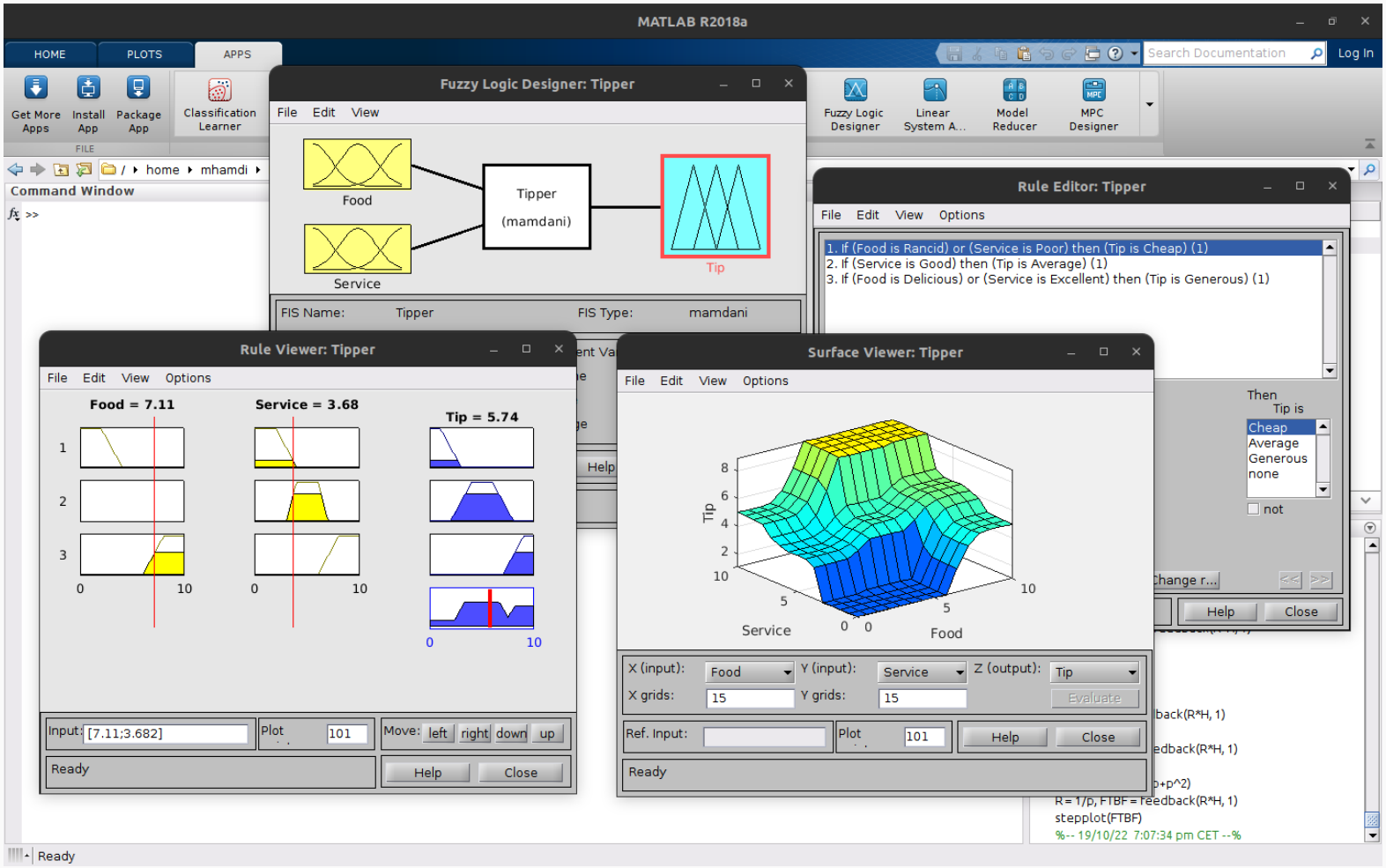
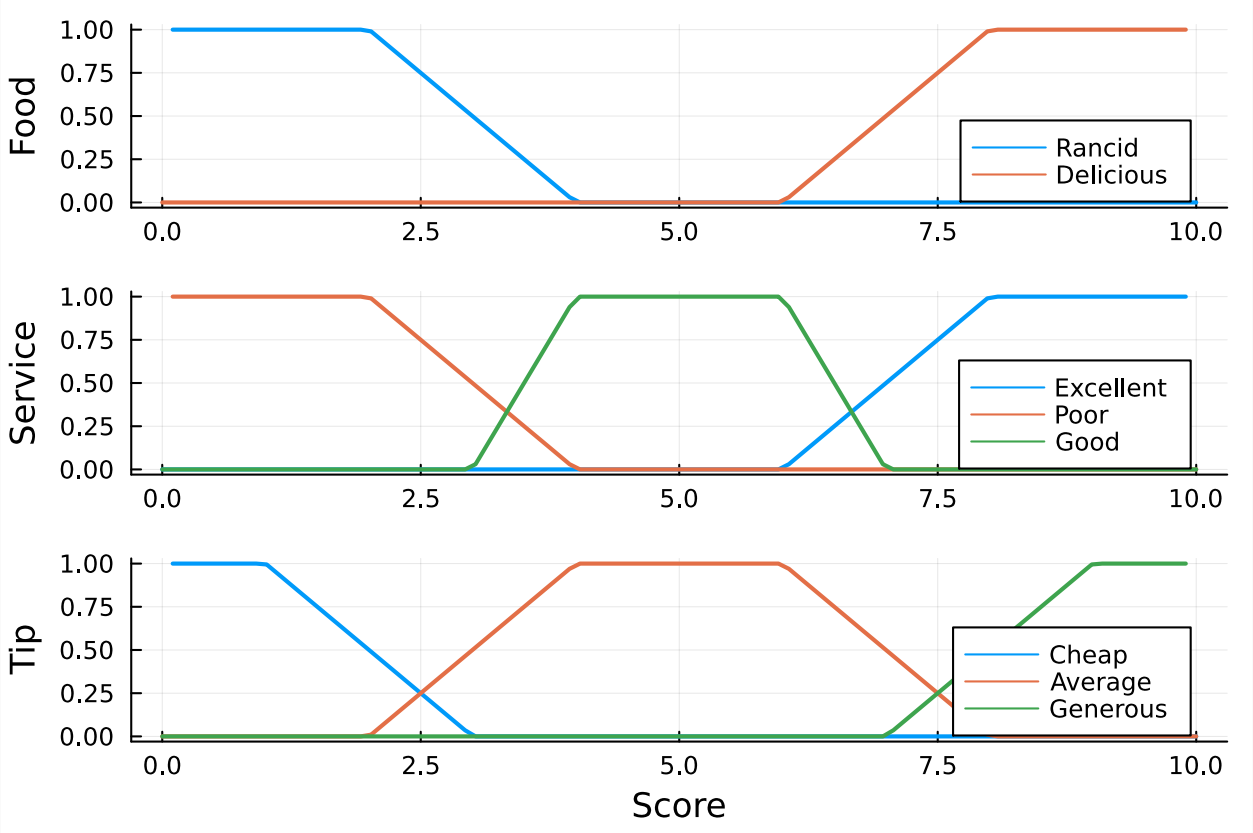
Using Fuzzy Logic Toolbox



The code is available at

https://github.com/a-mhamdi/isetbz/ → Machine Learning → Codes → Matlab → Tipper.fis

Using Fuzzy.jl Package



The code is available
at https://github.com/a-mhamdi/isetbz/ → Machine Learning → Codes → Julia → tipper.jl

"Fuzzy Logic," Microsoft® Encarta® Online Encyclopedia 2009

Fuzzy Logic, in computer science, a form of logic used in some expert systems and other artificial-intelligence applications in which variables can have degrees of truthfulness or falsehood represented by a range of values between 1 (true) and 0 (false). With fuzzy logic, the outcome of an operation can be expressed as a probability rather than as a certainty. For example, in addition to being either true or false, an outcome might have such meanings as probably true, possibly true, possibly false, and probably false.

Task #1[1]

Design a fuzzy lighting controller system, in which the control system dims the bulb light automatically according to the environmental light. Assume that the inputs to the system are the environmental light x_1 and the changing rate of the environmental light x_2. The output *dm* represents the control value of the dimmer.

- x_1 ranges between 120 and 220 lumens. x_1 can be:

  Dark (D) $\mathcal{L}(130, 150)$
  Ambient (A) $\Pi(130, 150, 190, 210)$
  Light (L) $\Gamma(190, 210)$.

- x_2 ranges between -10 and $+10$. x_2 can be:

  Negative-Small (NS) $\mathcal{L}(-10, 0)$
  Zero (Z) $\Delta(-10, 0, 10)$
  Positive-Small (PS) $\Gamma(0, 10)$.

- *dm* ranges between 0 and $+10$. *dm* can be:

  Very-Small (VS) $\mathcal{L}(2, 4)$
  Small (S) $\Delta(2, 4, 6)$
  Big (B) $\Delta(4, 6, 8)$
  Very-Big (VB) $\Gamma(6, 8)$.

Rule Base - case of $\wedge$

x_2 \ x_1	D	A	L
NS	B	S	VS
Z	B	B	S
PS	VB	B	B

Evaluate *dm* if $x_1 = 125$ & $x_2 = -6$.

[1]Credit: Dr. Mohammed A. T.

Neural Networks

References

[Bel78] R. E. Bellman. *An Introduction to Artificial Intelligence: Can Computers Think?* Boyd & Fraser Publishing Company, Jan. 1, 1978 (cit. on p. 13).

[CMM85] E. Charniak, D. McDermott, and D. V. McDermott. *Introduction to Artificial Intelligence*. Addison-Wesley series in computer science and information processing. Addison-Wesley, 1985 (cit. on p. 14).

[ENM15] I. El Naqa and M. J. Murphy. "What Is Machine Learning?" In: *Machine Learning in Radiation Oncology: Theory and Applications*. Ed. by I. El Naqa, R. Li, and M. J. Murphy. Cham: Springer International Publishing, 2015, pp. 3–11. DOI: 10.1007/978-3-319-18305-3_1 (cit. on p. 10).

[GBC16] I. Goodfellow, J. Bengio, and A. Courville. *Deep Learning*. MIT Press Ltd, Nov. 18, 2016. 800 pp.

[Hau89] J. Haugeland. *Artificial Intelligence: The Very Idea*. A Bradford book. MIT Press, 1989 (cit. on p. 13).

Further Reading (2/2)

[JPM21] L. M. John Paul Mueller. *Machine Learning For Dummies*. Wiley John + Sons, Apr. 8, 2021. 464 pp.

[Kur92] R. Kurzweil. *The Age of Intelligent Machines*. Viking, 1992 (cit. on p. 15).

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[Mit97] T. M. Mitchell. *Machine Learning*. McGraw-Hill International Editions. McGraw-Hill, 1997 (cit. on p. 8).

[RK91] E. Rich and K. Knight. *Artificial Intelligence*. Artificial Intelligence Series. McGraw-Hill, 1991 (cit. on p. 15).

[Sch90] R. J. Schalkoff. *Artificial Intelligence: An Engineering Approach*. McGraw-Hill Computer science series. McGraw-Hill, 1990 (cit. on p. 16).

[SNK12] T. Sai, D. Nakhaeinia, and B. Karasfi. "Application of Fuzzy Logic in Mobile Robot Navigation". In: *Fuzzy Logic - Controls, Concepts, Theories and Applications*. InTech, Mar. 2012. DOI: 10.5772/36358.

[Win92] P. H. Winston. *Artificial Intelligence*. A-W Series in Computer Science. Addison-Wesley Publishing Company, 1992 (cit. on p. 14).

Further Reading (3/2)

[Woj12] J. Wojtusiak. “Machine Learning”. In: *Encyclopedia of the Sciences of Learning*. Springer US, 2012, pp. 2082–2083. DOI: 10.1007/978-1-4419-1428-6_1927 (cit. on p. 9).