Advanced Artificial Intelligence Technologies and Applications

Course organiser: A/Prof. Shihua Zhou

Course presenter

Prof Nikola Kasabov

Visiting Professor at Dalian University

Life FIEEE, FRSNZ, FINNS, DVF RAE UK

Founding Director KEDRI

Professor, Auckland University of Technology, NZ

George Moore Chair/Professor, Ulster University, UK

Honorary Professor, University of Auckland NZ , Peking University China

Visiting Professor IICT/Bulgarian Academy of Sciences and Teesside University UK

Doctor Honoris Causa Obuda University Budapest

Director, Knowledge Engineering Consulting Ltd (https://www.knowledgeengineering.ai)

Assistants

A/Prof. Wei Qi Yan

Director of the CeRV Center, AUT

Weiqi.yan@aut.ac.nz

https://academics.aut.ac.nz/weiqi.yan

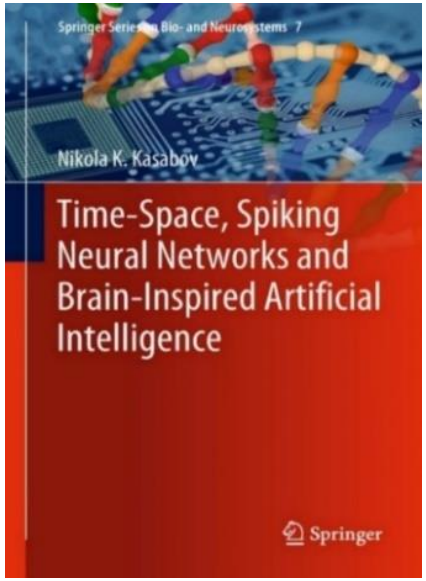
Ms Iman AbouHassan

iabouhassan@tu-sofia.bg

abouhassan.iman@gmail.com

Advanced Artificial Intelligence Technologies and Applications

1. AI and the evolution of its principles. Evolving processes in Time and Space (Ch1, 3-19)
2. From Data and Information to Knowledge. Fuzzy logic. (Ch1,19-33 + extra reading)
3. Artificial neural networks - fundamentals. (Ch2, 39-48).
4. Deep neural networks (Ch.2, 48-50 + extra reading)
5. Evolving connectionist systems (ECOS) (Ch2, 50-78). NeuCom software (IA)
6. Deep learning and deep knowledge representation in the human brain (Ch3)
7. Spiking neural networks (Ch4). Evolving spiking neural networks (Ch5)
8. Brain-inspired SNN. NeuCube. (Ch.6). NeuCube software (IA)
9. Evolutionary and quantum inspired computation (Ch.7)
10. AI applications in health (Ch.8-11)
11. AI applications for computer vision (Ch.12,13)
12. AI for brain-computer interfaces (BCI) (Ch.14)
13. AI for language modelling. ChatBots (extra reading)
14. AI in bioinformatics and neuroinformatics (Ch15,16, 17,18)
15. AI applications for multisensory environmental data (Ch.19)
16. AI in finance and economics (Ch19)
17. Neuromorphic hardware and neurocomputers (Ch20).



Course book: N.Kasabov, Time-Space, Spiking Neural Networks and Brain-Inspired Artificial Intelligence Springer, 2019, https://www.springer.com/gp/book/9783662577134

Additional materials: https://www.knowledgeengineering.ai/china

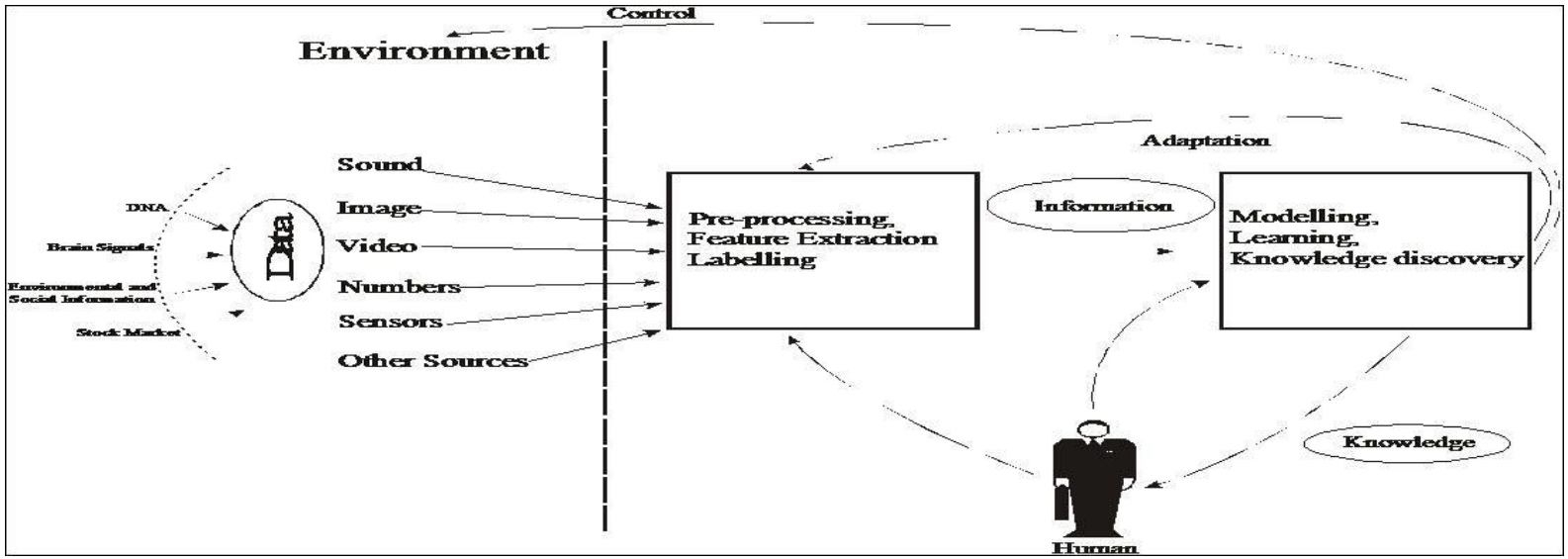
ZOOM link for all lectures: https://us05web.zoom.us/j/4658730662?pwd=eFN0eHRCN3o4K0FaZ0lqQmN1UUgydz09

Lecture 2.
From Data and Information to Knowledge. Fuzzy logic.

(Ch1, 19-33+ extra reading)

- Generally speaking, *data* are raw entities: numbers, symbols etc., e.g., 36.
- *Information* is labelled, understood, interpreted data, e.g., the temperature of the human body is 36 ◦C.
- *Knowledge* is the understanding of a human, the way we do things, interpretable information in different situations, general information; e.g.:
- IF the human temperature is between 36 ◦C and 37 ◦C degrees,
- THEN it is most likely that human body is in a healthy state.

From data and information to knowledge



- **S**earching: Observe phenomena; Collect data; Store data;
- **A**nalysis (e.g. pre-process data, filter, select features, visualise, label)
- **L**earning (create a model, validation and reasoning)
- **K**nowledge creation (Create/extract rules) and reasoning (deductive, inductive)
- **A**daptation (accommodate new data and knowledge)

Generic AI methods and tools → Specific methods and tools → Application systems

Human knowledge vs knowledge representation in machines

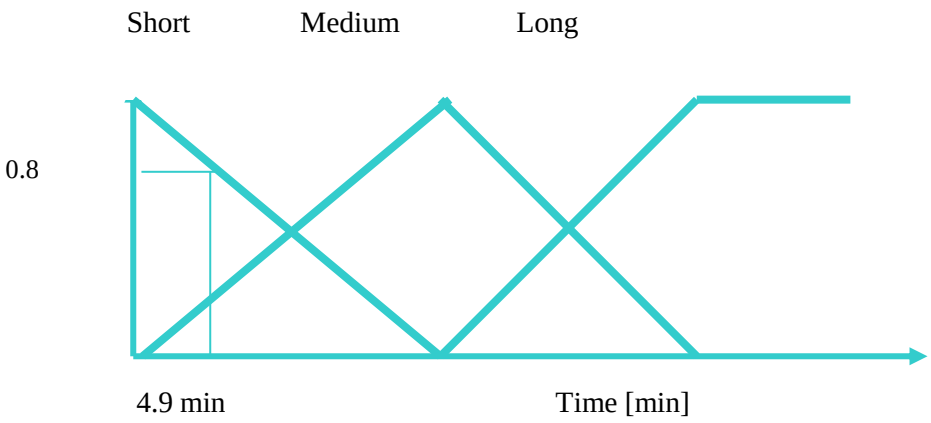
- Human knowledge - spatio-temporal patterns in the brain

- Knowledge representation in machines:
  - Relations and implications, e.g.: A-> (implies) B.
  - Propositional (true/false) logic, e.g.: IF (A and B) or C THEN D.
  - Boolean logic (George Boole).
  - Predicate logic: PROLOG.
  - Probabilistic logic: e.g. Bayes formula: p(A / C)) = p (C/A) . p(A) / p(C), where p(A/C denotes the conditional probability for an event A to happen if event C has already happened.
  - Rule based systems, expert systems.
  - Fuzzy logic systems

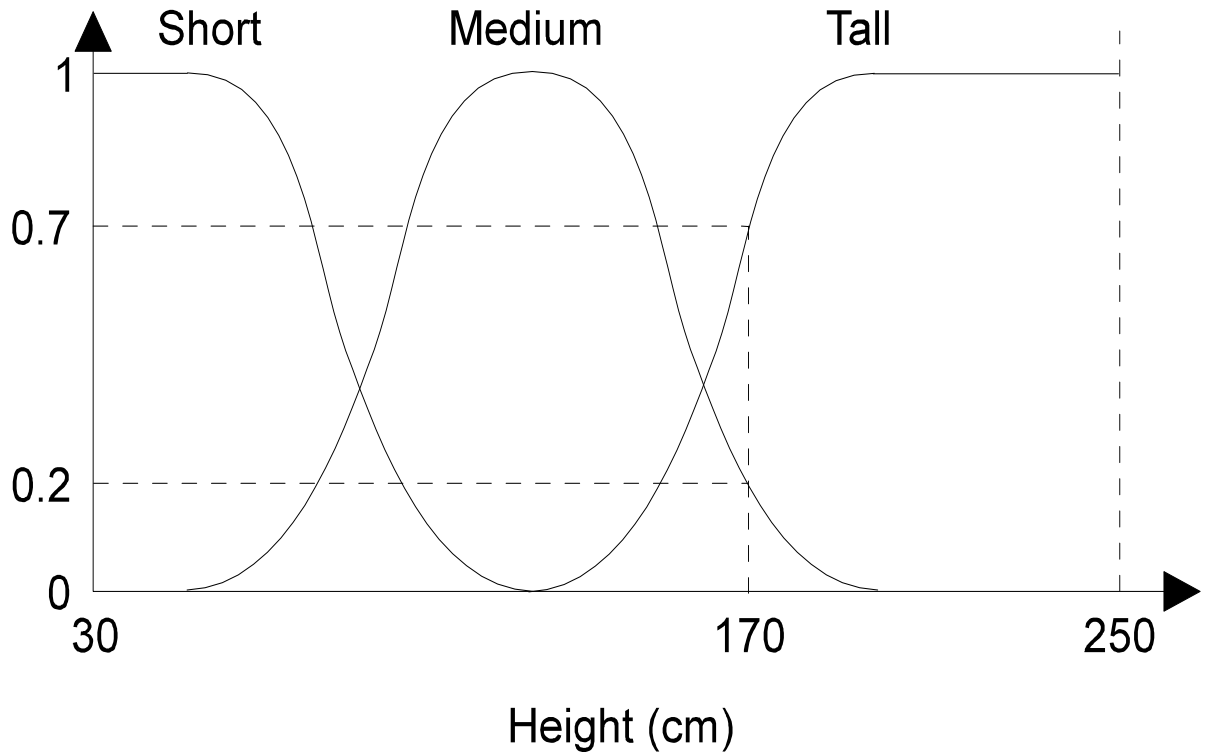
Fuzzy logic

In 1965 **(1920-2018) Lotfi Zadeh** introduced fuzzy logic that represents information uncertainties and tolerance in a linguistically expressed rules. He introduced fuzzy rules, containing fuzzy propositions and fuzzy inference.

- Fuzzy propositions can have truth values *between* true (1) and false (0), e.g. the proposition "washing time is short" is true to a degree of 0.8 if the time is 4.9 min, where *Short* is represented as a fuzzy set with its membership function.
- Fuzzy rules can be used to represent human knowledge and reasoning, e.g.
- *IF washing load is small* THEN washing time is short.



Fuzzy Sets



- Figure 3.1 Membership functions representing three fuzzy sets for the fuzzy variable "height". **A domain value belongs to each fuzzy set to a certain degree of [0,1]**

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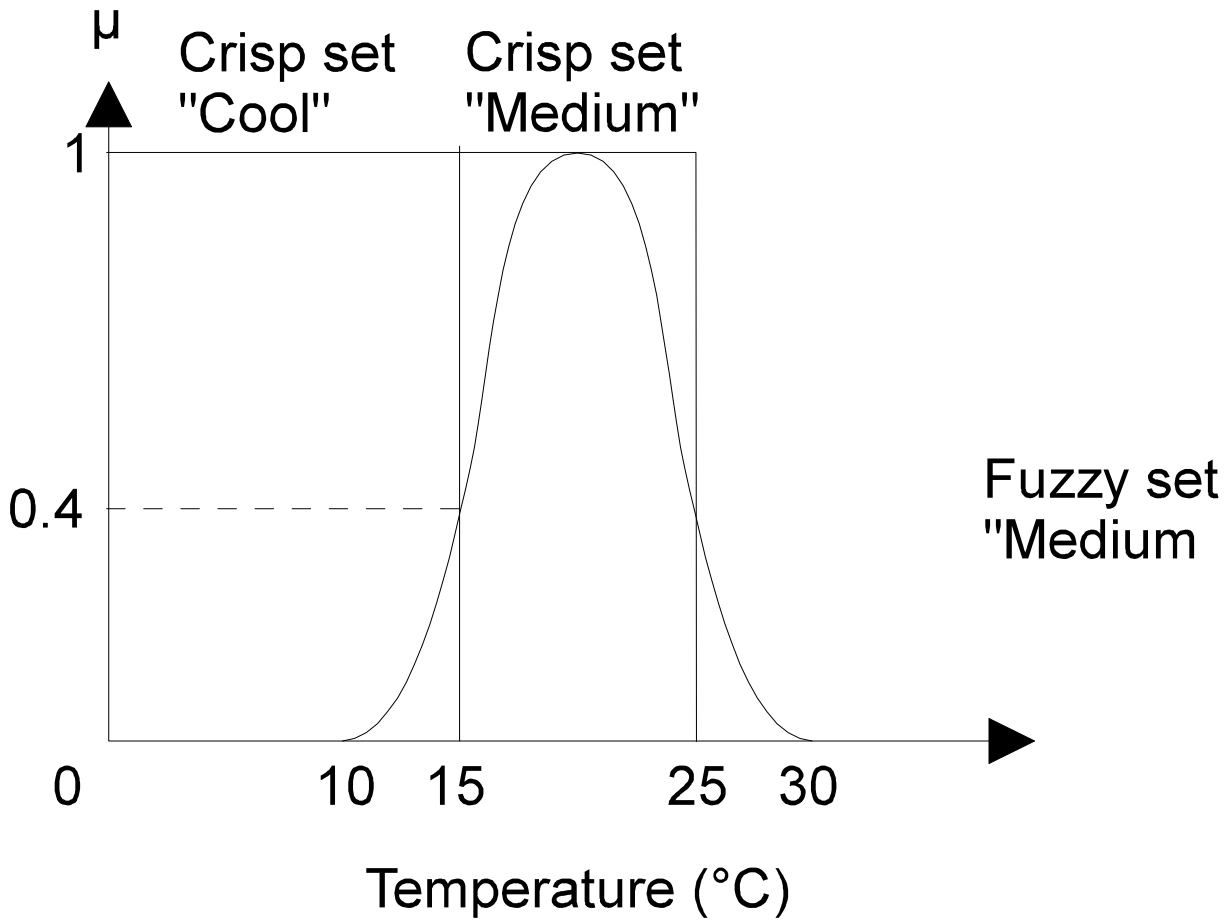
Fuzzy Sets…the difference between crisp and fuzzy sets



- Figure 3.2 Representing crisp and fuzzy sets as subsets of a domain (universe) U

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Fuzzy variables, fuzzy values, fuzzy rules and fuzzy inference

- **Rule 1**: IF (Score is high) and (Ratio is good) and (Credit is good)

  then (Decision is approve)

- **Rule 2**: IF (Score is low) and (Ratio is bad) or (Credit is bad)

  then (Decision is disapprove)

Fuzzy rules and fuzzy inference...

  - Inference: fuzzification-evaluation-defuzzification
- Inputs to a fuzzy system can be:
  - fuzzy, e.g. (Score = Moderate), defined by membership functions
  - exact, e.g.: (Score = 190); (Theta = 35), defined by crisp values.
- Outputs from a fuzzy system can be:
  - fuzzy, i.e. a whole membership function, or
  - exact, i.e. a single value is produced

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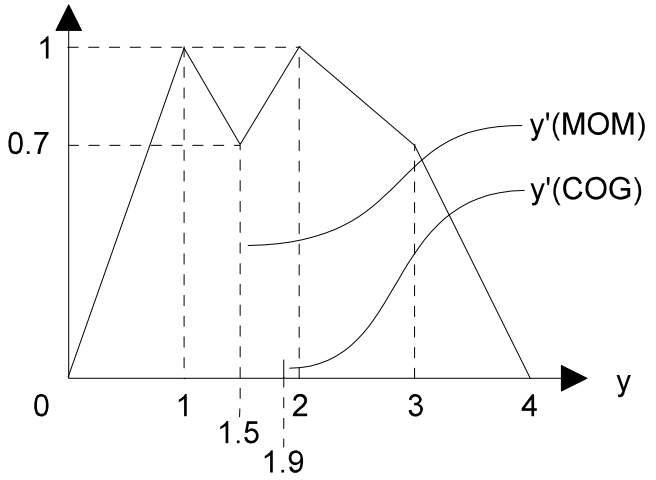
Fuzzy rules and fuzzy inference...

- Methods for defuzzification:
  - center of gravity
  - mean of maxima

- see Figure 3.26

Methods of defuzzification: the centre of gravity method (COG), and the mean of maxima method (MOM) applied over the same membership function for a fuzzy output variable y. They calculate different crisp output values.



$$y'(COG) = \frac{(0 \times 0) + (1 \times 1) + (1 \times 2) + (0.7 \times 3)}{1 + 1 + 0.7} \approx 1.9$$

$$y'(MOM) = \frac{1 + 2}{2} = 1.5$$

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Fuzzy information retrieval and fuzzy databases

- Fuzzy interfaces to standard databases
  (see fig 3.32)
- Fuzzy databases (see fig. 3.33)
- Fuzzy expert system shells (see fig. 3.36, 3.37)

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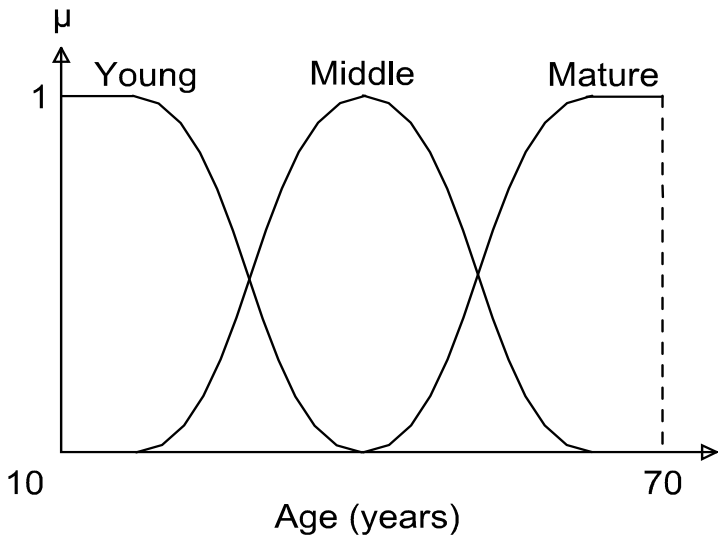
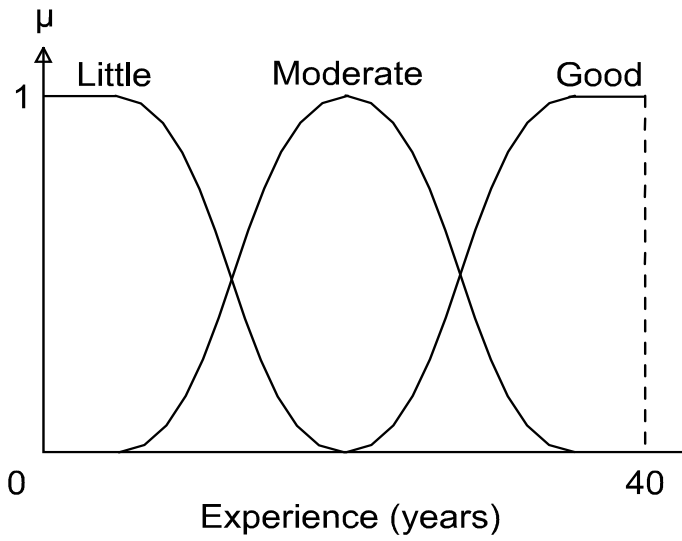
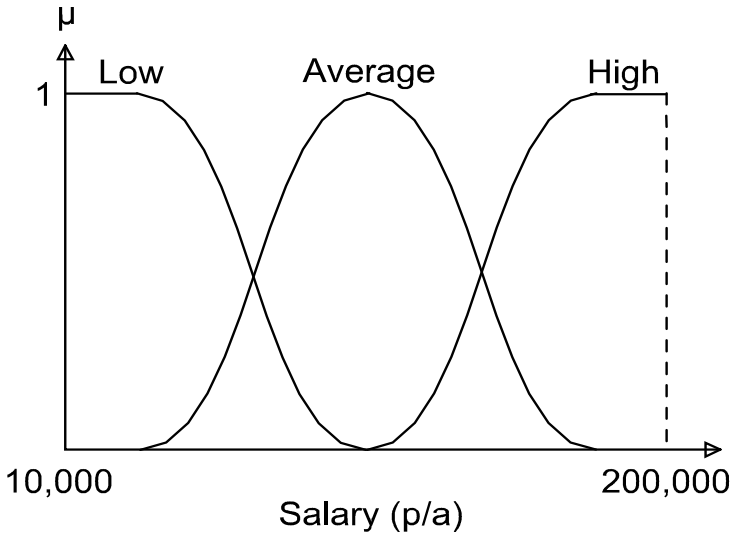
Fuzzy information retrieval and fuzzy databases

- Fig. 3.32 - fuzzy interfaces to standard databases: define fuzzy terms over the existing standard attributes







Deep learning and deep knowledge representation in time-space

In contrast to the "flat rules" as discussed in the previous section, deep knowledge represents a series of events that happen in space and time in their continuous interaction.

Continuous learning of time-space data, to capture dynamically changing and informative patterns, 'hidden' deep in time and space, and to predict future events, has been a fundamental science challenge. We call this here *deep learning in time-space.*

This is inspired by the deep learning capabilities of the human brain.

Example:

IF (event E1: function F1, location S1, time T1)

AND (event E2: function F2, location S2, time T2)

AND (event E3: function F3, location S3, time T3)

AND ... (event En : function Fn, location Sn, time Tn)

THEN (Task/event Q is recognised/executed)

Brain-inspired AI

Artificial Intelligence (AI) is part of the interdisciplinary information sciences area that develops and implements methods and systems that manifest cognitive behaviour .

- Main features of AI are: learning, adaptation, generalisation, inductive and deductive reasoning, human-like communication.
- Some more features are currently being developed: consciousness, self-assembly, self-reproduction, AI social networks.
- There is a trend in AI called *Artificial General Intelligence (AGI)* that considers machines to become able to perform any intellectual task that humans can do.
- Another trend in AI is called *Technological Singularity*. This trend argues that machines will become super intelligent that they take over from humans and develop on their own, beyond which point the human societies can collapse in their present forms, which may ultimately lead to the perish of humanity.
- A new trend in AI is the *Brain-Inspired AI (BI-AI)*, which is being developed and presented in this book. BI-AI systems use principles of deep learning in the human brain to reveal deep knowledge and to enable machines to manifest cognitive functions. BI-AI systems adopt structures and methods from the human brain to intelligently learn spatio-temporal data.

BI-AI systems have six distinctive features:

(1) They have their structures and functionality inspired by the human brain; they consist of spatially located neurons that create connections between them through deep learning in time-space by exchanging information – spikes. They are built of spiking neural networks (SNN), as explained in Chapters 4-6 in the book.

(2) Being brain-inspired, BI-AI systems can achieve not only *deep learning*, but *deep knowledge* representation as well.

(3) They can manifest cognitive behaviour.

(4) They can be used for knowledge transfer between humans and machines as a foundation for the creation of symbiosis between humans and machines, ultimately leading to the integration of human intelligence and artificial intelligence (HI+AI) as discussed in the last chapter of the book.

(5) BI-AI systems are universal data learning machines, being superior than traditional machine learning techniques when dealing with time-space data.

(6) BI-AI systems can help us understand-, protect-, and cure the human brain.

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Questions, exercises, assignments and project work

1. Name 6 types of knowledge representation in machines

2. What is fuzzy logic and how it is used for fuzzy inference?

3. How would you define brain-inspired AI?