University of Ljubljana, Faculty of Computer and Information Science

Intelligent Sytems

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Lecturer

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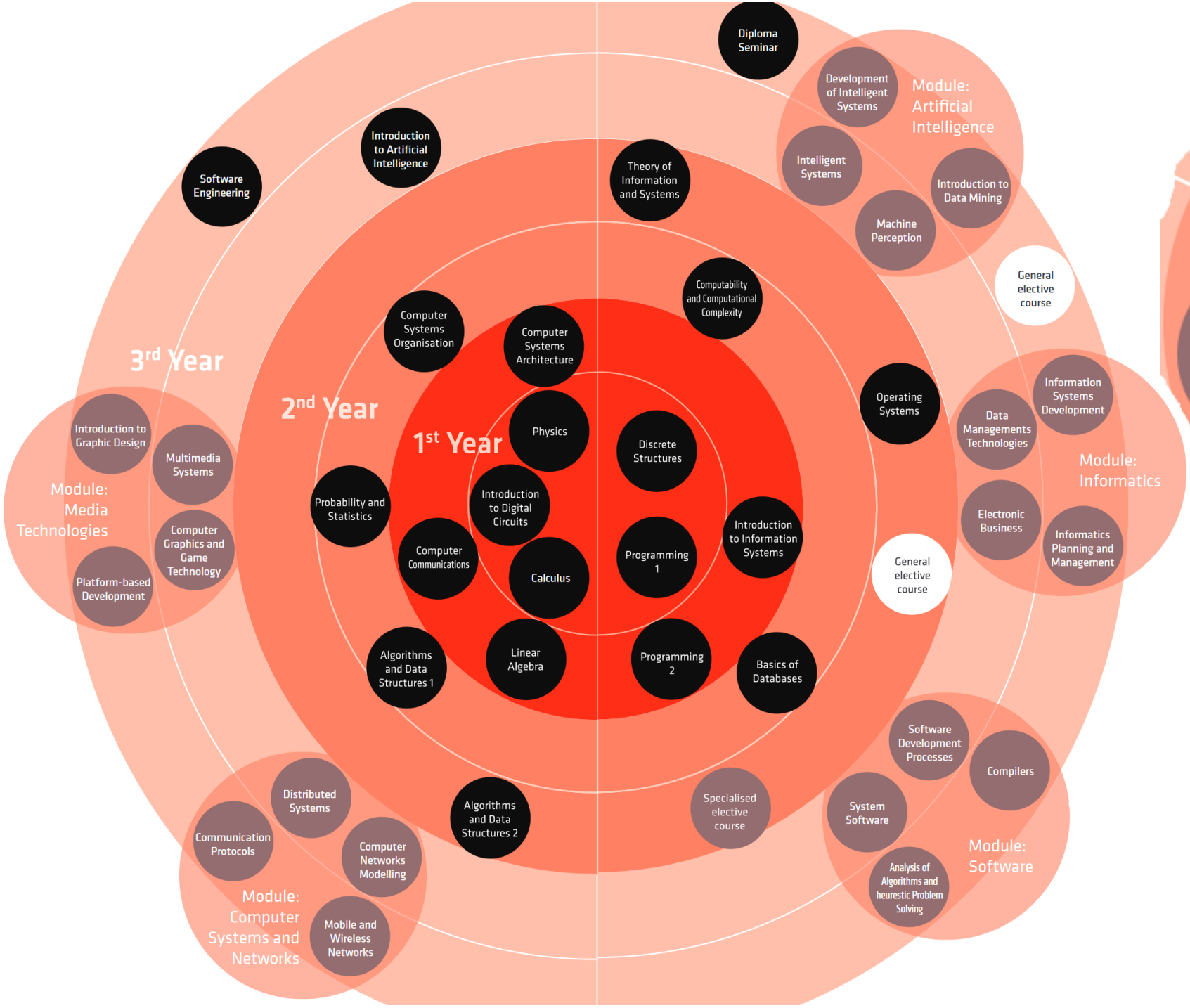
- Contact hours (see the webpage)
  - currently, Wednesdays, 10:00 - 11:00; email me for other times or video connection
- **Research interests**: artificial intelligence, machine learning, natural language processing, network analytics, data science, data mining, algorithms and data structures
- **Teaching:** courses from areas of machine learning, natural language processing, and algorithms
- **Software and resources:** supporting open science, an author of three open source R packages from the area of predictive modelling and data analytics (CORElearn, semiArtificial, ExplainPrediction), many neural prediction models and language resources

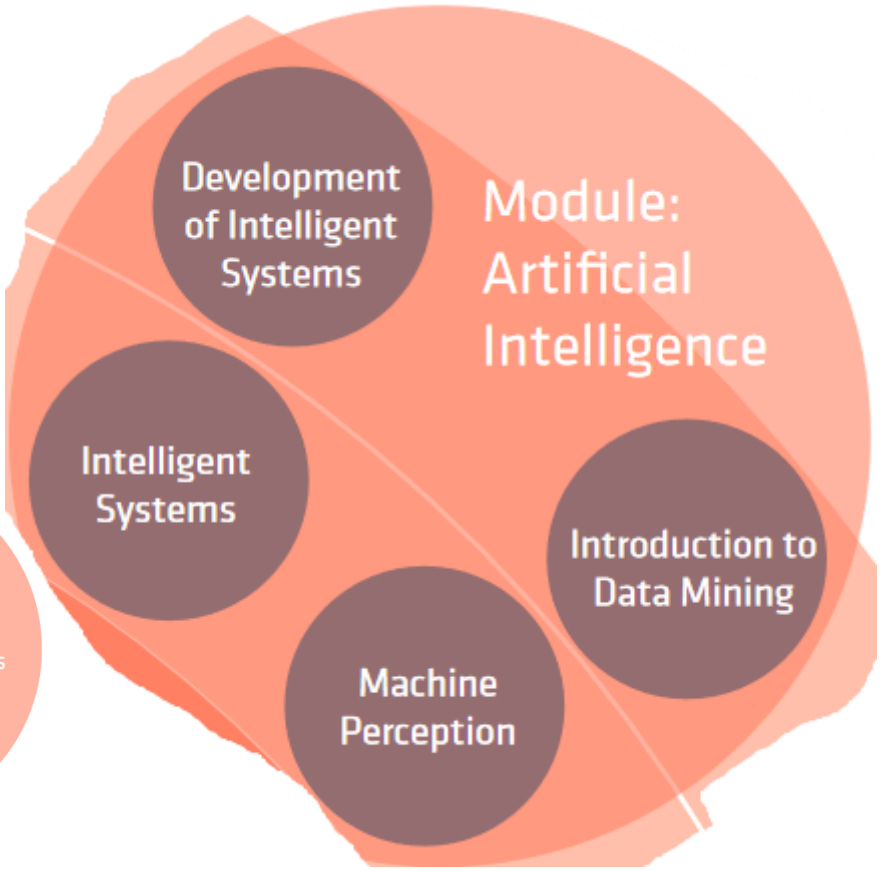
Assistants

- Dr Blaž Škrlj
- Dr Tadej Škvorc
- Aleš Žagar, PhD student



- tutorials, assignments, work in R please, prepare questions!


Diploma Seminar
Development of Intelligent Systems
Module: Artificial Intelligence
Intelligent Systems
Introduction to Data Mining
Machine Perception
Introduction to Artificial Intelligence
Software Engineering
Theory of Information and Systems
Computability and Computational Complexity
General elective course
Computer Systems Organisation
Computer Systems Architecture
3rd Year
2nd Year
1st Year
Operating Systems
Physics
Discrete Structures
Introduction to Graphic Design
Multimedia Systems
Module: Media Technologies
Computer Graphics and Game Technology
Platform-based Development
Probability and Statistics
Introduction to Digital Circuits
Introduction to Information Systems
Computer Communications
Calculus
Programming 1
Information Systems Development
Data Managements Technologies
Module: Informatics
Electronic Business
Informatics Planning and Management
General elective course
Algorithms and Data Structures 1
Linear Algebra
Programming 2
Basics of Databases
Software Development Processes
Compilers
System Software
Module: Software
Analysis of Algorithms and heurestic Problem Solving
Distributed Systems
Communication Protocols
Computer Networks Modelling
Module: Computer Systems and Networks
Mobile and Wireless Networks
Algorithms and Data Structures 2
Specialised elective course


Development of Intelligent Systems
Module: Artificial Intelligence
Intelligent Systems
Introduction to Data Mining
Machine Perception

Syllabus

- nature inspired computing (genetic algorithms, genetic programming)
- basics of machine learning,
- bias, variance and overfitting
- representation learning and feature selection
- ensemble methods
- kernel methods
- neural networks
- model inference and explanation
- natural language processing
- reinforcement learning

Objectives

- students shall become acquainted with
  - nature inspired computing
  - machine learning
    - model selection and evaluation techniques
    - model comprehensibility and explanation
    - practical application of predictive modeling in R programming language and environment
  - natural language processing
  - reinforcement learning
- practical use of theoretical knowledge on (almost) real-world problems
- awareness of domain expertise and ethical issues in data science
- increase the (mental) problem-solving toolbox with
  - predictive modeling techniques
  - evolutionary optimization approaches
  - reinforcement learning
  - Experiment design, result understanding, visualization and explanation approaches
- for a given prediction problem students shall be able to
  - transform it to a form suitable for predictive modeling
  - select and train an appropriate predictive model
  - evaluate the model and present the results in a comprehensible form and language.

Odd-one out

Concrete course goals

Be able to explain

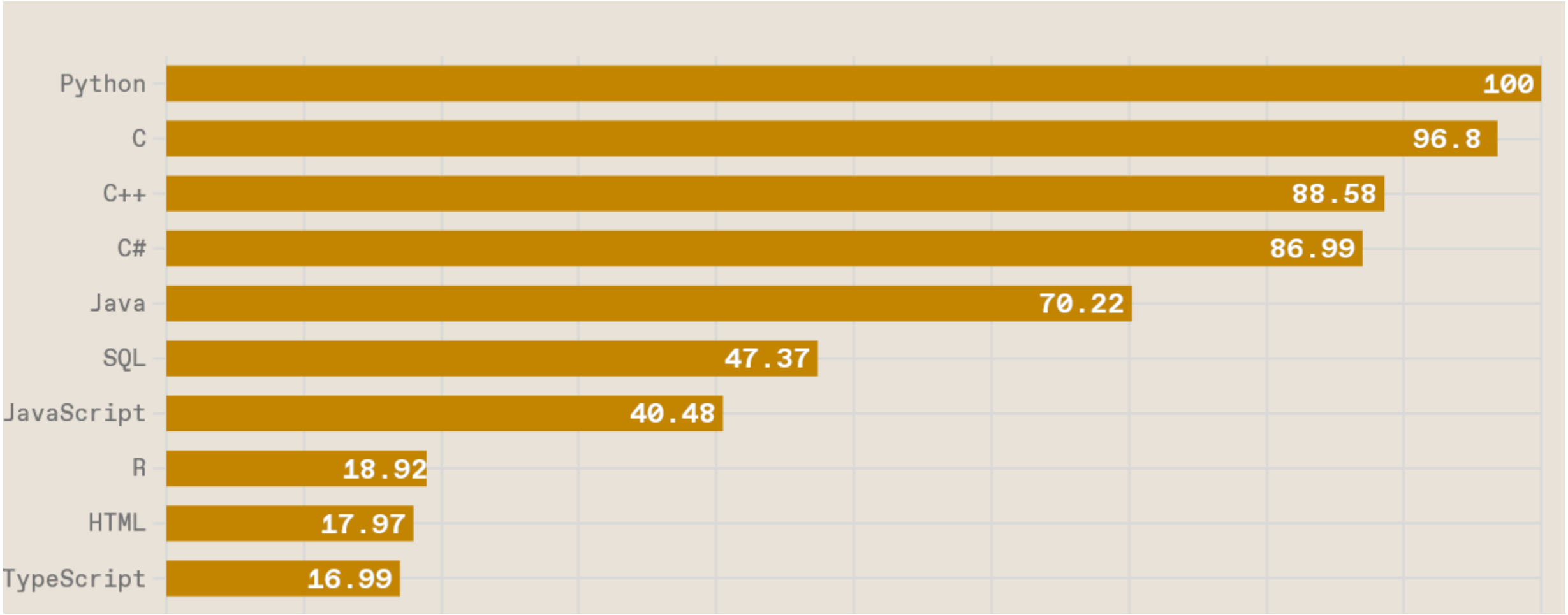
- difference between different types of machine learning models
- properties of models: bias, variance, generalization, hypothesis language
- properties of the following models: kNN, decision rules, bagging, boosting, random forests, stacking, SVM, neural networks
- properties and purpose of evaluation approaches and metrics: cross-validation, bootstrapping, ROC curves, sensitivity, specificity etc.
- inference methods for predictive methods and explanation of predictions
- when and why to apply reinfocement learning
- how to prepare and process text
- when and how and to optimize a problem using evolutionary algorithms

Build and evaluate models in R

- visualize datasets and created models
- prepare data into a suitable form for modeling algorithms
- apply classification and regression models to solve a prediction task with a given data set
- estimate error of models using statistically valid approaches
- select models and tune their parameters using cross-validation and bootstrapping
- visualize models and explain their predictions
- given a new dataset, select an appropriate modeling technique and evaluate the created model

Why R?

- IEEE Spectrum 2022 list of popular programming languages



Why R?

- [IEEE Spectrum 2019 list of popular programming languages]

Rank	Language	Type	Score
1	Python	web, desktop, server	100.0
2	Java	web, mobile, desktop	96.3
3	C	mobile, desktop, server	94.4
4	C++	mobile, desktop, server	87.5
5	R	desktop	81.5
6	JavaScript	web	79.4
7	C#	web, mobile, desktop, server	74.5
8	Matlab	desktop	70.6
9	Swift	mobile, desktop	69.1
10	Go	web, desktop	68.0

Syllabus explained

Nature inspired computing

- genetic algorithms
- genetic programming
- neuro-evolution
- automatic code generation

Introduction to statistical predictive modelling

- Learning as modelling: data, evidence, background knowledge, predictive models, hypotheses, learning as optimization, learning as search, criteria of success, inductive learning, generalization.
- Classification and regression: supervised and unsupervised learning, learning discrete and numeric functions, learning relations, learning associations.
- Simple classification models: nearest neighbor, decision rules

Model selection

- Bias and variance: error decomposition, trade-off, estimating bias and variance
- Generalization performance: training and testing set error, cross-validation, evaluation set, bootstrapping.
- Performance measures: confusion matrix, sensitivity and specificity, ROC curves, AUC, cost-based classification.
- Parameter tuning: regularization, MDL principle.
- Calibration of probabilities: binning, isotonic regression.
- No free lunch theorem.

Ensemble methods

- Model averaging, why ensembles work.
- Tree based ensembles: bagging, boosting, random forests.
- MARS and AODE ensembles.
- Stacking.

Kernel methods

- SVM for classification and regression: kernels, support vectors, hyperplanes.
- SVM for more than two classes: one vs. one, one vs. all.

Neural networks

- perceptron,
- backpropagation,
- RBF networks,
- setting structure of networks
- deep neural networks
- transformer architecture
- autoencoders
- GANs
- the role of embeddings

Explaining prediction models

- Model comprehensibility, visualization and knowledge discovery.
- General methodology for explaining predictive models.
- Model level and instance level explanations, methods SHAP, LIME, EXPLAIN, and IME.

Learning with special settings

- imbalanced data,
- multi-task learning,
- multi-label learning,
- Etc.

Reinforcement learning

- basics
- Markov decision problem
- Q learning
- Deep RL

Natural language processing

- text preprocesing
- text representation
- text similarity
- text classification
- sentiment analysis

Course organisation

Obligations

- 5 quizzes
- Two +1 projects, 50 points
- written exam, 50 points

Grading

Obligation	% of total	subject to
Five quizzes	0%	≥ 50% alltogether
Projects	50%	≥ 50% each
Written exam	50%	≥ 50%

Learning materials

- learning materials in eClassroom
- slides
- links to textbook and papers
- R code and examples
- links to data sets
- install the open-source systems R and RStudio

Readings

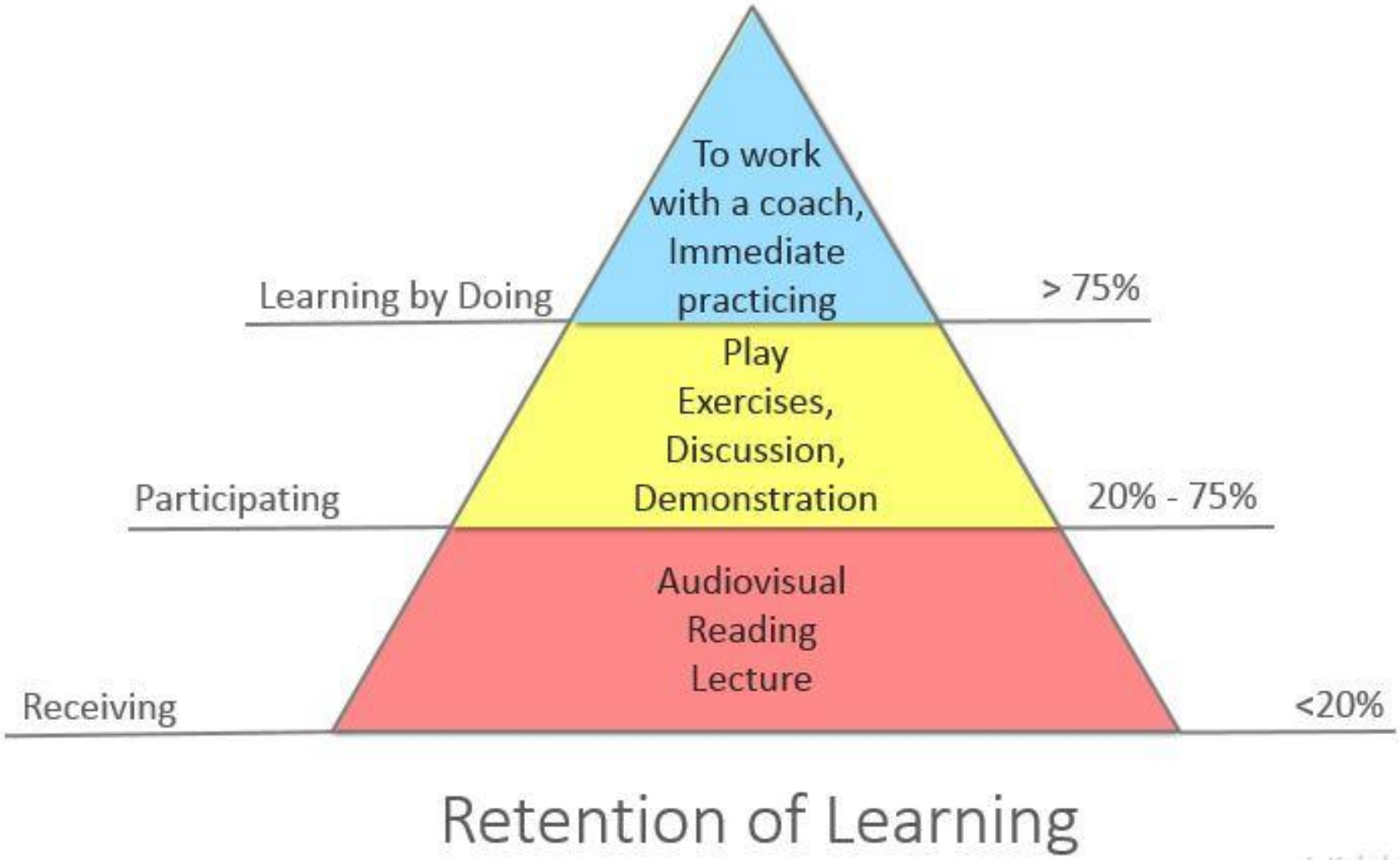
James, G., Witten, D. , Hastie, T. , and Tibshirani, R., 2021. *An introduction to statistical learning with applications in R, 2nd edition*. New York: Springer.

- Freely available at https://www.statlearning.com/
- code and slides from authors and Abbass Al Sharif (some used in this course)

Further readings:

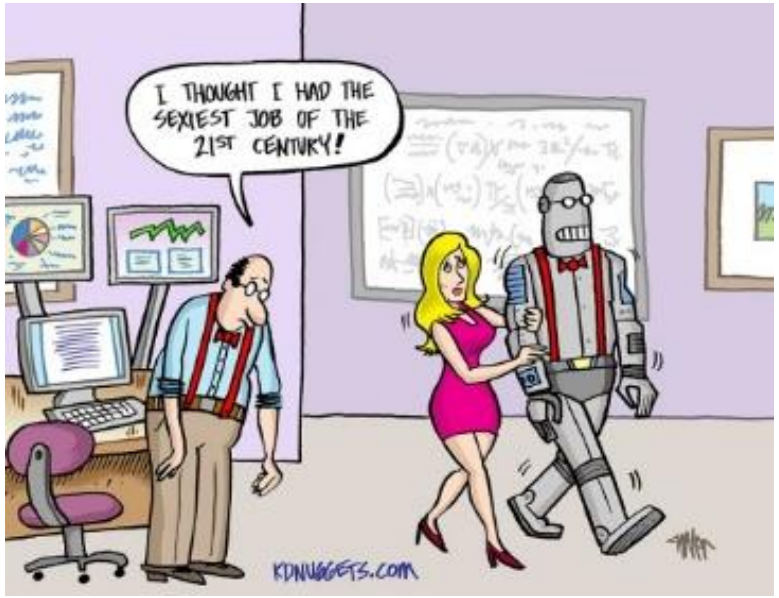
- Friedman, J., Hastie, T., & Tibshirani, R., 2009). *The elements of statistical learning, 2nd edition*. Springer, Berlin, freely available from https://web.stanford.edu/~hastie/ElemStatLearn/
- Ian Goodfellow, Yoshua Bengio, and Aaron Courville (2016). *Deep Learning*. MIT press, freely available from authors' homepages
- François Chollet (2017). Deep Learning with Python. Manning.
- Kononenko, I., Robnik-Šikonja, M.: Inteligentni sistemi. Založba FE in FRI, 2010 (in Slovene)
- scientific papers
- many excellent machine learning and data mining courses on Coursera and edX

BTW: retention of learning



Data Science

- good job perspective
- Forbes list of the most promising jobs in the USA in 2022
- Thomas H. Davenport, D.J. Patil: Data Scientist: The Sexiest Job of the 21st Century. *Harvard Business Review*, October 2012



Jobs	Job Satisfaction	Number of Job Openings	Median Base Salary
Enterprise Architect	4	14.021	$144,997
Full Stack Engineer	4	11.252	$101,794
Data Scientist	4	10.071	$120,000
Devops Engineer	4	8.548	$120,095
Strategy Manager	4	6.977	$140,000
Machine Learning Engineer	4	6.801	$130,489
Data Engineer	4	11.821	$113,960
Software Engineer	4	64.155	$116,638
Java Developer	4	10.201	$107,099
Product Manager	4	17.725	$125,317
Back End Engineer	4	6.221	$112,384
Cloud Engineer	4	10.689	$118,999

MODERN DATA SCIENTIST

Data Scientist, the sexiest job of the 21th century, requires a mixture of multidisciplinary skills ranging from an intersection of mathematics, statistics, computer science, communication and business. Finding a data scientist is hard. Finding people who understand who a data scientist is, is equally hard. So here is a little cheat sheet on who the modern data scientist really is.

MATH & STATISTICS

- Machine learning
- Statistical modeling
- Experiment design
- Bayesian inference
- Supervised learning: decision trees, random forests, logistic regression
- Unsupervised learning: clustering, dimensionality reduction
- Optimization: gradient descent and variants

PROGRAMMING & DATABASE

- Computer science fundamentals
- Scripting language e.g. Python
- Statistical computing packages, e.g., R
- Databases: SQL and NoSQL
- Relational algebra
- Parallel databases and parallel query processing
- MapReduce concepts
- Hadoop and Hive/Pig
- Custom reducers
- Experience with xaaS like AWS

DOMAIN KNOWLEDGE & SOFT SKILLS

- Passionate about the business
- Curious about data
- Influence without authority
- Hacker mindset
- Problem solver
- Strategic, proactive, creative, innovative and collaborative

COMMUNICATION & VISUALIZATION

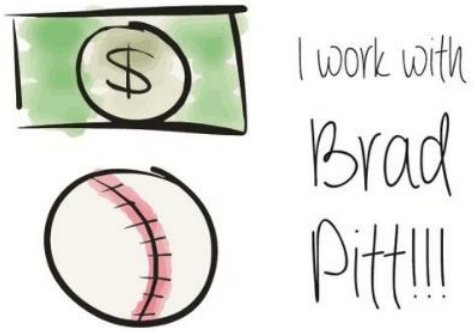
- Able to engage with senior management
- Story telling skills
- Translate data-driven insights into decisions and actions
- Visual art design
- R packages like ggplot or lattice
- Knowledge of any of visualization tools e.g. Flare, D3.js, Tableau

DATA SCIENTIST

What my **CUSTOMERS** think I do

What my **MUM** thinks I do

What my **FRIENDS** think I do



What my **HUSBAND** thinks I do

What **I** think I do

What I **ACTUALLY** do

Intelligent systems and media

Will robots destroy us?

Will they take our jobs?

Will we still need a driving licence?

Will we still need doctors?

How will humanoid robots evolve?

What about cyborgs?

What is artificial general intelligence?

What is technological singularity?

New prophets of tehnological singularity

Elon Musk says humans must become cyborgs to stay relevant. Is he right?

Sophisticated artificial intelligence will make 'house cats' of humans, claims the entrepreneur, but his grand vision for mind-controlled tech may be a long way off

Some scientific responses

- Rodney Brooks: The Seven Deadly Sins of Predicting the Future of AI. https://rodneybrooks.com/the-seven-deadly-sins-of-predicting-the-future-of-ai/ also in MIT Technology Review

- Marko Robnik-Šikonja: Is artificial intelligence a (job) killer?. The Conversation, Jul. 2017 https://theconversation.com/is-artificial-intelligence-a-job-killer-80473

- …

Short history of optimism

- starting in 1950s,
  1956 Dartmouth conference
- great expectations, enormous underestimation
  of problem difficculty
- AI winter (2 x)

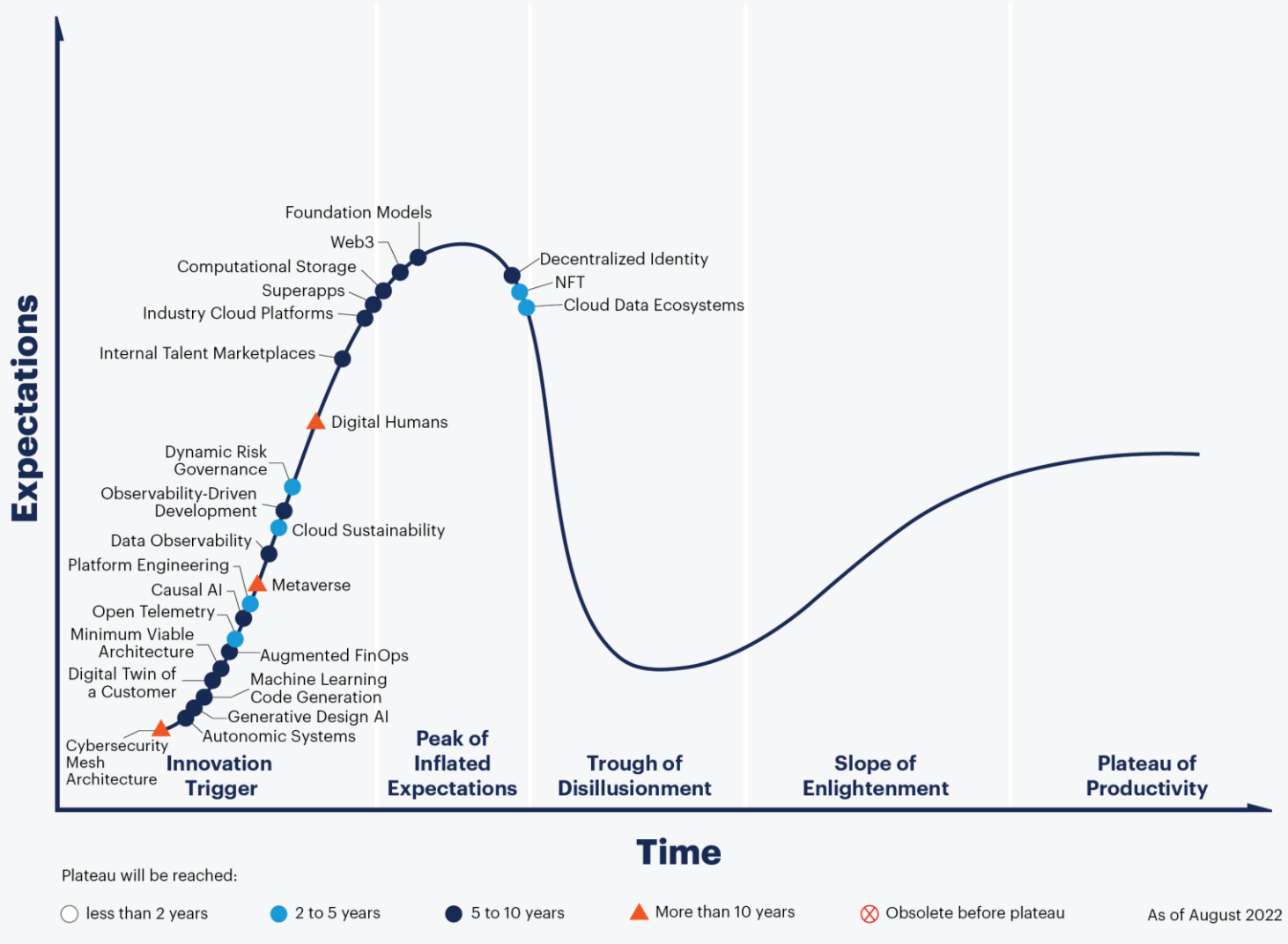
1958, H. A. Simon and Allen Newell: “… within ten years a digital computer will discover and prove an important new mathematical theorem.”

1965, H. A. Simon: “… machines will be capable, within twenty years, of doing any work a man can do.”

1967, Marvin Minsky: "Within a generation ... the problem of creating 'artificial intelligence' will substantially be solved.”

1970, Marvin Minsky: "In from three to eight years we will have a machine with the general intelligence of an average human being."

Hype Cycle for Emerging Tech, 2022



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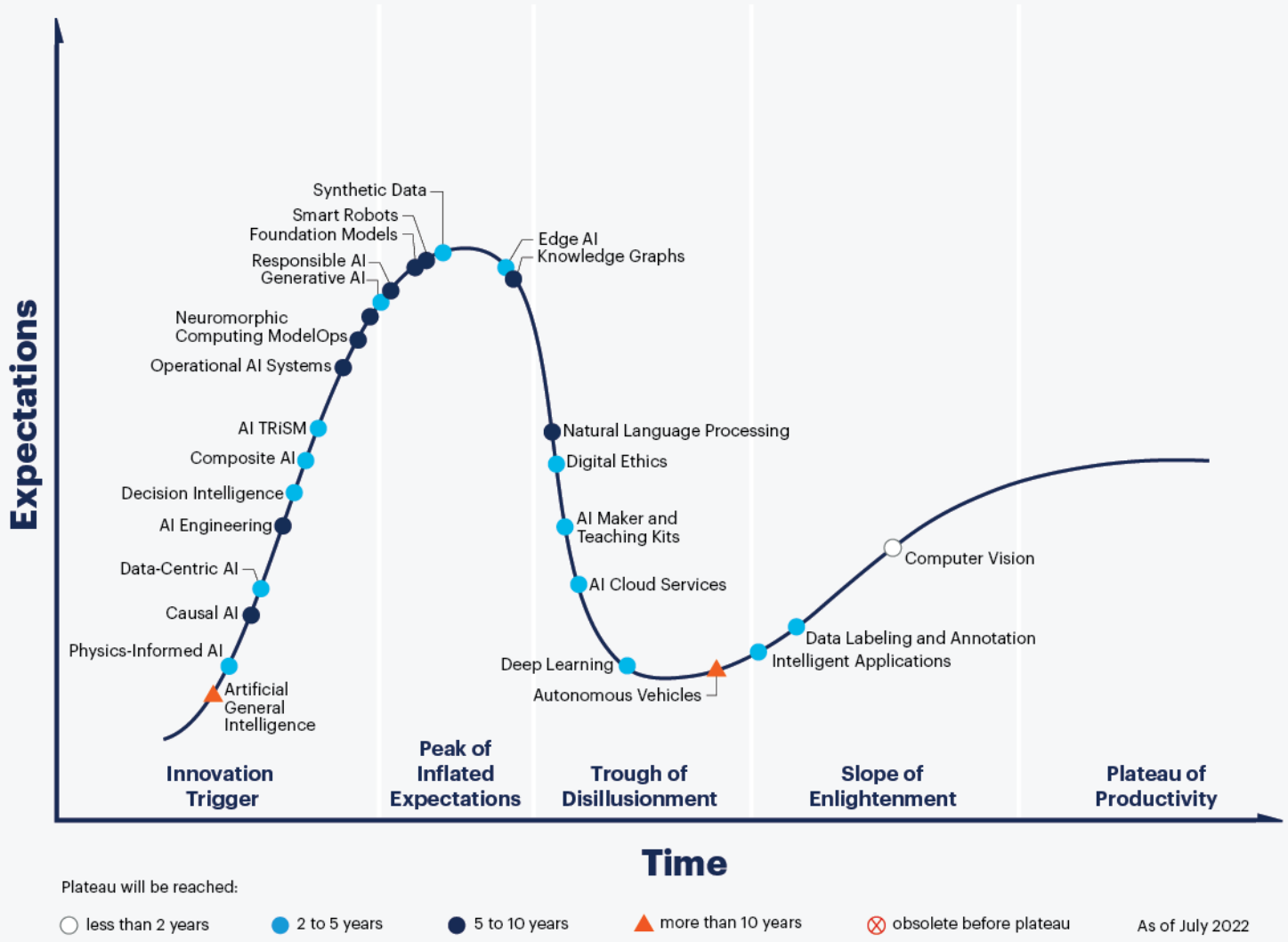
Hype Cycle for Artificial Intelligence, 2022



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