Artificial Intelligence and Machine Learning (AIML)

2023–24

Who's who

Lecturers

- **Max Little** (me) littlemz@bham.ac.uk, Module Lead and Lecturer (Part I+II); office hours Tuesdays 1.30pm-3.30pm, weeks 1-4, please email in advance to arrange
- **Rickson Mesquita** r.c.mesquita@bham.ac.uk, Lecturer (Part III), office hours TBA
- **Ruchit Agrawal** r.r.agrawal@bham.ac.uk , Lecturer (Dubai), office hours TBA

TAs

- Feifei Zheng fxz156@student.bham.ac.uk
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- Omer Eryilmaz obe851@student.bham.ac.uk
- Xi He xxh164@student.bham.ac.uk

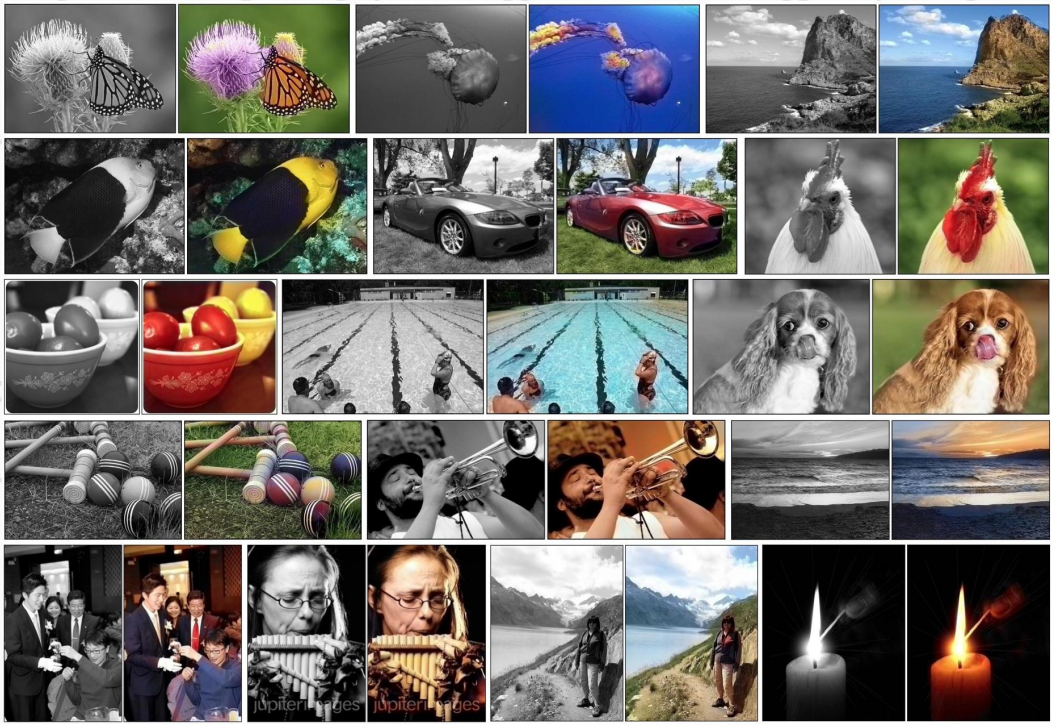
Part I: Module introduction

- AI and ML address challenging real-world problems which require the **manipulation** or **processing** ("computation") of **information** ("data") in some way, to come up with **rational decisions** given this information
- In principle, all these problems could be solved **manually**, but humans, unless paying careful attention, easily make **mistakes** or get **tired**; so this is not practical for many problems
- In principle, all these problems could be solved by **exhaustively** generating all possible solutions and testing them out one-by-one to select the best solution, or storing **all possible** input-output relationships in memory, but this is usually infeasible

Cutting edge applications

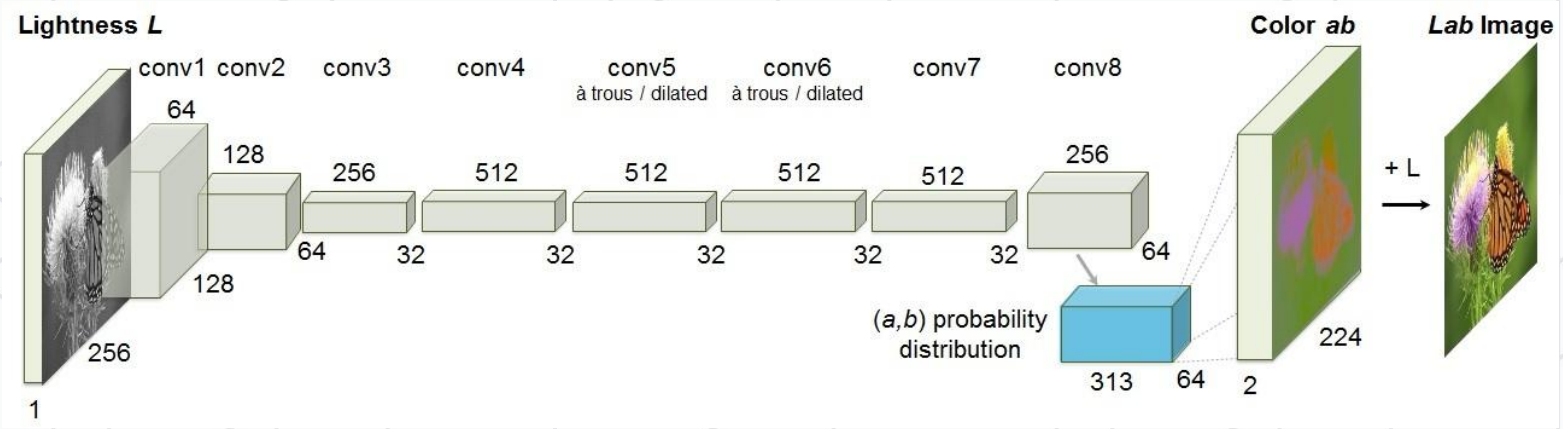
- **Photorealistic image rendering** (StableDiffusion, DALL.E)
- **Protein structure prediction** (AlphaFold, RosettaFold)
- **Software coding assistant** (GitHub Copilot)
- **Stable crystal discovery** (GNoME)
- **Breast cancer image reading assistant** (Kheiron Medical)
- **Music track separation** (RipX AI DAW)

Real-world applications: image colorization



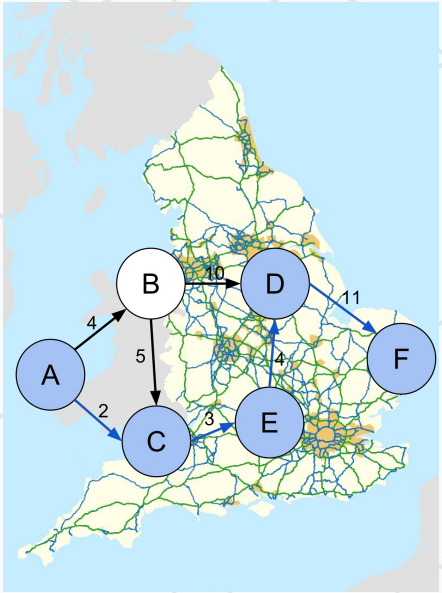
http://richzhang.github.io/colorization/

Real-world applications: image colorization

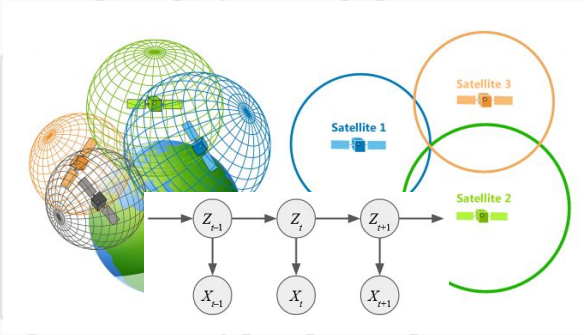


Learned input-output mapping function
(deep convolutional image ML)

Real-world applications: GPS navigation

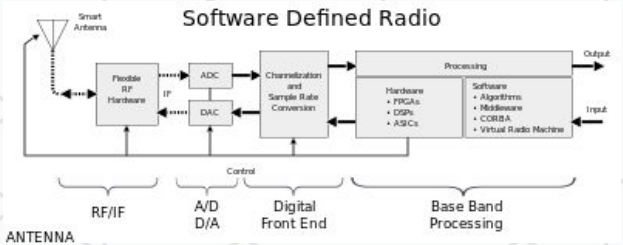


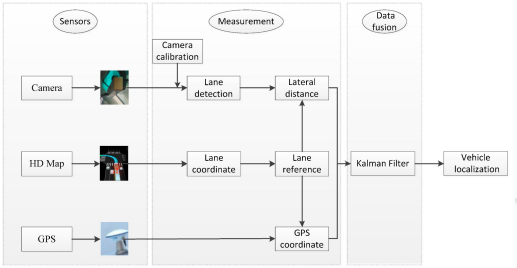
Plan/update optimal route
(shortest path-finding AI)



Track GPS position
(probabilistic ML)

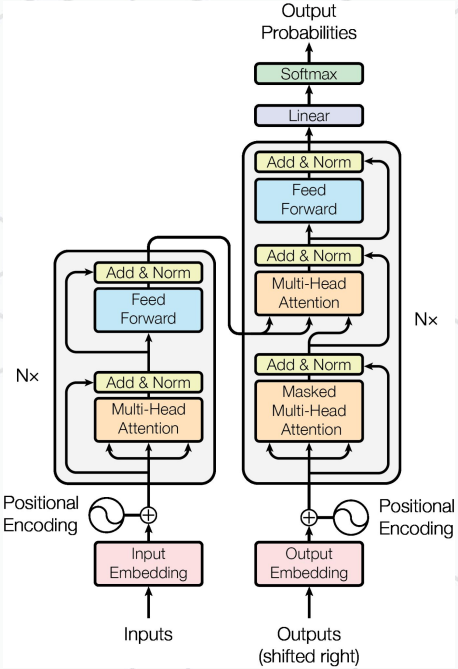
Download traffic updates
(software digital radio)





Locate on road network
(geoinformatics)

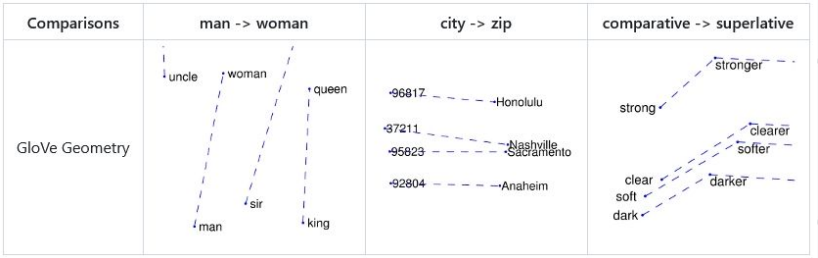
Real-world applications: language translation



https://paperswithcode.com/method/transformer

Sequence-to-sequence prediction
(deep learning ML)

https://github.com/stanfordnlp/GloVe



Word vector embeddings
(natural language processing)

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References and further reading

- ❏ **R&N**, Section 1.1
- ❏ **MLSP**, Preface
- ❏ **PRLM**, Section 1 (up to start of Section 1.1)

Course contents

Part I: Introduction

- ❏ Module overview
- ❏ Essential mathematical background

Part II: Symbolic AI

- ❏ Combinatorial optimization
- ❏ Exact combinatorial algorithms
- ❏ Dynamic programming
- ❏ Approximate combinatorial algorithms
- ❏ Simulated annealing
- ❏ Logic

Part III: Machine learning

- ❏ Gradient descent
- ❏ Clustering and K-means
- ❏ Classification
- ❏ The perceptron
- ❏ Neural networks and deep learning
- ❏ Automatic differentiation
- ❏ Probability and probabilistic graphical models
- ❏ Bayesian models
- ❏ Sequential problems and hidden Markov models
- ❏ Other sequential models

How to study this course

- **Lecture notes**: Summary of entire course contents, in sections. Advisable: read notes as early as possible, preferably before the start of the relevant week
- **Lectures** and **lecture recordings**: Attend each week in person, recordings available after the lecture
- **Textbooks**: Read suggested sections of reference material
- **Tutorial questions**: Practice hand calculations, study under supervision in tutorial session
- **Python lab exercises**: Computational exercises, exploration is key. Run code, vary data and parameters, check understanding against expectations. Attempt challenge coding questions

Study materials: overview

- **Lecture notes**: Available now
- **Lecture slides**: Updated each week
- **Lecture recordings**: Updated each week
- **Tutorial questions**: Available now
- **Python lab exercises**: Available now
  https://jupyterhub.oc1.aws.cs.bham.ac.uk
- **Mock exam paper**: Available before Easter break
- **Coursework assignment**: Released week 9, due week 10,
- **Reference reading list**: See link in Canvas page
- All materials through Canvas:
  https://canvas.bham.ac.uk/courses/73004

Assessment

Exam (80% of marks)

- General course knowledge (concepts and their significance, terminology), anything from the module
- Specific knowledge of particular algorithms
- Ability to perform certain computations (e.g. run a Bellman recursion or K-means for a handful of iterations, solve a small logical inference problem)
- Demonstrate ability to analyze results and interpret them in context
- General and specific knowledge from **reference textbooks**, **lecture notes**, attending **lectures**; analytical skills obtained from **tutorials**

Coursework (20% of marks)

- Demonstrate coding of a specific algorithm, submitted as Python file
- Computational/coding skills obtained from **Python lab exercises**

Timetable

Week	Lecture 1: Tuesday 12-1, Aston Webb Main Lecture Theatre	Lab/tutorial sessions: Thursday 1-3 and Friday 2-4, CS UG04	Lecture 2: Friday 12-1, Haworth Room 101
1 (Jan 15)	S1 Introduction	General Python coding practice, General maths practice	S2 Background maths
2 (Jan 22)	S3 Combinatorial optimization	Ex3, S3, S4	S4 Exact algorithms
3 (Jan 29)	S5 Dynamic programming	Ex4, Ex5, S5, S6	S6 Approximate algorithms
4 (Feb 5)	S7 Simulated annealing	Ex6, S7, S8	S8 Logic
5 (Feb 12)	S9 ML and gradient descent	Ex8, Ex9, S9, S10	S10 Clustering
6 (Feb 19)	Consolidation	Consolidation	Consolidation
7 (Feb 26)	S11 Classification	Ex10, S11, S12	S12 The perceptron
8 (Mar 4)	S13 Deep learning	Ex12, Ex13, S13, S14	S14 Automatic differentiation
9 (Mar 11)	S15 Probability and PGMs	Ex14, Ex15, S15, S6, CW released	S16 Bayesian models
10 (Mar 18)	S17 HMMs	Ex16, Ex17, S17, S18, CW due	S18 Sequential models
11 (Apr 22)	Mock exam walkthrough	Python coding revision	Mock exam walkthrough

Reading list

AI textbooks

- **R&N**: Russell and Norvig, 2010, *Artificial Intelligence: A Modern Approach*, 3rd Edition/4th Edition, Prentice Hall
- **CLRS**: Cormen, Leiserson, Rivest and Stein, 2022, *Introduction to Algorithms*, 4th Edition, The MIT Press

ML textbooks

- **PRML**: Bishop, 2006, *Pattern Recognition and Machine Learning*, Springer
- **MLSP**: Little, 2019, *Machine Learning for Signal Processing*, Oxford University Press
- **H&T**: Hastie and Tibshirani, 2008, *The Elements of Statistical Learning*, 2nd Edition, Springer

Extended reading list

AI textbooks

- Kleinberg and Tardos, 2006, *Algorithm Design*, Pearson/Addison-Wesley
- Papadimitriou and Steiglitz, 1998, *Combinatorial Optimization*, Dover Books

ML textbooks

- Murphy, 2012, *Machine Learning: A Probabilistic Perspective*, The MIT Press

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Background mathematics textbooks

- **Gill**, 2006, *Essential Mathematics for Political and Social Research*, Cambridge University Press
- **Stirzaker**, 2003, *Elementary Probability*, Cambridge University Press
- **Strang**, 1991, *Calculus*, Wellesley-Cambridge Press