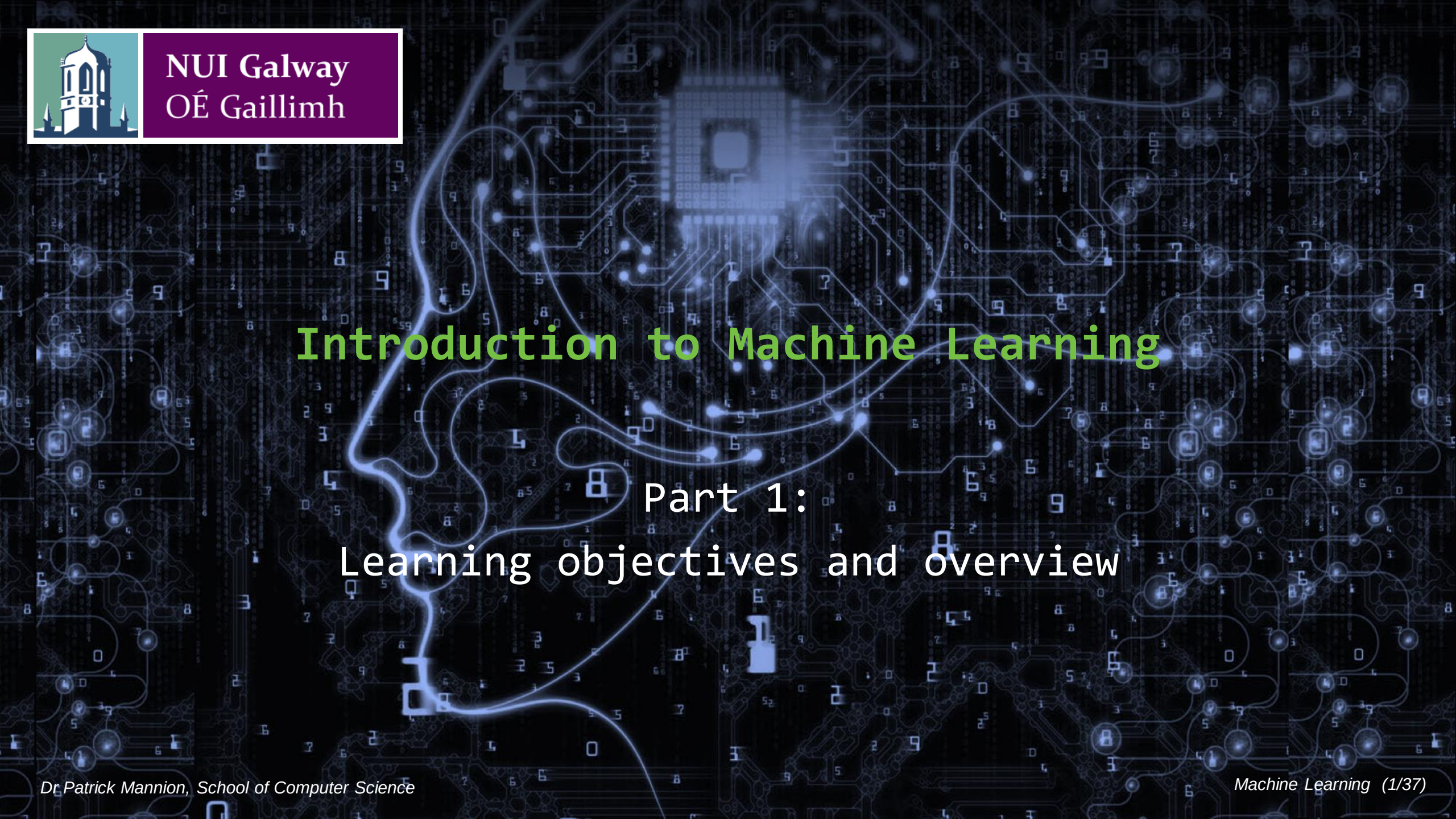

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Introduction to Machine Learning

Part 1:
Learning objectives and overview

Dr Patrick Mannion, School of Computer Science

Learning objectives for this section

Having completed this section successfully, you will be able to …

1. Discuss definitions of Machine Learning
2. Describe what major categories of ML task entail: classification, regression, clustering, relationship discovery and reinforcement learning
3. Discuss the relationship with Data Mining
4. Explain the Data Mining process
5. Consider current and future applications of Machine Learning and Data Mining

Prerequisites

- This is for students who already have a degree or substantial experience in computer science, software development or a closely related subject area

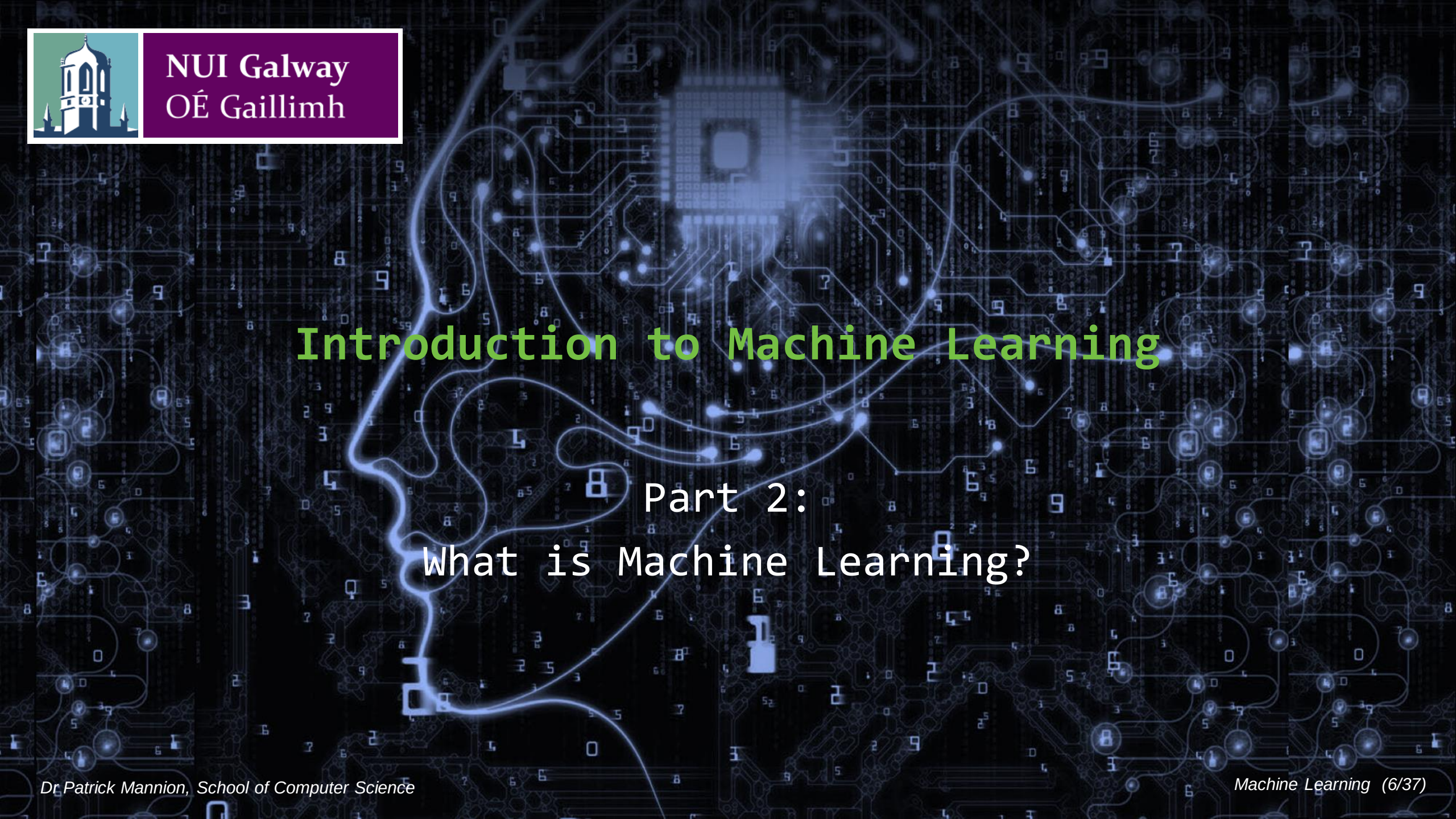
- You need to understand:
  - How to program (any language)
  - Algorithm analysis
  - Basic statistics and probability
  - Knowledge of standard mathematical notation (i.e. how to read an equation)

Resources

- Course slides:
  - Necessary but insufficient!
- Recommended books:
  - List available on Blackboard
  - Will also provide references in individual sections
- Others:
  - Andrew Ng's Coursera Machine Learning Course
  - Sebastian Thrun's Udacity AI Course
  - Contributions welcome!
    If you find useful links, email them either to me (patrick.mannion@nuigalway.ie) or to Prof Michael Madden (michael.madden@nuigalway.ie).

Overview of topic

1. Learning objectives and overview
2. What is Machine Learning?
3. Types of Machine Learning task
4. Overview of Data Mining
5. Applications of Machine Learning



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Introduction to Machine Learning

Part 2:
What is Machine Learning?

What is Machine Learning? [1]

- Samuel, 1959:
  - "Field of study that gives computers the ability to learn without being explicitly programmed"

- Witten & Frank, 1999:
  - Learning is changing behaviour in a way that makes performance better in the future

Arthur Samuel, 1901-1990

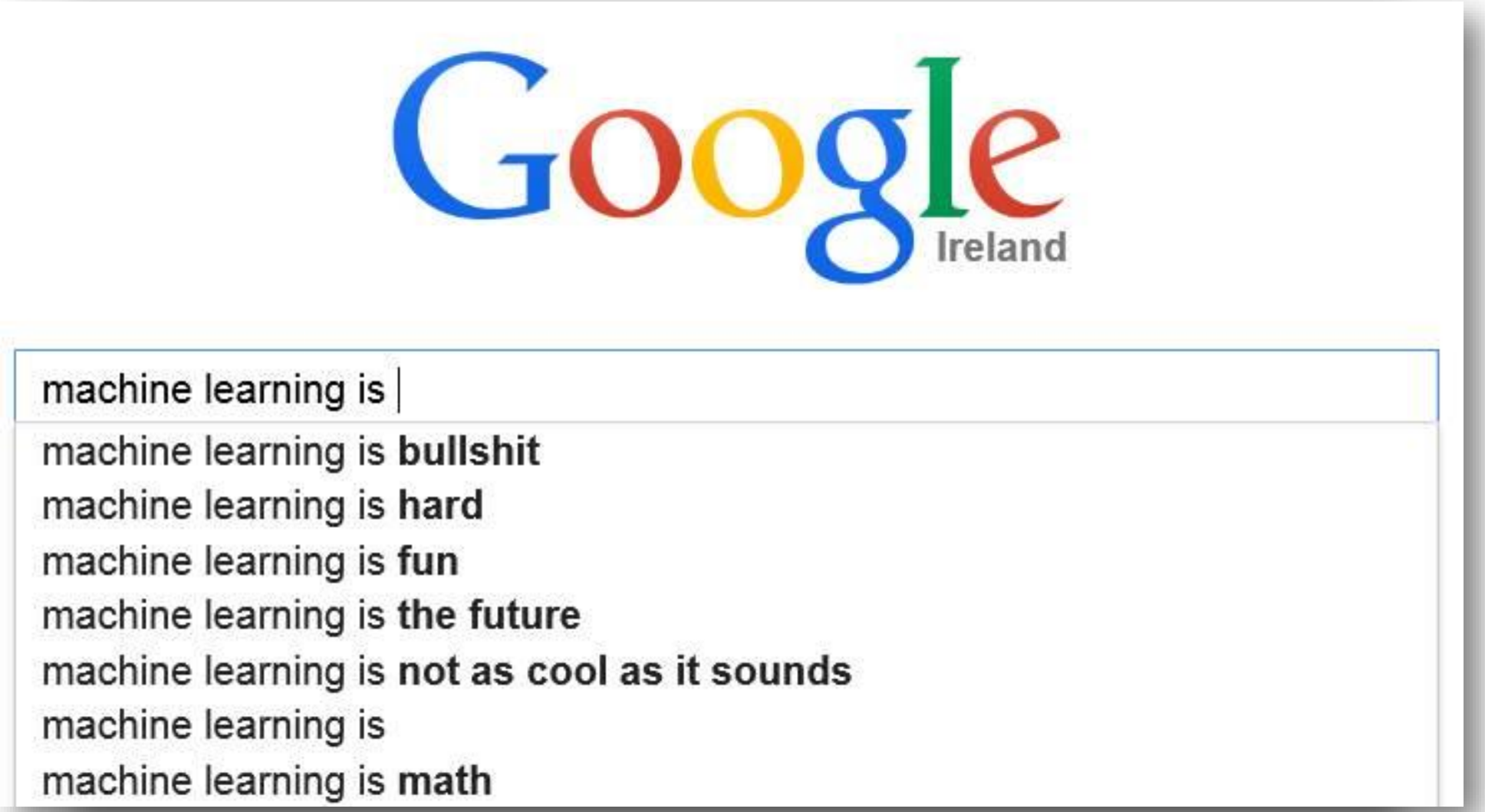
Image source: http://www.computer.org/portal/web/awards/cp-samuel

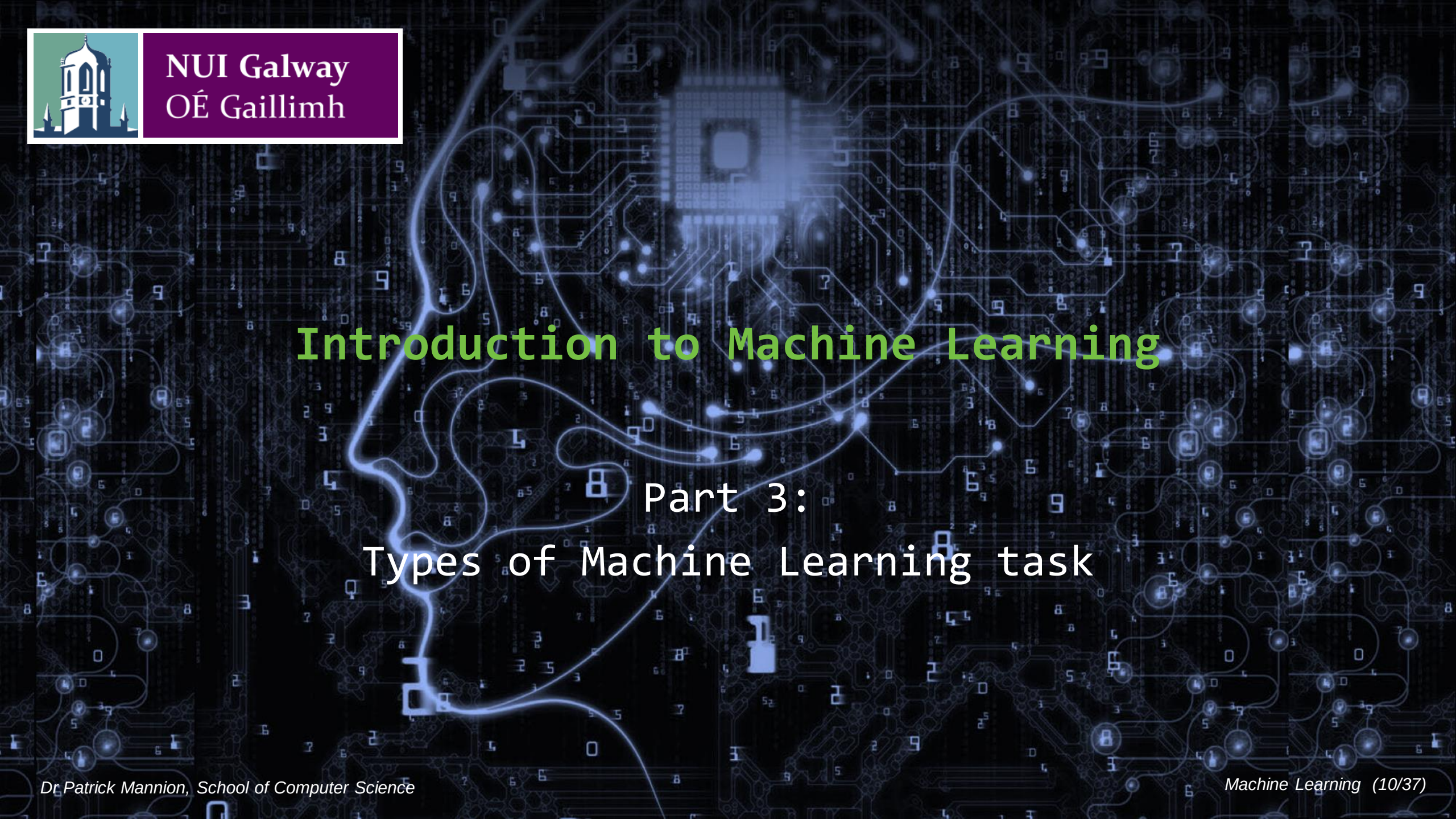
What is Machine Learning? [2]

- Mitchell, 1997:
  - Improvement with experience at some task
  - A well-defined ML problem:
    - Improve over task *T*
    - wrt performance measure *P*
    - based on experience *E*
  - For draughts/checkers example, what are T, P, E?

- Other possible definitions
  - Philosophical and psychological considerations …
  - Relationship to Artificial Intelligence generally …
  - Artificial Intelligence ≠ Machine Learning ≠ Deep Learning
  - **Artificial Intelligence ⊋ Machine Learning ⊋ Deep Learning**

What is Machine Learning? [3]





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Introduction to Machine Learning

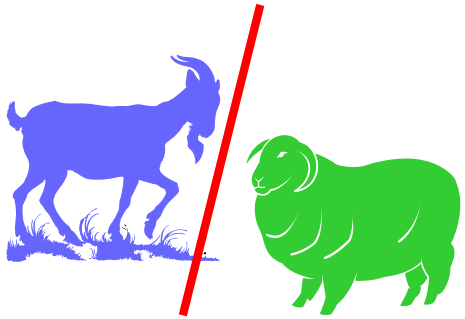
Part 3:
Types of Machine Learning task

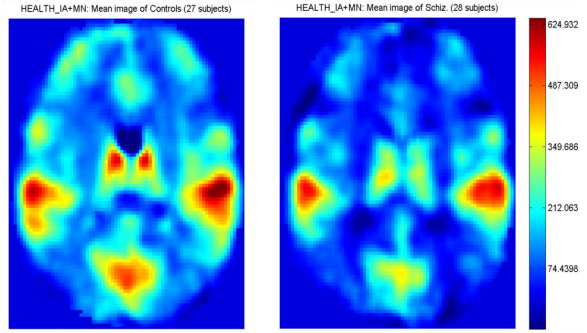
Machine Learning techniques

- Supervised learning
- Unsupervised learning
- Semi-supervised learning
- Reinforcement learning

Major Types of Task [1]

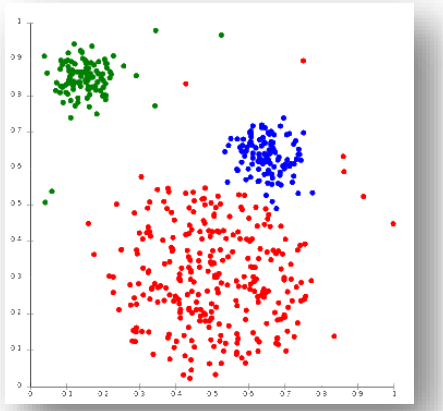
1. **Classification**





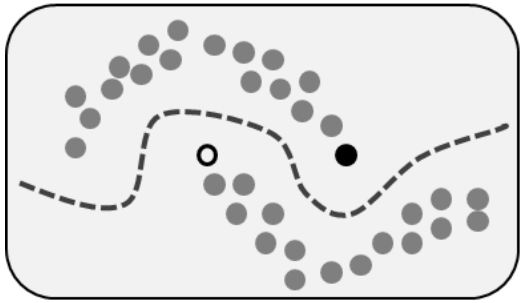
2. **Regression**

3. **Clustering**



Major Types of Task [2]

4. Co-Training



5. Relationship Discovery

beer <=> diapers

6. Reinforcement Learning

Techniques for these Tasks

- Classification
  Decision trees, SVMs
- Regression
  Linear Regression, Neural nets; k-NN
  (good for Classification too)

Supervised

- Clustering
  k-Means, EM-clustering
- Relationship Discovery
  Association Rules; Bayesian nets

Unsupervised

- Learning From Part-Labelled Data
  Co-Training; Transductive Learning
  [Combines ideas from clustering & classification]

Semi-supervised

- Reinforcement Learning
  Q-Learning, SARSA

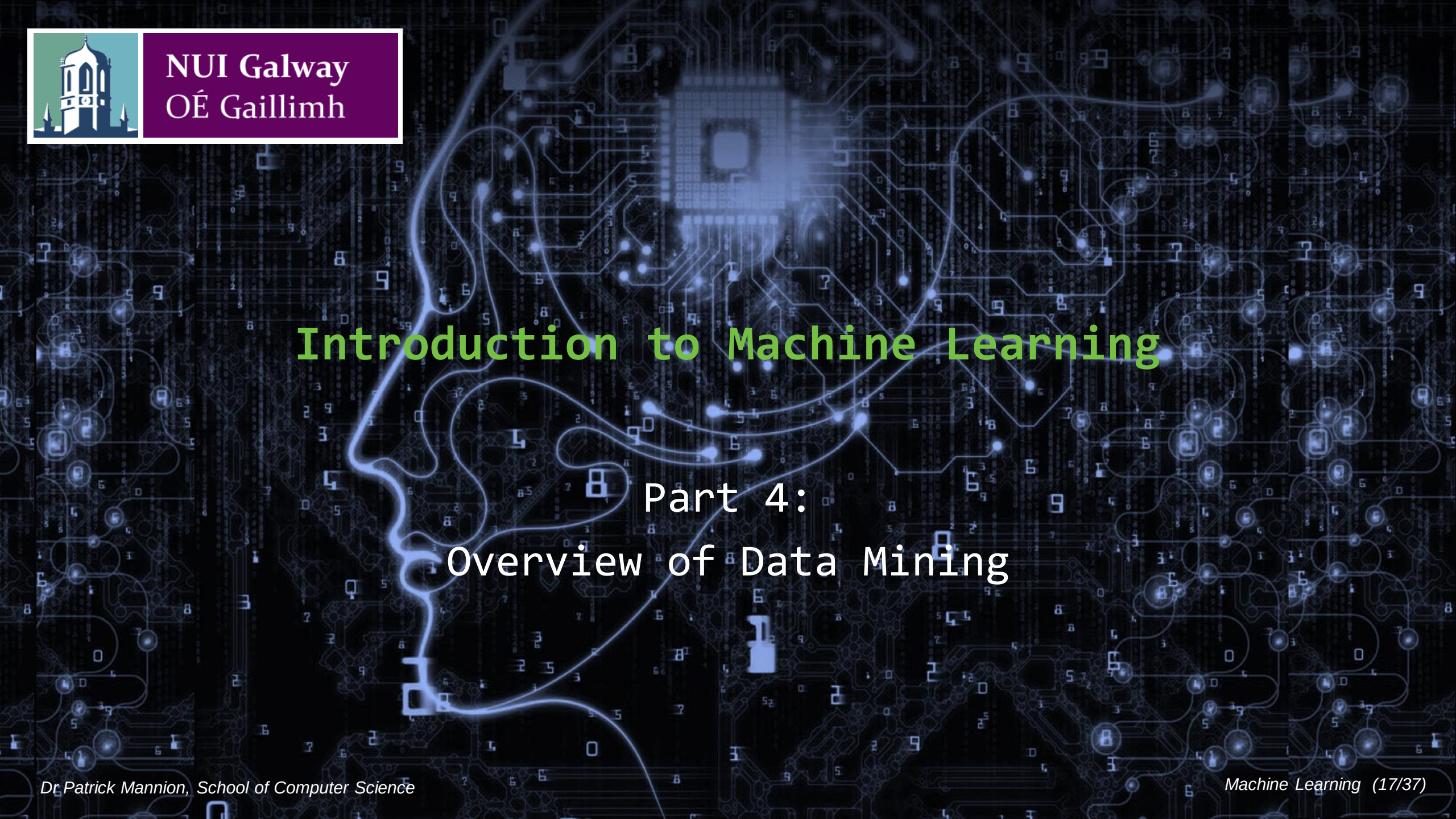
Reward-based

What do these have in common?

- In all cases, machine searches for a hypothesis that best describes the data presented to it
- Choices to be made:
  - How is hypothesis expressed?
    mathematical equation, logic rules, diagrammatic form, table, parameters of a model (e.g. weights of an ANN), …
  - How is search carried out?
    systematic (breadth-first or depth-first),
    heuristic (most promising first), …
  - How do we measure quality of hypothesis?
  - What is appropriate format for data?
  - How much data is required?

What else to we need to know about?

- To apply ML:
  - How to formulate a problem
  - How to prepare the data
  - How to select an appropriate algorithm
  - How to interpret the results
- To evaluate results and compare methods:
  - Separation between training, testing & validation
  - Performance measures:
    simple metrics, statistical tests, graphical methods
  - To improve performance
  - Ensemble methods
  - Theoretical bounds on performance



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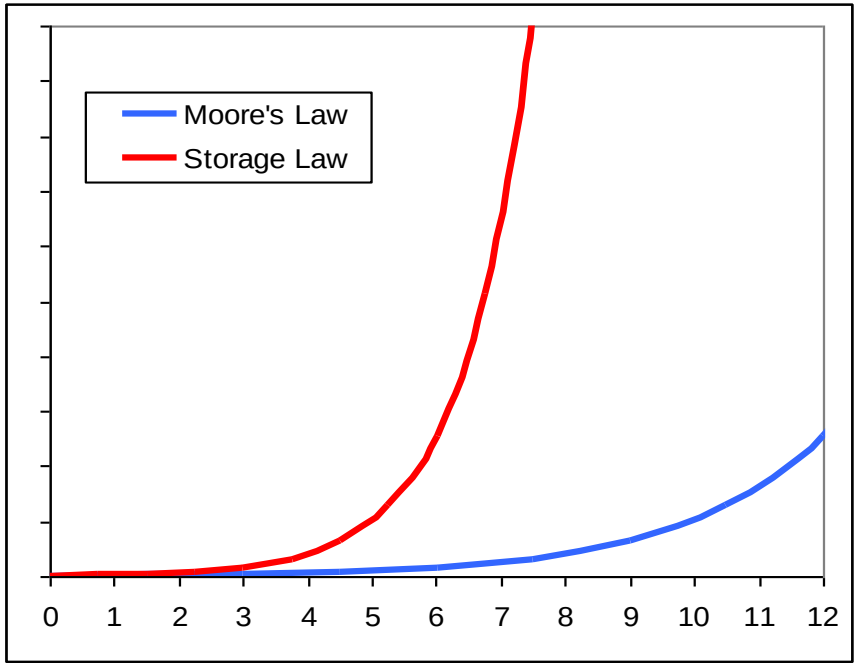
Introduction to Machine Learning

Part 4:
Overview of Data Mining

Data Mining: What's the Link?

- Data Mining:
  - Extract interesting knowledge from large unstructured datasets
  - non-obvious / comprehensible / meaningful / useful
- Storage Law (Fayyad & Uthurusamy, Comms.ACM 2002)
  - Storage capacity doubling every year
  - Faster than Moore's law
  - Result: write-only "data tombs"
- Developments in ML essential to be able to process and exploit this lost data



Big Data

Data sets of scale and complexity such that they can be difficult to process using current standard methods

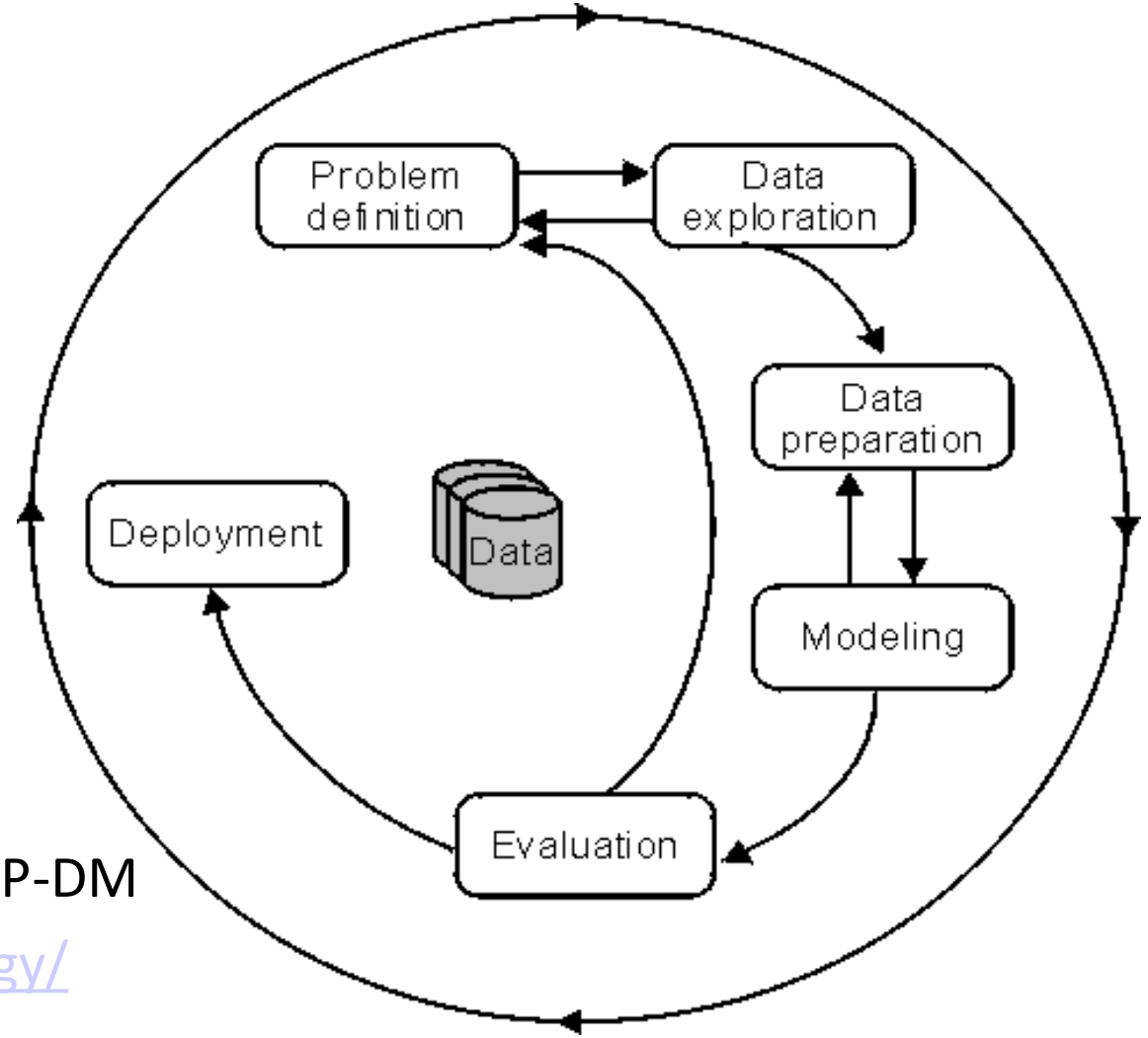
- Standard DB tools & data management apps
- Moving target

Big Data

- Data scale dimensions (One or more of “3 Vs”):
  - **Volume**: terabytes and up
  - **Velocity**: from batch to streaming data
  - **Variety**: numeric, video, sensor, unstructured text …
- Fashionable to add others that are not key …
  - Veracity: quality & uncertainty associated with items
  - Variability: change / inconsistency over time
  - Value: for the organisation
- Key techniques:
  - Sampling; inductive learning; clustering; associations
  - Distributed programming methods

CRISP-DM Data Mining Process

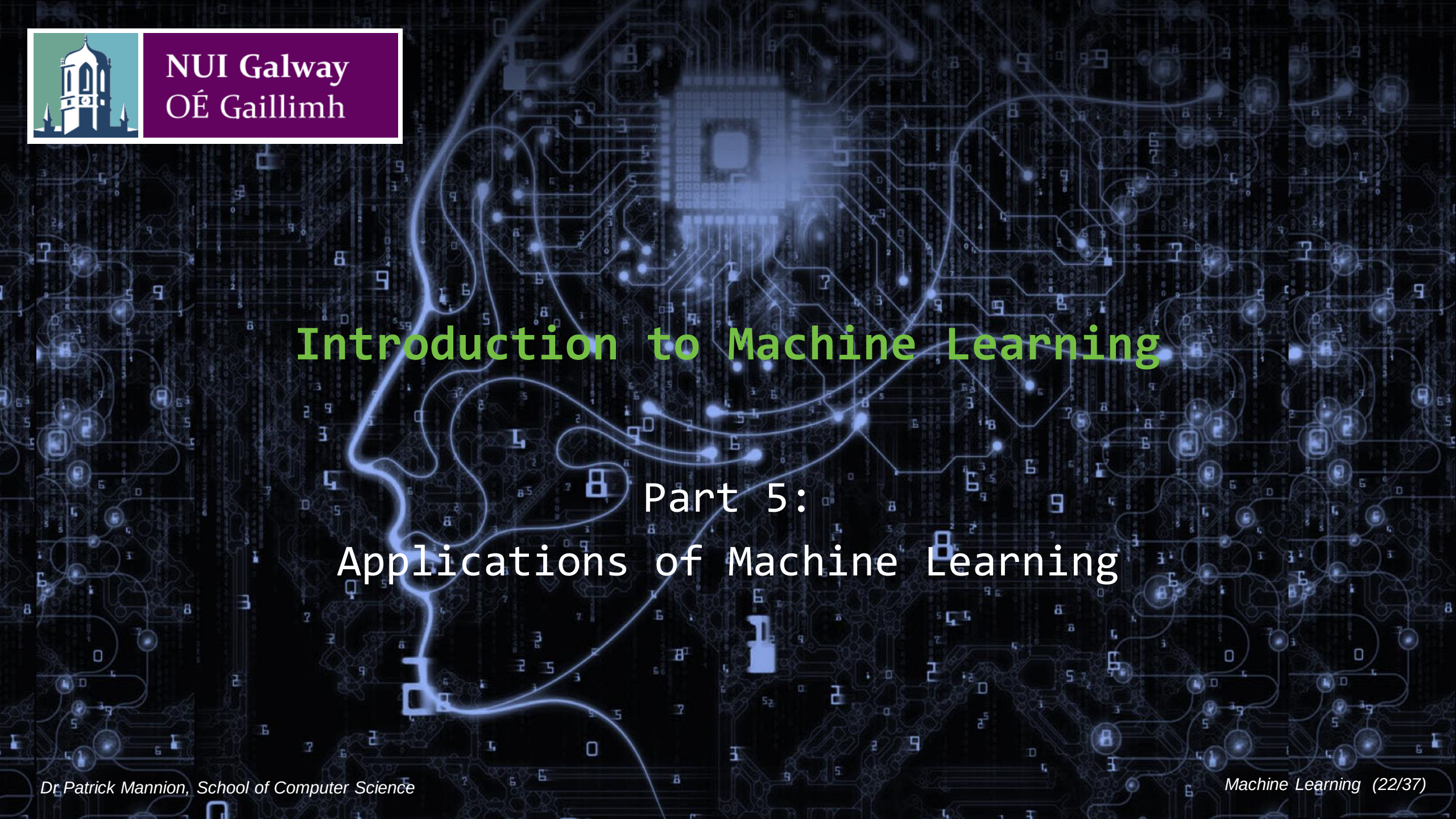
- Problem Definition
- Data Exploration
- Data Preparation
- Modelling
- Evaluation
- Deployment



Cross Industry Standard Process for
Data Mining (CRISP-DM) process model

This link gives a summary of the main steps in CRISP-DM

https://www.sv-europe.com/crisp-dm-methodology/



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Introduction to Machine Learning

Part 5:
Applications of Machine Learning

Current & Emerging Applications

Any ideas?

What companies use ML & DM?

Users of ML & DM

amazon

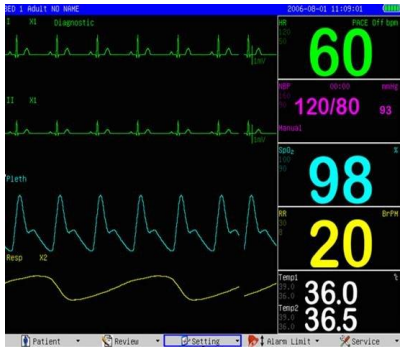
NETFLIX

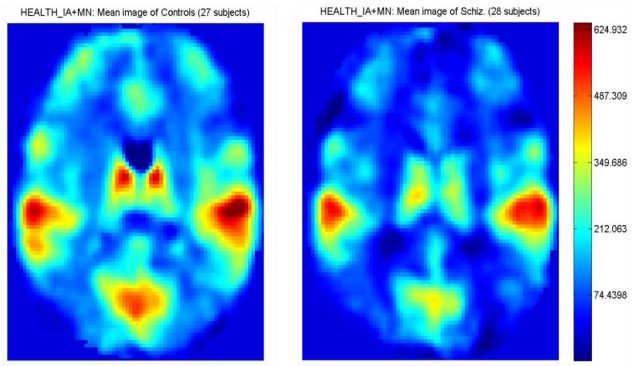
Microsoft

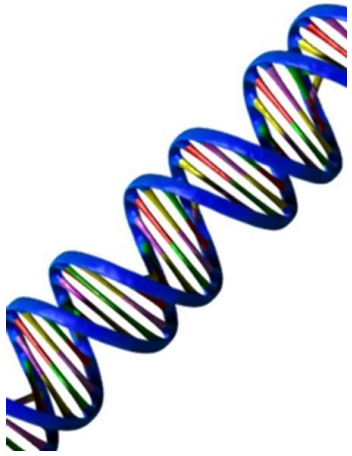
YAHOO!

facebook

Google







High-Profile Examples ...

Forbes, 16 Feb 2012
http://www.forbes.com/sites/kashmirhill/2012/02/16/how-target-figured-out-a-teen-girl-was-pregnant-before-her-father-did/

How Netflix is turning viewers into puppets

"House of Cards" gives viewers exactly what Big Data says we want. This won't end well

BY ANDREW LEONARD

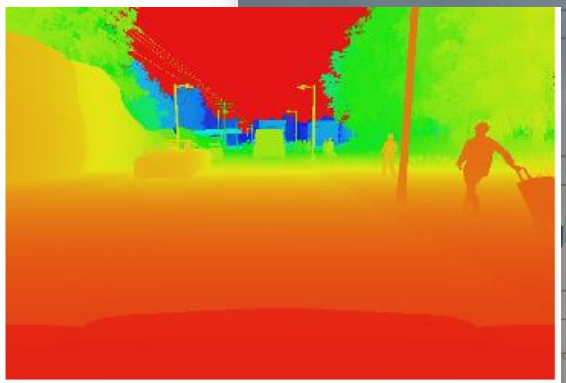
House of Cards (BBC, 1990)

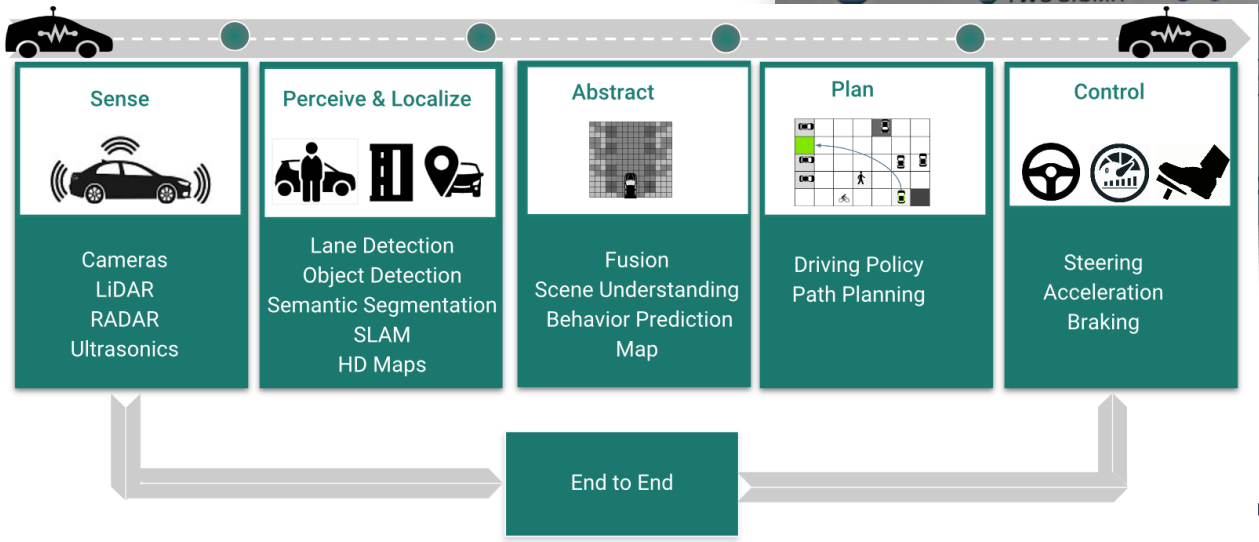
- ⇔ ★ ★ ★ ★ ★
- ⇔ Kevin Spacey (Actor)
- ⇔ David Fincher (Dir.)

Salon, 1 Feb 2013
https://www.salon.com/2013/02/01/how_netflix_is_turning_viewers_into_puppets/

Deep Learning for Object Recognition: Hinton & colleagues, NIPS 2012

AI/ML for Autonomous Vehicles





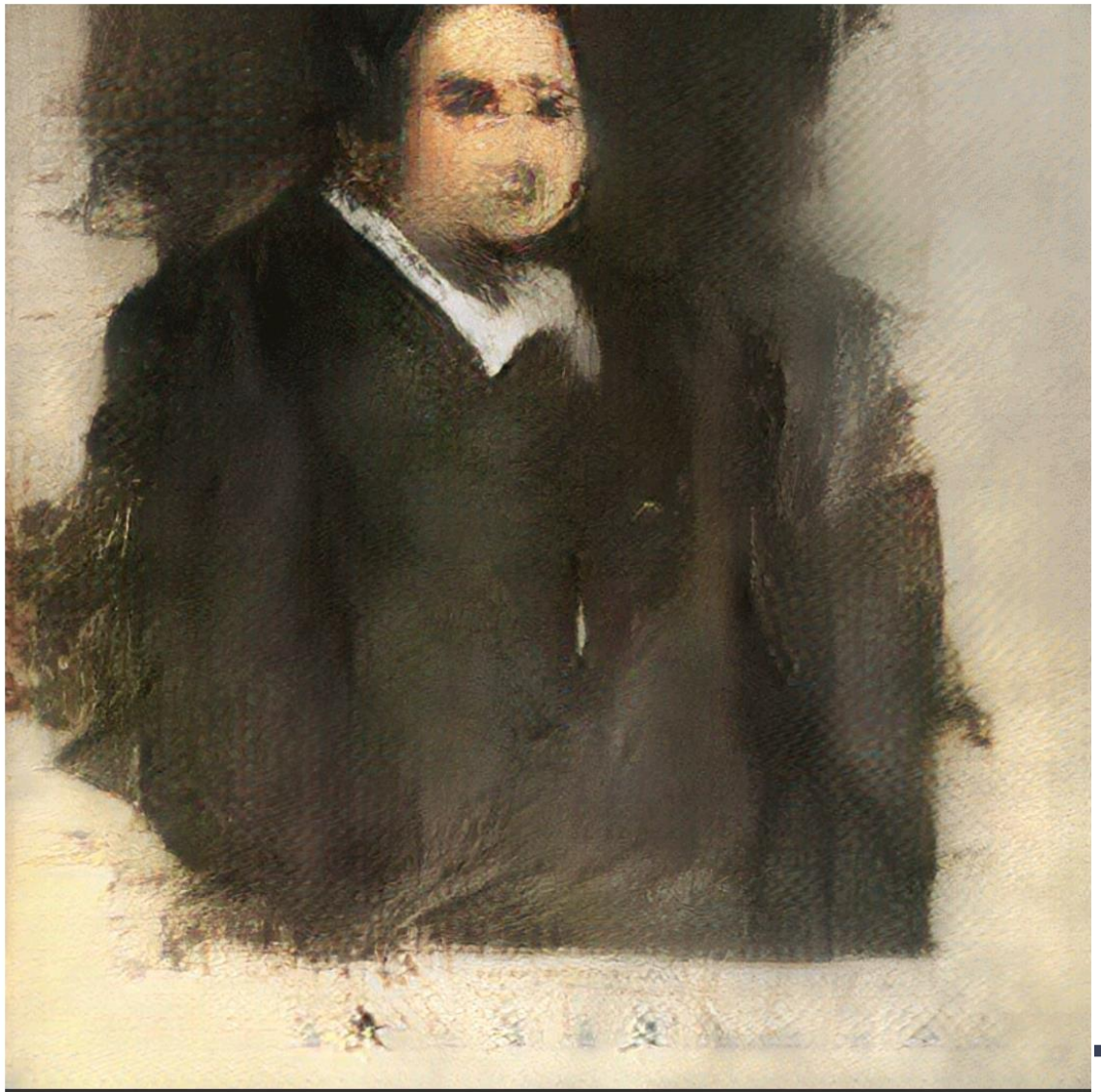
Learning from Experience Without a Teacher

Learns to play the game Go, just by playing games against itself

Starting from completely random play

https://deepmind.com/blog/alphago-zero-learning-scratch/

Generative adversarial networks



Obvious' "Portrait of Edmond Belamy" exceeded expectations at Thursday's sale (Courtesy of Obvious)

SMARTNEWS *Keeping you current*

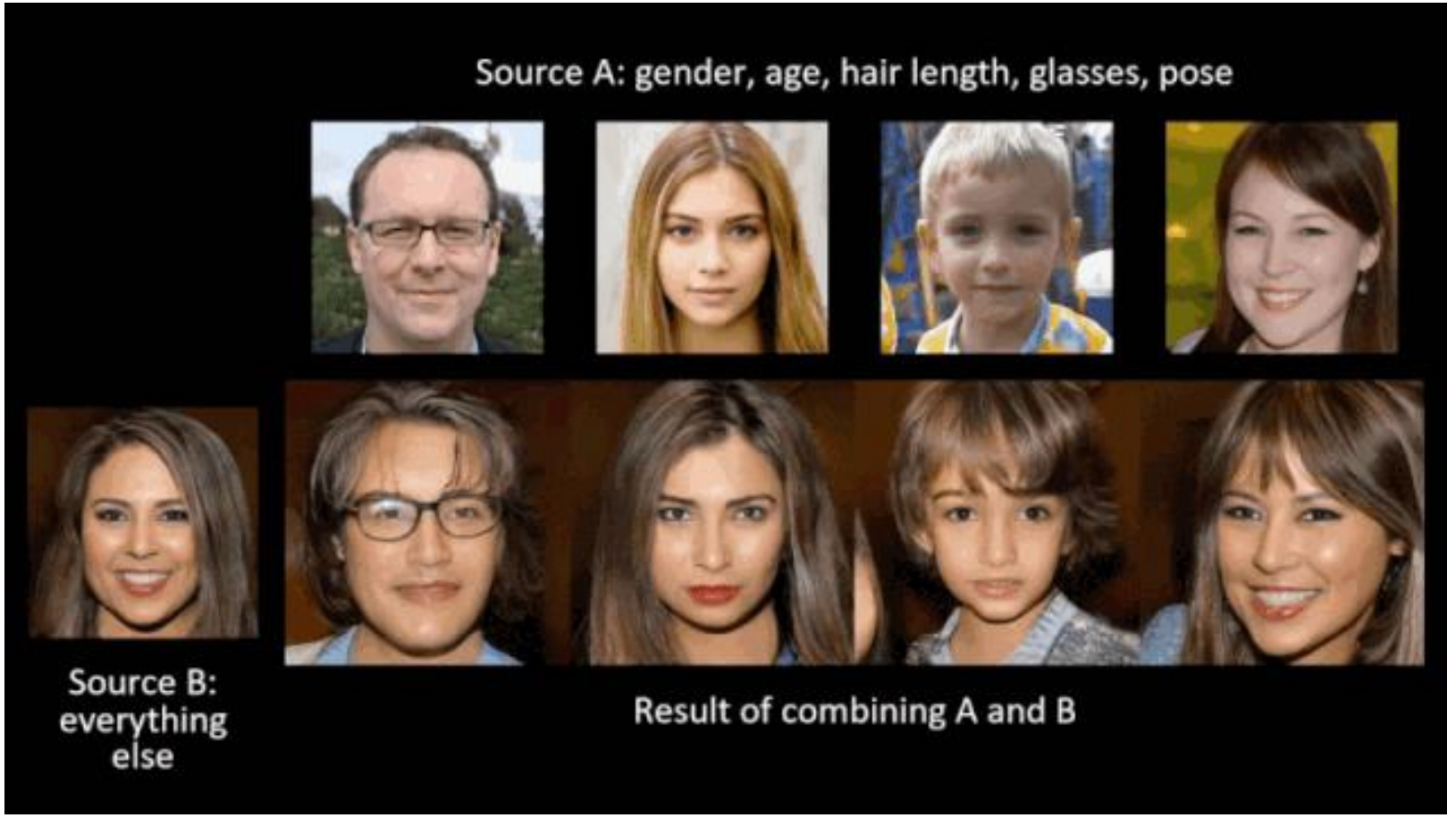
Christie's Is First to Sell Art Made by Artificial Intelligence, But What Does That Mean?

Paris-based art collective Obvious' 'Portrait of Edmond Belamy' sold for $432,500, nearly 45 times its initial estimate

October 2018

https://www.smithsonianmag.com/smart-news/christies-first-sell-art-made-artificial-intelligence-what-does-mean-180970642/

Generative adversarial networks

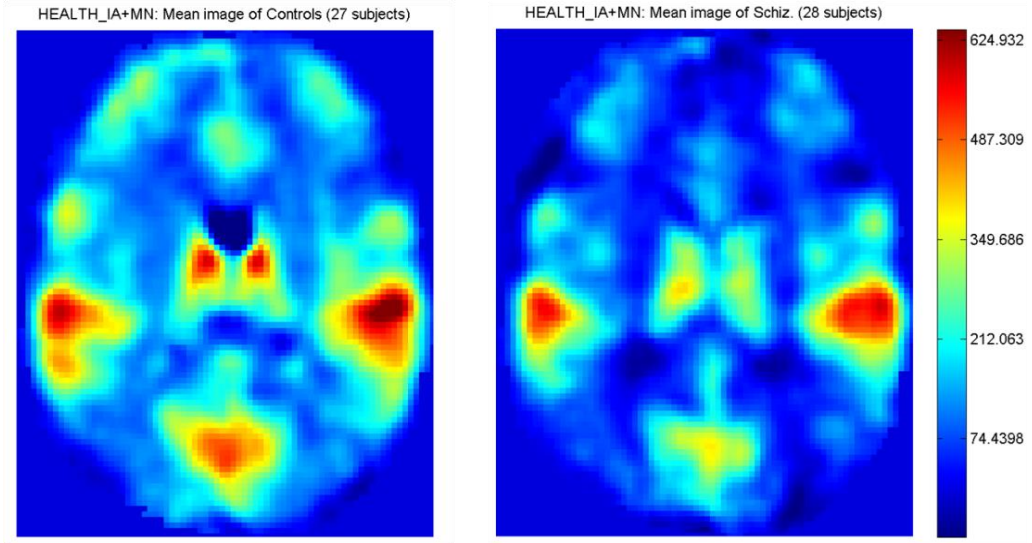


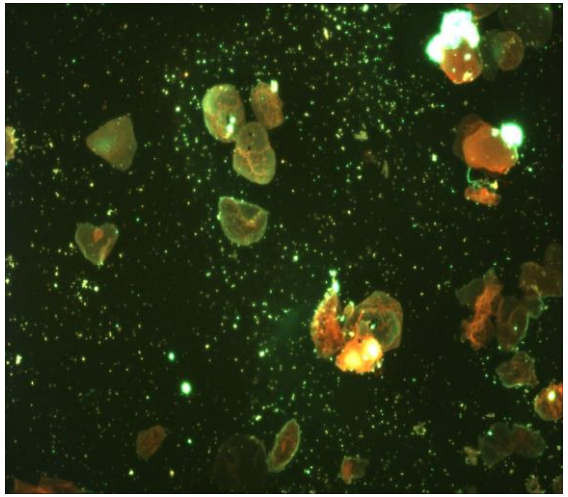
https://medium.com/syncedreview/nvidia-open-sources-hyper-realistic-face-generator-stylegan-f346e1a73826

https://www.theverge.com/2019/3/19/18272602/ai-art-generation-gan-nvidia-doodle-landscapes

Some local examples at NUI Galway: Image & Sensor Data Mining

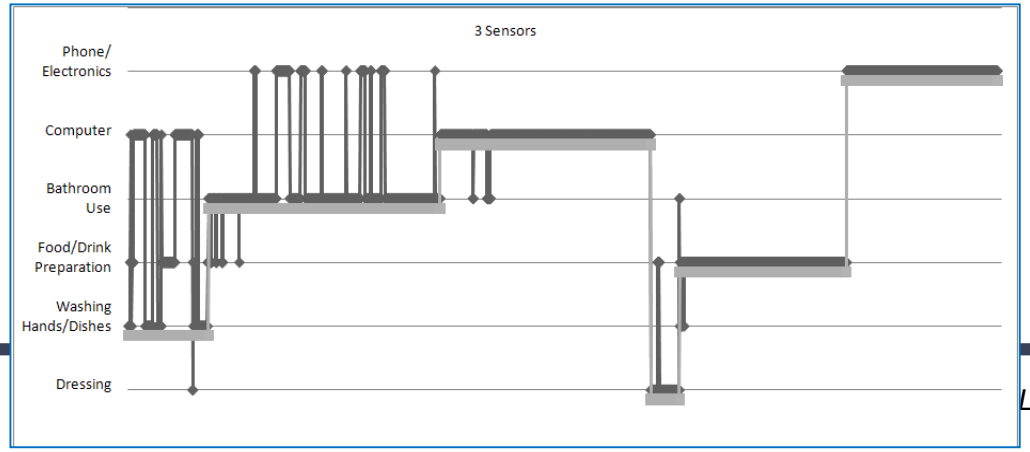
UC Irvine / NIH BIRN collaboration:
Using fMRI to distinguish subjects with Schizophrenia from controls





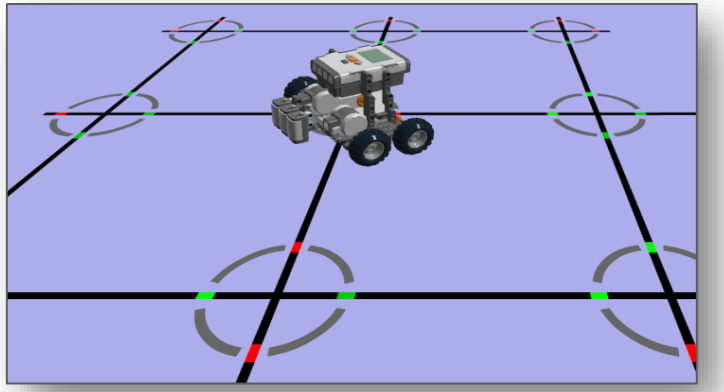
Analysing microscope images of sputum to screen for TB:
Image processing, ML, Sequential statistics

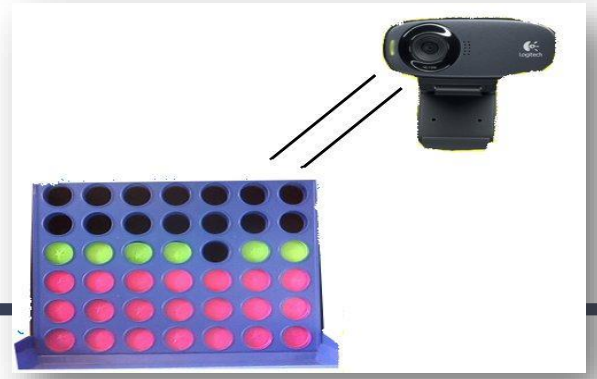
Identify Activities of Daily Living from sensors: Ensemble DTW Classifier



Some local examples at NUI Galway: Reinforcement Learning

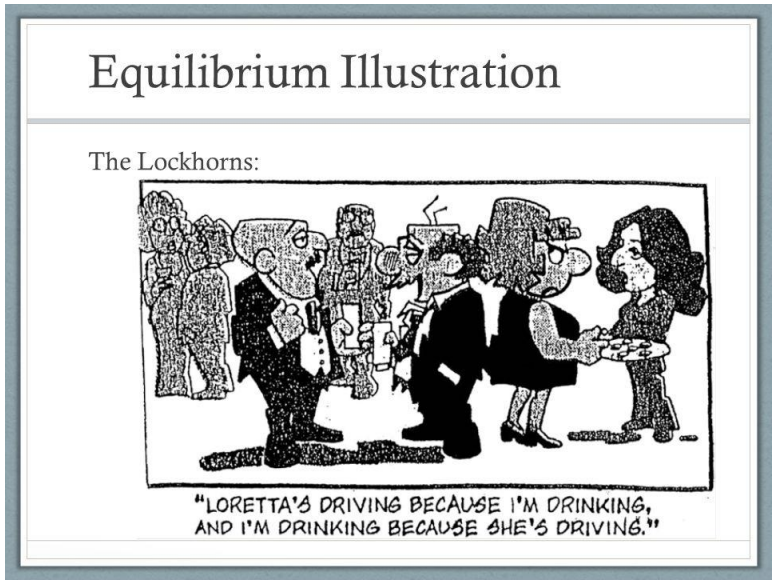
- RL Agent that learns to play UT2004 through trial & error
  - Goal: human-like performance
- Robots that learn to navigate mazes & solve puzzles

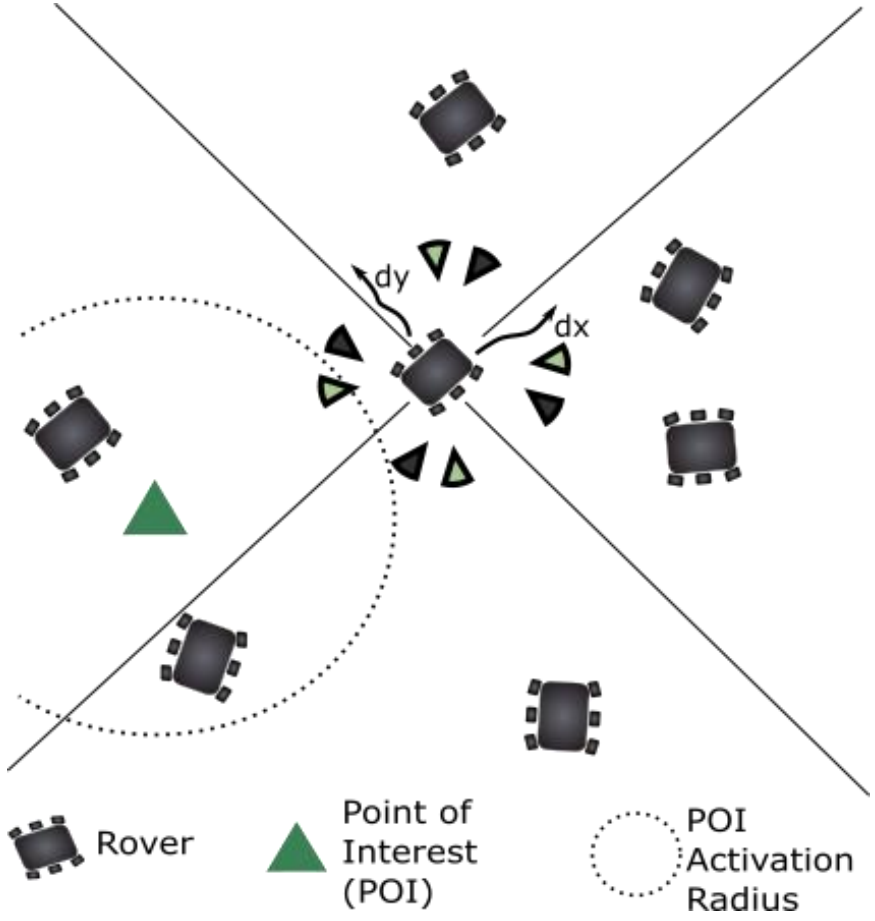




Some local examples at NUI Galway: Multi-agent learning and decision making

- Learning equilibrium concepts such as Nash equilibria
- Multi-agent / multi-robot coordination
- Multi-objective decision making
- Applications to many different areas e.g. transportation, smart grid, conflict negotiation, auctions, etc.





ROCSAFE: Remotely Operated CBRNE Scene Assessment & Forensic Examination

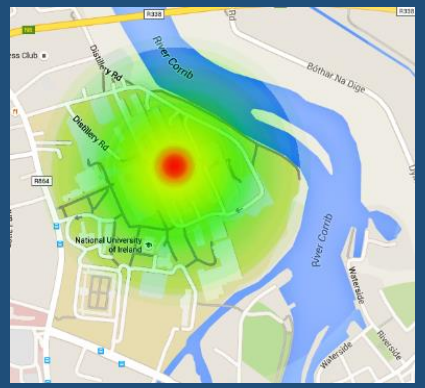
RAVs with automatic navigation and routes optimised for finding zones of interest and scene overview

Video, images, relayed to Central Decision Management.
Command Centre with map-based GUI showing threat colour maps, etc.
Video & maps augmented with analysed sensor results.

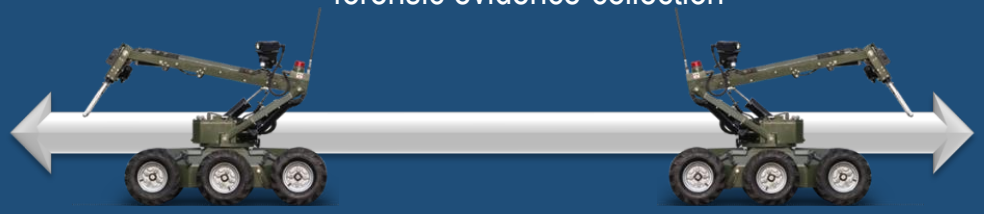
All data streamed to Central Decision Management

Forensic results, when available, transmitted to Central Decision Management

ROCSAFE Remote Forensics



RGVs deployed directly to zones of interest. Equipped with tools for forensic evidence collection



Forensic samples delivered to mobile lab [which is outside the scope of ROCSAFE]

The Future …

- Algorithms for learning from mixed media
- Systems that can automatically adapt to changing circumstances (adaptive, 'self-healing')
  - Software and embedded in hardware
- Search engines capable of resolving ambiguity and synthesising results from multiple sources
  - What will the weather be like in Finland next week?
  - Wolfram|Alpha, IBM's Watson
- Cumulative learning and transfer of skills
- Active experimentation
- Databases and programming languages with built-in learning; Cloud APIs
- Sensors everywhere; small & wearable computing

Learning Objectives: Review

If you have been paying close attention, you will now be able to …

1. Discuss definitions of Machine Learning
2. Describe what major categories of ML task entail: classification, regression, clustering, relationship discovery and reinforcement learning
3. Discuss the relationship with Data Mining
4. Explain the Data Mining process
5. Consider current and future applications of Machine Learning and Data Mining