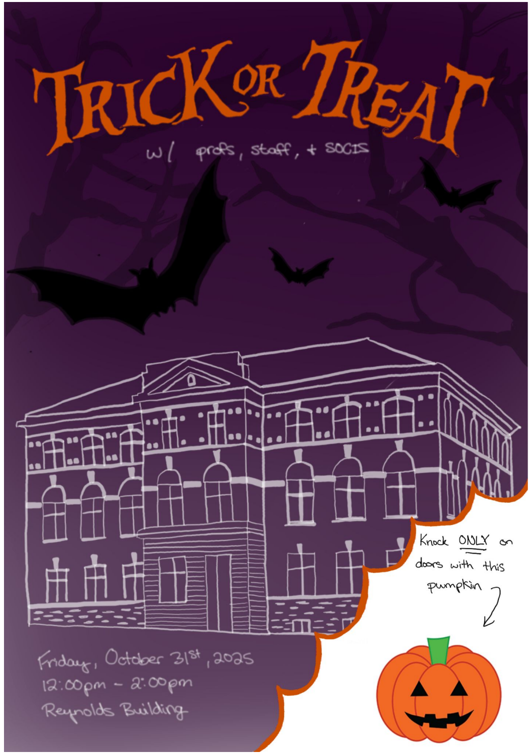
CIS*3750 - System Analysis and Design in Applications

Luiza Antonie, Fall 2025, University of Guelph

Week 10 Demo (Nov 3 & 5)

- In person, during your regular lab session
- 10-minute live demo of your high-fidelity prototype
- It must showcase **2-3 key user walkthroughs** focused on the core "intelligent" learning functionality of your ITS
- Simple walkthroughs like account creation or logging in will not be considered a valid main walkthrough
- While a code-based UI is recommended, navigating a Figma prototype is also acceptable
- Provide a shareable link to your prototype (e.g., GitHub or Figma link) for review. The entire group must be present for the demo.

Trick-or-Treat in Reynolds!

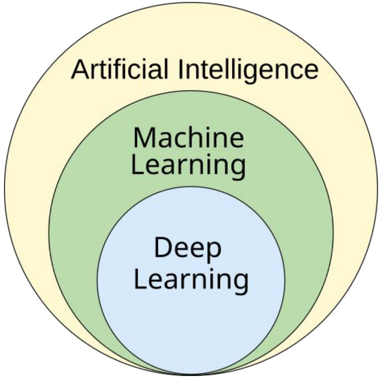


What is Learning?

"Learning is any process by which a system improves performance from experience."

Herbert Simon (1916-2001), American economist, political scientist and cognitive psychologist

Machine Learning



- Machine Learning (ML)
  - A subfield of artificial intelligence
  - Development of algorithms that **learn from data** and generalize to unseen data
  - Performs tasks without explicit programmed instructions

- "A computer program is said to learn from experience E with respect to some class of tasks T and performance measure P if its performance at tasks in T, as measured by P, improves with experience E" - Tom. Mitchell

Image source: https://en.wikipedia.org/wiki/Machine_learning

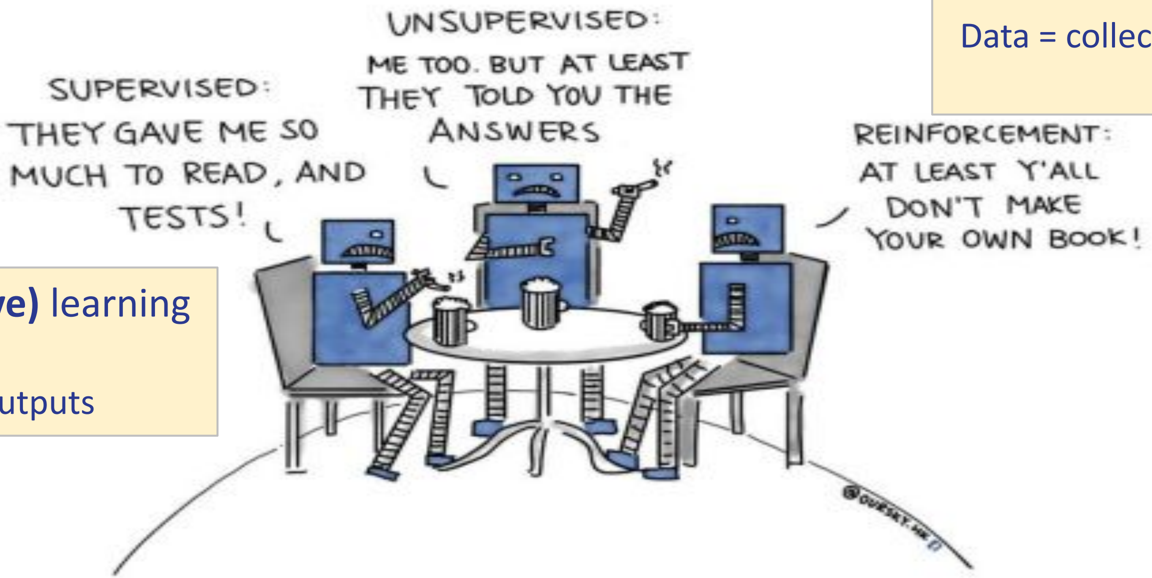
Types of Learning

Unsupervised learning

Data = inputs

Reinforcement learning

Data = collected from a sequence of actions

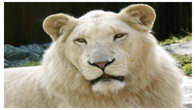


Supervised (inductive) learning

Data = inputs + outputs

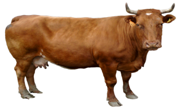
https://www.reddit.com/r/TheInsaneApp/comments/rf8ytg/three_main_types_of_machine_learning_algorithms/

Supervised learning



Dangerous

Dangerous



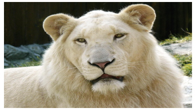
Not dangerous

Not dangerous

Dangerous

Not dangerous

Supervised learning



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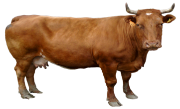
Dangerous



Not dangerous

Not dangerous

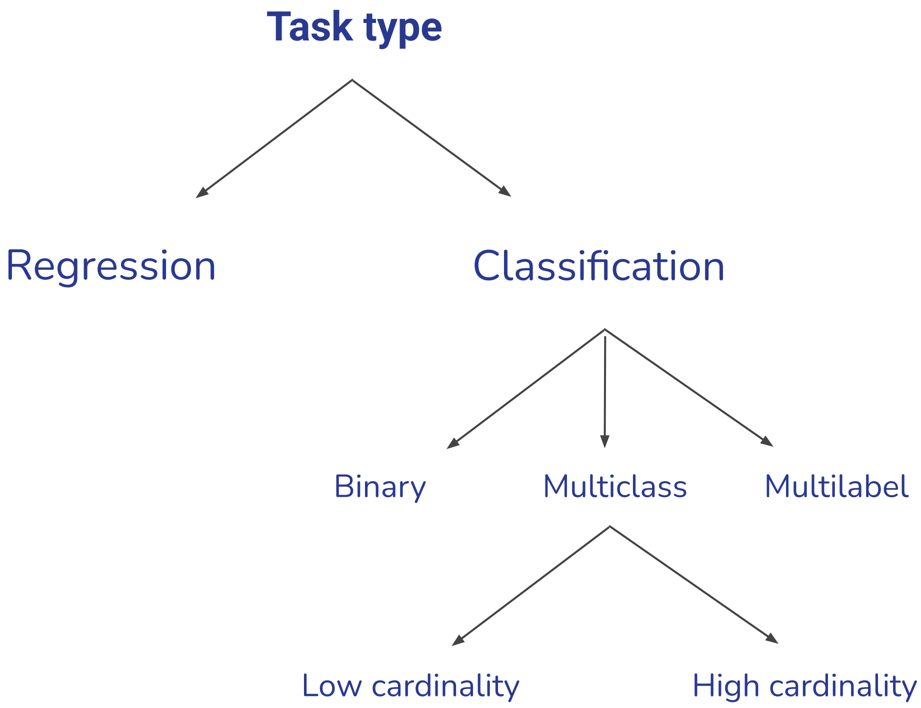
Dangerous

Not dangerous

Is this dangerous?

Tasks: classify animals, decide, predict

Framing the problem



Multiclass vs. multilabel

Task type

Regression

Classification

Binary

Multiclass

Multilabel

0	0	0	1

A label can belong to only one class

0	1	0	1

A label can belong to multiple classes

How to handle multilabel tasks

Multilabel problem solution

A multiclass problem

0	1	0	1

A set of multiple binary problems

Model 1: Does this belong to class 1?

Model 2: Does this belong to class 2?

...

Multilabel is harder than multiclass

Multilabel problem solution

A multiclass problem

0	1	0	1

A set of multiple binary problems

Model 1: Does this belong to class 1?

Model 2: Does this belong to class 2?

...

1. How to create ground truth labels?
2. How to decide decision boundaries

A problem can be framed as different task types

Problem: predict the app users will most likely open next

Classification

INPUT

0.072	0.15	...	...	0.067	0.154

User's features

Environment
time, location, etc.

OUTPUT

0.2	App 0
0.02	App 1
...	...
0.04	

A problem can be framed as different task types

Problem: predict the app users will most likely open next

Classification

INPUT

0.072	0.15	...	...	0.067	0.154

$\underbrace{\text{0.072 | 0.15 | ...}}_{\text{User's features}}$ $\underbrace{\text{... | 0.067 | 0.154}}_{\text{Environment}}$

User's features

Environment
time, location, etc.

OUTPUT

0.2	App 0
0.02	App 1
...	...
0.04	

⚠️ Every time an app is added/removed, you have to retrain your model ⚠️

Framing can make the problem easier/harder

Problem: predict the app users will most likely open next

Regression

										OUTPUT	
INPUT 0	0.072	0.15	...	...	0.067	0.154				0.03	**App 0**
	User's features			Environment time, location, etc.			App's features				
INPUT 1	0.072	0.15	...	...	0.067	0.154				0.06	**App 1**
INPUT ...	0.072	0.15	...	...	0.067	0.154				0.25	**App ...**

Framing can make the problem easier/harder

Problem: predict the app users will most likely open next

Very common framing for recommendations

Regression

INPUT 0

0.072	0.15	...	...	0.067	0.154			

User's features | Environment (time, location, etc.) | App's features

INPUT 1

0.072	0.15	...	...	0.067	0.154			

INPUT ...

0.072	0.15	...	...	0.067	0.154			

OUTPUT	
0.03	**App 0**
0.06	**App 1**
0.25	**App ...**

Supervised learning tasks in an ITS

- Difficulty estimation
  - predicting difficulty of a concept/problem
- Knowledge tracing
  - estimate mastery of concepts
- Predict which type of explanation works best for a student
- Predict if the the student will answer the problem correctly

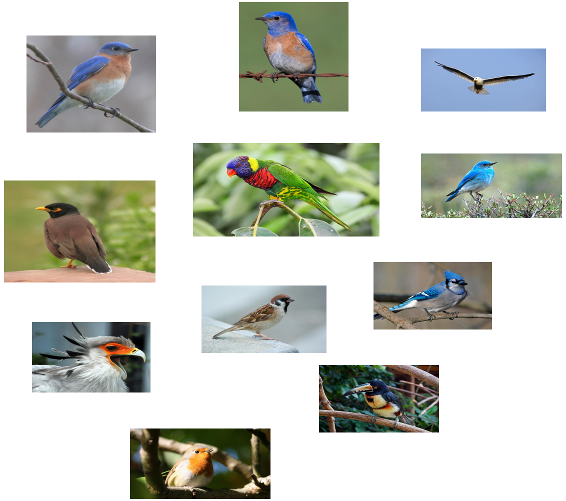
Supervised learning tasks in an ITS

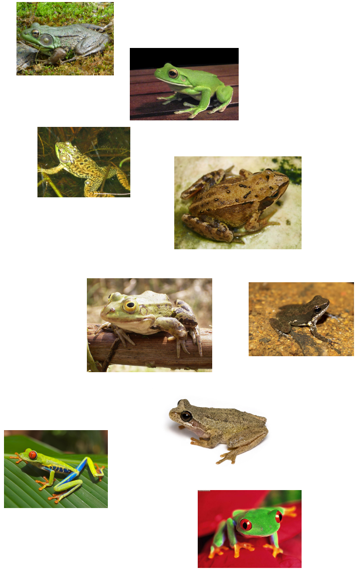
- Detect/classify misconceptions or error types.
- Classify the student's state and select the most helpful hint level.
- Sentiment classification:
  - detect frustration/engagement from clicks, pauses

Unsupervised learning

How can these pictures be grouped?

Data

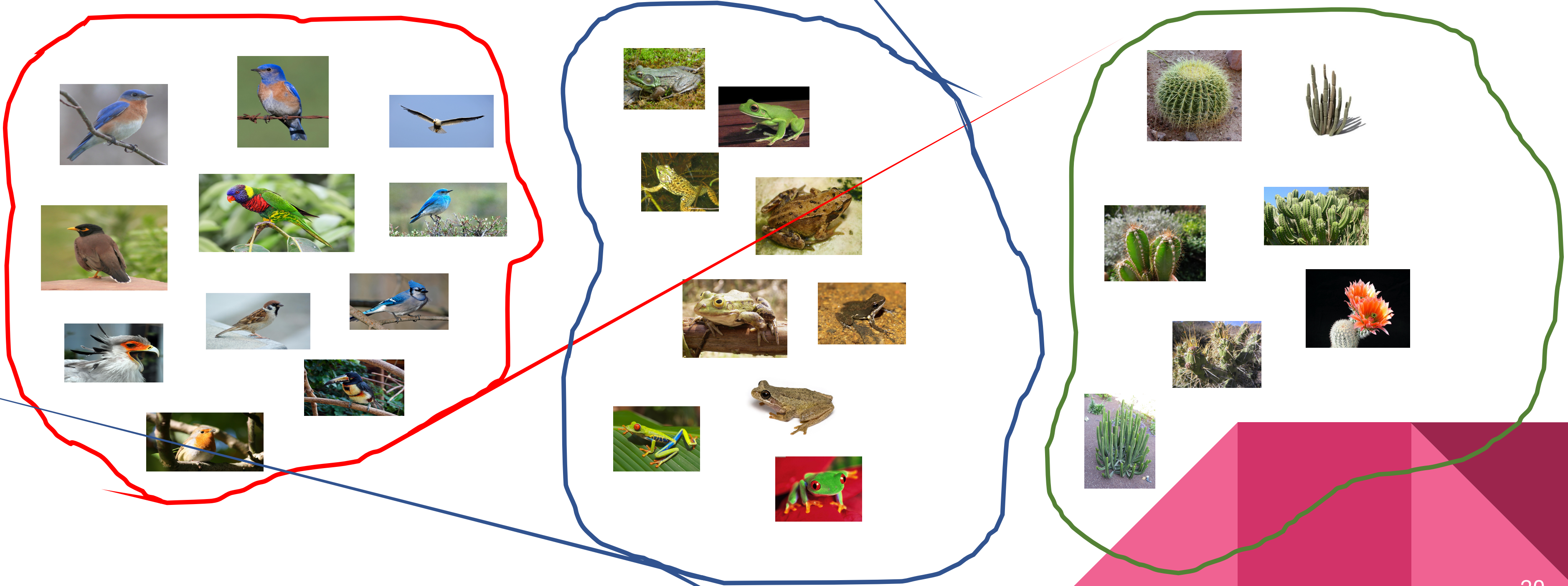




Unsupervised learning

How can these pictures be grouped?

Data

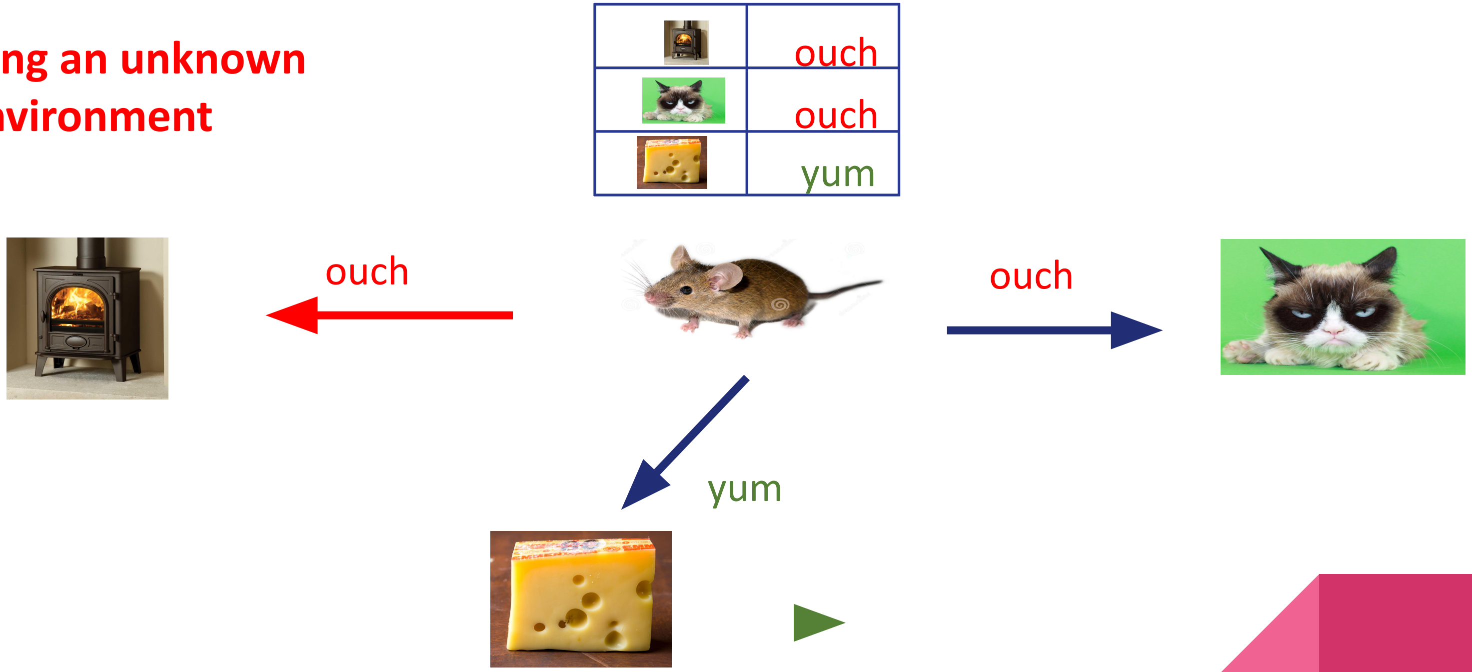


Unsupervised learning tasks in an ITS

- Recommend what skill/concept the student should practice next
- Group students by learning behaviors (fast/slow, high/low engagement).
- Group questions/problems by difficulty/skill

Reinforcement learning

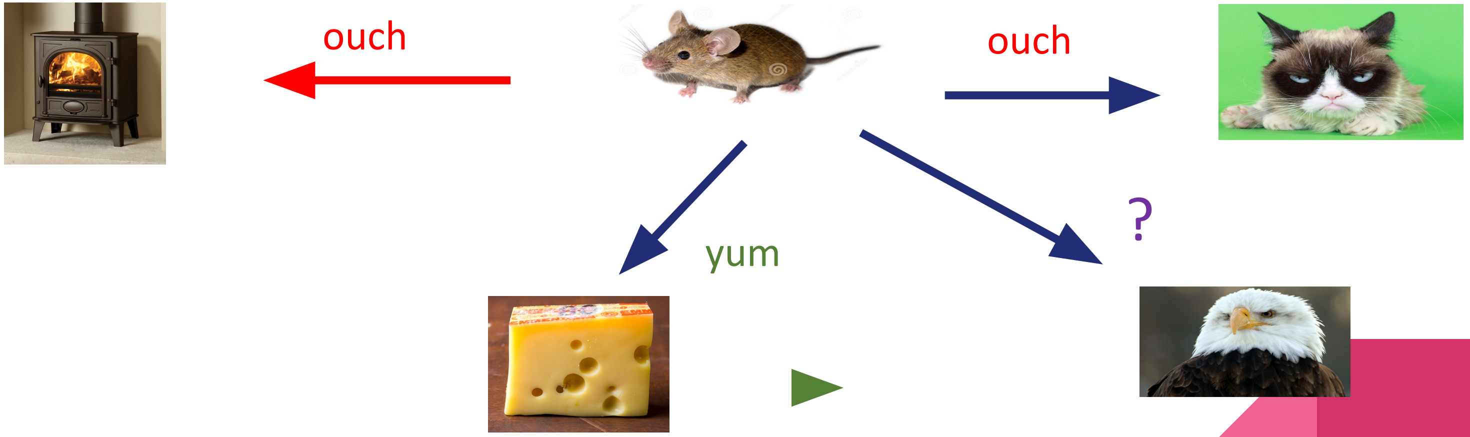
Exploring an unknown environment



Reinforcement learning

Exploring an unknown environment

	ouch
	ouch
	yum



Tasks: explore, react, remember, extrapolate

Reinforcement learning in an ITS

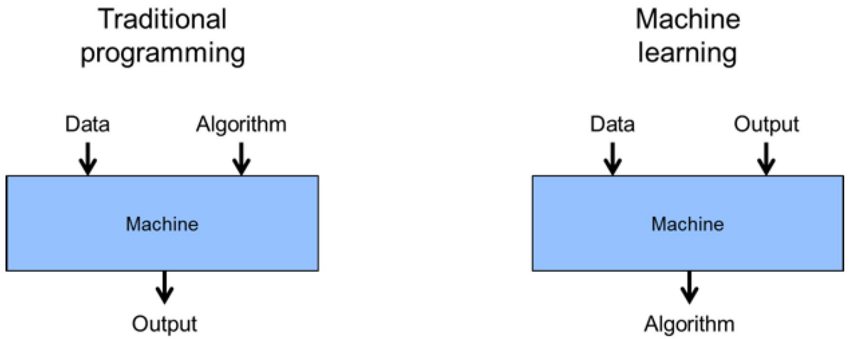
- Policy learning: Use reinforcement learning (RL) to decide the “best” next action for learning gains
- Adapting feedback: Use RL to provide feedback that is optimized for the learner

Machine learning (ML)

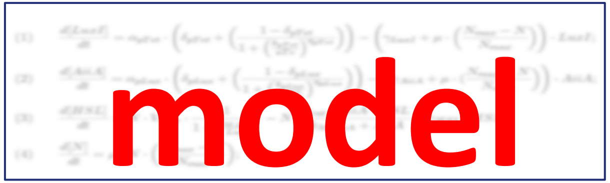
- The field of machine learning is concerned with the question of how to construct computer programs that automatically improve with experience.

Tom Mitchell, Machine Learning (1997)

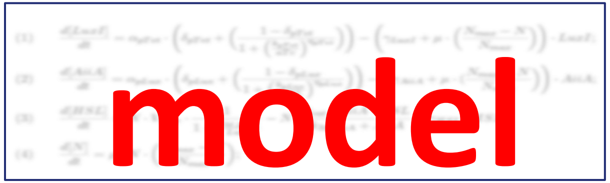
i.e. get computers to program themselves



Machine learning (ML) modelling

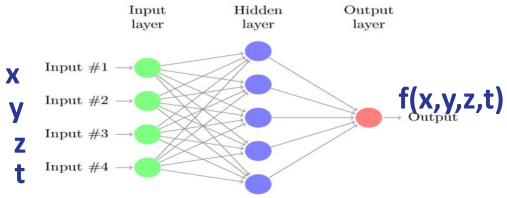


Machine learning (ML) modelling



Example:

x	y	z	t	Output: f(x,y,z,t)
1	1	-10	0	-18
2	1	-9	2	-11
3	2	-8	4	5
4	2	-7	6	28
5	3	-6	8	60
6	3	-5	10	99
7	4	-5	12	145
8	4	-3	14	202
9	5	-2	16	266
10	5	-1	18	337

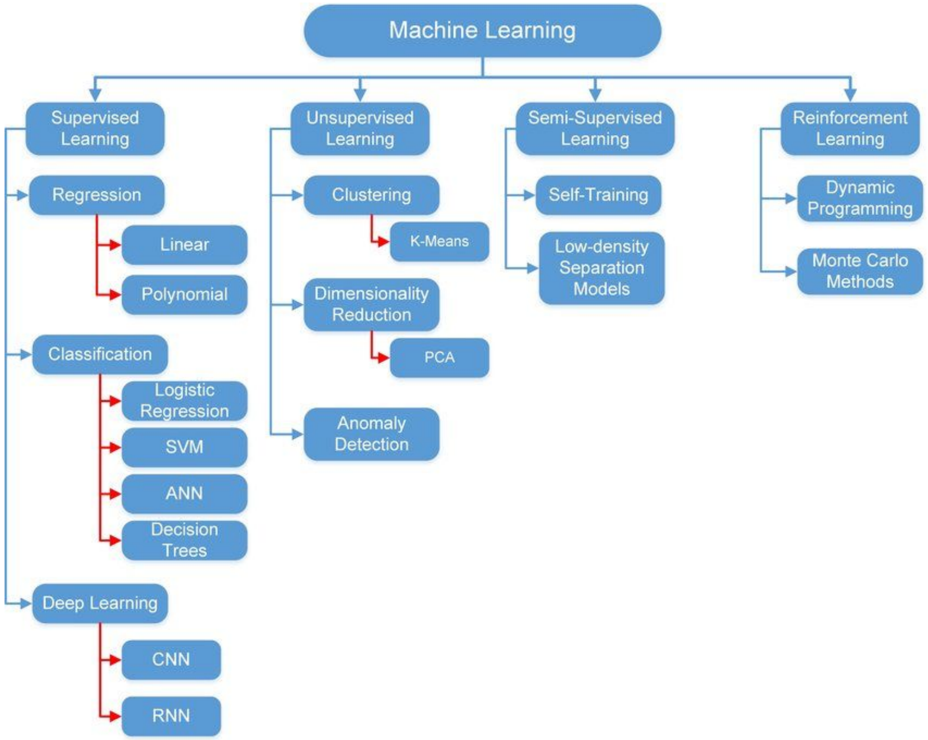


ML model

$$f(x,y,z,t) = x + y + 2z + t^2$$

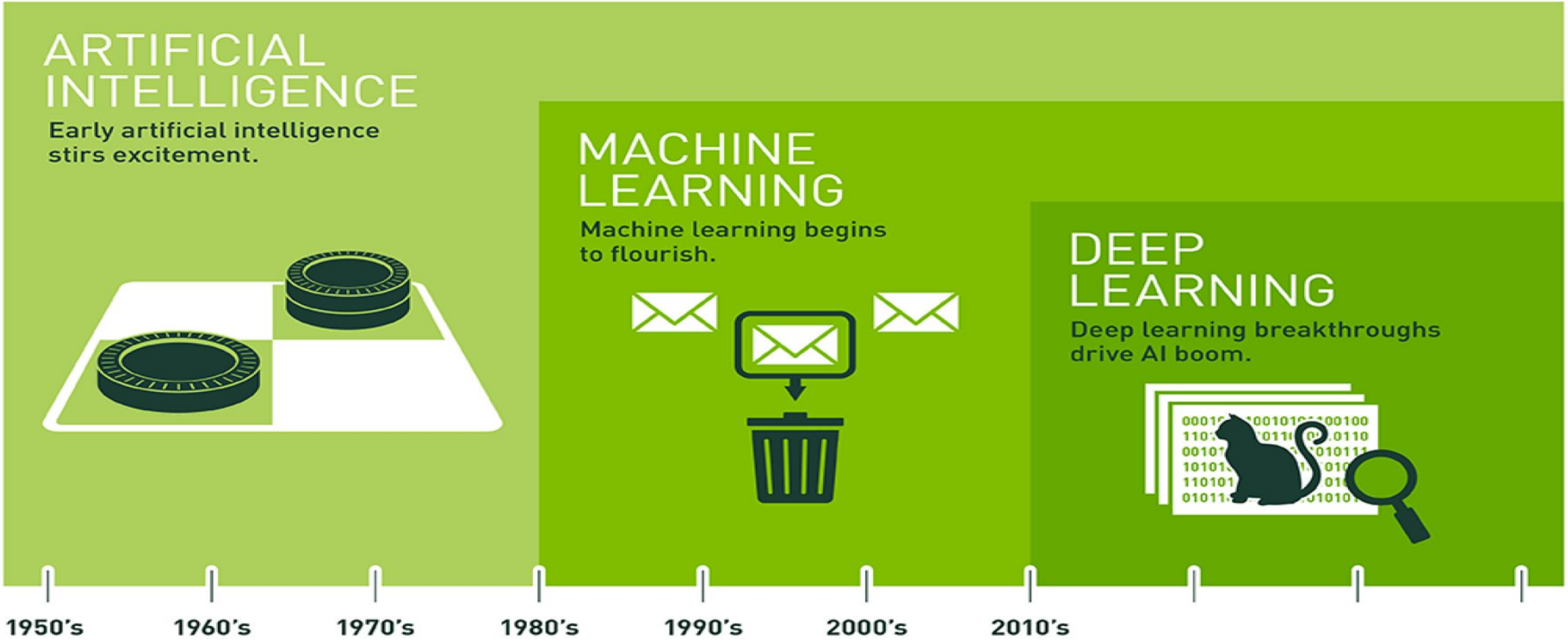
traditional mathematical model

Machine Learning Algorithms



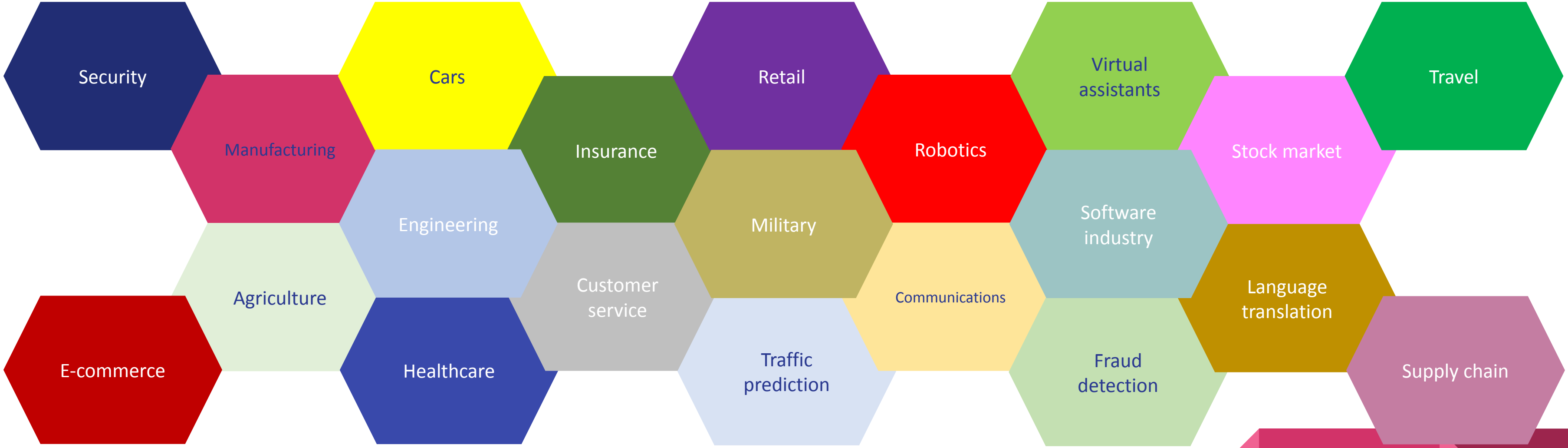
https://www.dataexpertise.in/machine-learning-beginners-guide/

History of ML



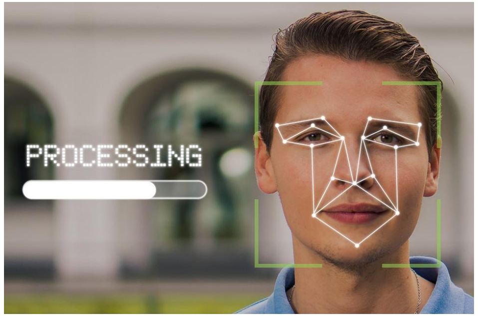
https://blogs.nvidia.com/blog/2016/07/29/whats-difference-artificial-intelligence-machine-learning-deep-learning-ai/

Applications of ML



Applications of ML

Face detection



Self driving cars

Drones

Toys ?!?!

Types of problems solved by ML

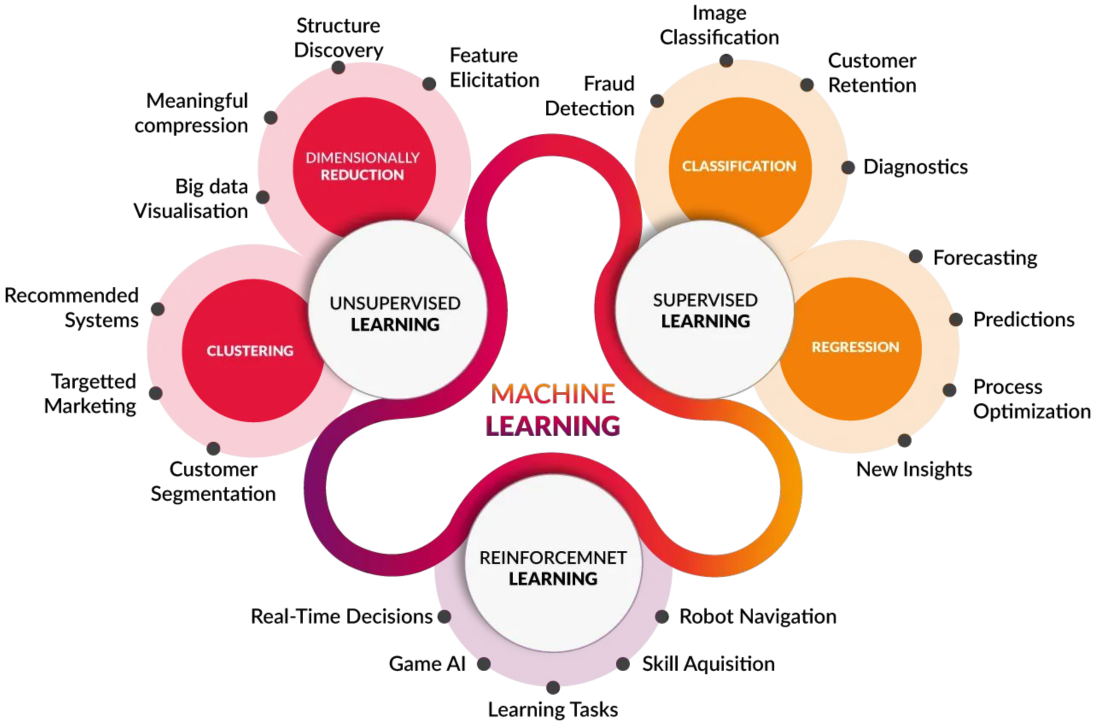


Image source: https://arnabsaha1.medium.com/what-is-machine-learning-ml-artificial-intelligence-ai-deep-learning-dl-bc58253fef57

How does ML work?

- **Step 1 [data]:** The user provides the learning system with **examples** of the concept to be learned or plain **data**.

DATA

Step 2 (Training/validation)	Step 3 (Testing)

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DATA

Step 2 (Training/validation)	Step 3 (Testing)

- **Step 2 [training + validation]:** The learning system algorithm **builds** a characteristic **model** from these examples.

How does ML work?

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DATA

Step 2 (Training/validation)	Step 3 (Testing)

- **Step 2 [training + validation]:** The learning system algorithm **builds** a characteristic **model** from these examples.

- **Step 3 [testing]:** The **model is used to predict** quickly and with high accuracy whether or not future **novel instances** follow the model.

How does ML work?

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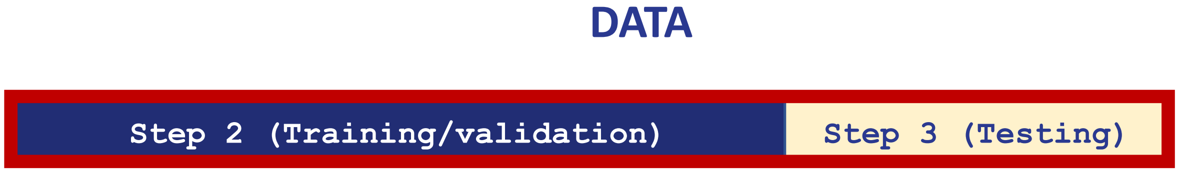


- **Step 2 [training + validation]:** The learning system algorithm **builds** a characteristic **model** from these examples.

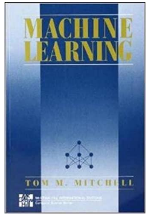
- **Step 3 [testing]:** The **model is used to predict** quickly and with high accuracy whether or not future **novel instances** follow the model.

Golden Rule of ML: The test data cannot be used in the training process.

Step 1: Define the problem

A computer program is said to **learn** from experience *E* with respect to some class of tasks *T* and performance measure *P*, if its performance at tasks in *T*, as measured by *P*, improves with experience *E*.

Tom Mitchell, Machine Learning, McGraw Hill, 1997
http://www.cs.cmu.edu/~tom/mlbook.html



1. What problem do I solve?

- Informal definition
- Formal definition (tasks, experience, performance)
- Assumptions
- Similar problems: anyone else proposed/solved this problem

2. Why do I want/need to solve this problem?

- Motivation: learning, project, …
- Benefits of finding a solution: to market it to others, novelty, …
- Use of solution: who benefits, maintenance, lifetime, write papers, …

3. How do I solve the problem?

- Manual approach for smaller problem
- What do you need: data collection, storage, preparation, programming needs, knowledge
- Refine steps 1 and 2
- Do I need ML to solve it?

Case study: sheep body weight prediction

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Need a model to predict sheep body weight from body measurements.

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- **Task** = estimate body weight of a new sheep for which we do not know its real weight.
- **Experience** = a collection of measurements for which we have known weights
- **Performance** = the difference between the predicted and known body weight

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- Measurements are performed with high accuracy (small errors)
- Data is collected by the same person using the same tools
- Sheep age might influence the prediction accuracy

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Significant number of publications available:

Sowande and Sobola, 2008; Kunene et al., 2009; Chay-151 Canul et al., 2019; Canul-Solis et al., 2020

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Associations potentially interested in this project:

Canadian Sheep Breeders' Association
La Société Canadienne des Éleveurs de Moutons

CSF•FCM
Canadian Sheep Federation/Fédération canadienne du mouton

1. Sheep welfare
2. Industrial automation

2. Why do I want/need to solve this problem?
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- Reduce stress for both sheep and handlers
- Enable continuous growth monitoring
- Optimize time-to-market
- Appealing for agro-tech companies

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- Beneficiaries: researchers, industry, breeders, farmers
- Maintenance: medium to long-term
- Lifetime value: 5-10 years (until new tech arrives)
- Publications: articles or patents
- Used on mobile devices and computers

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- Collect 5 measurements from 100 sheep (manual + images).
- Store data as text and images.
- Remove/impute missing data
- Programming in Python (OpenCV,…) and later for mobile platforms

Case study: sheep body weight prediction

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- Might need more data (more sheep, more measurements).
- Results could be influenced by sheep color □ breed □ adjust assumptions
- Might be able to apply the same process for cows and pigs.
- **Shocking realization:** sheep have a lot of hair □ overestimations □ adjust assumptions

3. How do I solve the problem?
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   - Do I need ML to solve it?

YES
- Can be formulated as a regression problem
- Unknown relation (linear, non-linear) between measurements and body weight
- Output (weight) is known supervised learning

In-class exercise

Use these questions to explore one of the problems you want to solve with ML for your project

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