

Welcome to Machine Learning!

COMP 4630 | Winter 2026

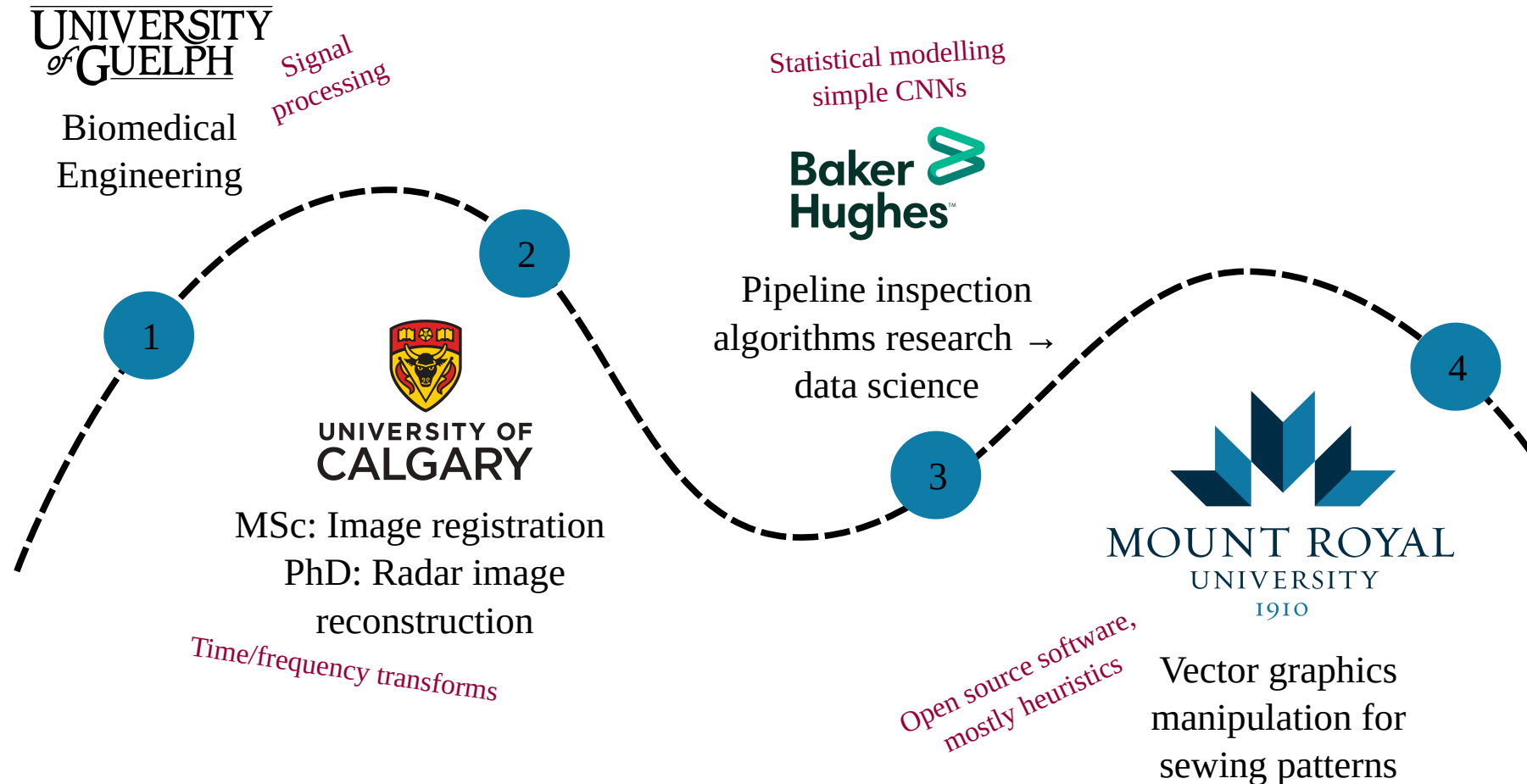
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What is this course about?

- Continuing the supervised/unsupervised learning algorithms from COMP 3652, with a focus on **Neural Networks**
- First half: the history, theory, and math behind neural networks
- Second half: applications of NNs in computer vision, natural language processing, and more

This is not (just) a course on building models using libraries like TensorFlow or PyTorch, it is a course on understanding the theory

How did I get involved with ML?



What do you want to learn about ML?



Grade Assessment

Component	Weight
Assignments	3 x 10%
Midterm (theory) exam	20%
Journal club	10%
Final project	40%

Bonus marks may be awarded for *substantial* corrections to materials, submitted as pull requests

Course materials repo: <https://github.com/mru-comp4630/w26>

Rendered at: <https://mru-comp4630.github.io/w26/>

Textbooks and other readings

Primary Textbook:

- [Hands on Machine Learning with Scikit-Learn and \[Tensorflow/PyTorch\]](#)
- [Associated GitHub repo \(Tensorflow\)](#)
- [Associated GitHub repo \(PyTorch\)](#)

More mathy details:

- [Deep Learning](#)

Journal club list: on D2L under "Course Info" (requires MRU library login)

Generative AI policy

- Yes, AI can do a lot of what I'm asking for in this course
- No, I do not want to read about what AI "thinks"
- ? What do you think is an appropriate use?

Machine Learning Project Checklist

[Appendix A of the hands-on textbook](#)

1. **Frame the problem** and look at the big picture.
2. **Get the data.**
3. **Explore the data** to gain insights.
4. **Prepare the data** to better expose the underlying data patterns to Machine Learning algorithms.
5. Explore many different models and short-list the best ones.
6. Fine-tune your models and combine them into a great solution.
7. Present your solution.
8. Launch, monitor, and maintain your system.

1. Look at the big picture

Example Dataset: California housing prices (1990)

? Discussion questions:

- How does the company expect to use and benefit from this model?
- What is the current solution?
- What kind of ML task is this?
- What kind of performance measure should we use?

Where we left off - Monday, January 12

First, some stuff about assessments

- [Assignment 1](#)
- [Journal club guidelines](#)
- [Example](#) of a math-heavy paper
- Additional references for papers:
 - [Google Scholar](#)
 - [ArXiv](#)

2. Get the data

For this class, we'll use readily available datasets. Some sources are:

- [UCI Machine Learning Repository](#)
- [Kaggle](#)
- [Google Dataset Search](#)
- Various Government open data portals (e.g. [Calgary](#), [Alberta](#), [Canada](#))

After fetching the data, set aside a test set and **don't look at it**.

"Get the data" can often be a huge task in itself!

2a. Set aside a test set

? Discussion questions:

- Why do we need an independent test set?
 - Avoid data snooping bias
 - [Relevant XKCD](#)
- Why would we use a random seed?
- What is naive about simply selecting a random sample?
- What else could we do?
- What is stratified sampling?

Side tangent: Sampling bias

- Simple example: assume 80% of population likes cilantro
- Goal: ensure our sample is representative of the population, $\pm 5\%$

The [binomial distribution](#) can be used to model the probability of choosing k people who like cilantro from n total participants:

$$P(X = k) = \binom{n}{k} p^k (1 - p)^{n-k}, \text{ where } \binom{n}{k} = \frac{n!}{k!(n - k)!}$$

Side tangent: Sampling bias continued

$P(X = k)$ is the probability mass function, and the corresponding cumulative distribution function is just the sum up to k :

$$P(X \leq k) = \sum_{i=0}^k \binom{n}{i} p^i (1-p)^{n-i}$$

Suppose we **randomly** sample 100 people. What is the probability of fewer than 75 or more than 85 cilantro lovers?

This is also my excuse to review some probability theory and notation

3. Explore the data

? Discussion questions:

- What do you notice about the data?
- Do the values make sense for the labels?
- Is the scale of the features comparable? Does this matter?
- What possible biases might be present in the data?

3a. Look for correlations

The **Pearson correlation coefficient** is a measure of the linear correlation between two variables X and Y (commonly denoted as r):

$$r = \frac{\sum_{i=1}^n (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^n (x_i - \bar{x})^2} \sqrt{\sum_{i=1}^n (y_i - \bar{y})^2}}$$

where \bar{x} and \bar{y} are the sample means of X and Y , respectively.

- What do correlations of 0, 1, and -1 mean?
- What are some limitations of Pearson correlation?

4. Prepare the data

General goals:

- Handle missing data, and maybe outliers
- Drop irrelevant features
- Combine features using domain knowledge
- Apply various transformations (e.g. scaling, encoding)
- Apply scaling when necessary

4a. Handling missing data

In the book 3 options are listed to handle the NaN values:

```
housing.dropna(subset=["total_bedrooms"], inplace=True) ## option 1
housing.drop("total_bedrooms", axis=1)                  ## option 2
median = housing["total_bedrooms"].median()             ## option 3
housing["total_bedrooms"].fillna(median, inplace=True)
```

? Discussion questions:

- What is each option doing?
- What are the pros and cons of each option?
- Which one should we choose?

4b. Handling non-numeric data

Most of the math in ML algorithms is based on numbers, so we need to convert text and categorical attributes to numbers. This is called **encoding**.

? Discussion questions:

- Which columns of our data are categorical?
- What methods could we use to convert them to numbers?
- What are the assumptions about the various encoding methods?

4c. Scaling the data

Many ML algorithms don't like features with vastly different scales. Common scaling methods are **min-max scaling** and **standardization**.

*Important: scaling is **computed** on the training set and **applied** to the validation and test sets - they are not scaled independently!*

? Discussions questions:

- What are the bounds of each method?
- Which method is more affected by outliers?
- How would you decide which method to use?

4e. Standardization details

A general Gaussian distribution is given by:

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2}$$

where μ is the mean and σ is the standard deviation. The standard normal distribution is a special case where $\mu = 0$ and $\sigma = 1$, reducing the equation to:

$$f(x) = \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}x^2}$$

4f. Other transformations

- **Log transformation:** useful for data that is heavily skewed
- Also **square root, squaring, etc.:** try to remove heavy tails
- **Feature engineering:** combining features to create new ones
- **Binning:** turning continuous data into discrete categories
 - Possibly using K-means clustering
 - Relies on domain knowledge
- Best to create a **transformation pipeline** and apply it to the data rather than saving the transformed data

Coming up next

- Math review:
 - Linear algebra
 - Differential calculus
 - Statistics
- A brief introduction to vector calculus