COMPSCI 389
Introduction to Machine Learning

Days: Tu/Th. **Time:** 2:30 – 3:45 **Building:** Morrill 2 **Room:** 222

Topic 2.0: Introduction to Supervised Learning

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Data & Supervised Learning

- Different subfields of ML assume access to different kinds of data.
- During the first part of the course, we will focus on **supervised learning** problems.
- These are problems where the data is a set of points, and so it is called a **data set** or **dataset.**
- Each point consists of a pair of **inputs** and **outputs**.
- Given a data set of such input-output pairs, a supervised learning algorithm learns to predict the output given the input, even for points not in the data set.

Data Set Notation

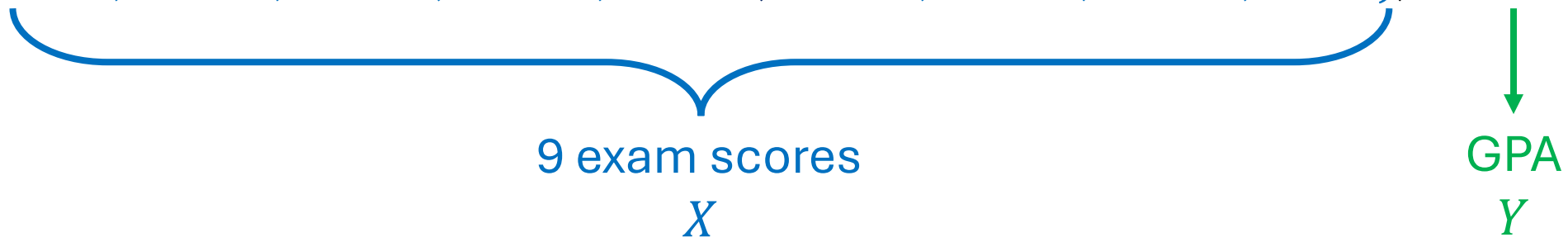
- X: **Input** (also called **features**, **attributes**, **covariates**, or **predictors**)
  - Typically, X is a vector, array, or list of numbers or strings.
- Y: **Output** (also called **labels** or **targets**)
  - Typically, Y is a single number or string.
- An input-output pair is (X, Y).

- **Note**: We will *frequently* flip between terms for X and Y.
  - Different sources use different terms, and it's important to be comfortable with all of them.

Example Input-Output Pairs

- Predict university student GPAs from entrance exam scores.
  - Features = scores on 9 entrance exams.
  - Labels = GPA
  - Example input-output pair:

$$((622.6, 491.56, 439.93, 707.64, 663.65, 557.09, 711.37, 731.31, 509.8), 1.33333)$$



Example Input-Output Pairs

- Predict whether a sentence is a lie.
  - Input = a statement made by a person.
  - Output = a label indicating whether the sentence was truthful or a lie.
  - Example input-output pair:

("I am not a crook.", "lie")

Statement	Truth/Lie
X	Y

Data Set Notation (Revisited)

- X: **Input** (also called **features**, **attributes**, **covariates**, or **predictors**)
  - Typically, X is a vector, array, or list of numbers or strings.
- Y: **Output** (also called **labels** or **targets**)
  - Typically, Y is a single number or string.
- An input-output pair is (X, Y).
- Let n, called the **data set size** or **size of the data set**, be the number of input-output pairs in the data set.
- Let (X_i, Y_i) denote the i^{th} input output pair.
- The complete data set is

$$(X_i, Y_i)_{i=1}^{n} = \big((X_1, Y_1), (X_2, Y_2), \dots, (X_n, Y_n)\big).$$

Data Set Notation

$$(X_i, Y_i)_{i=1}^{n} = \big((X_1, Y_1), (X_2, Y_2), \ldots, (X_n, Y_n).\big)$$

- Different sources use different notation.
  - X, X_i, x, or x_i can denote one input vector.
  - X can denote all the input vectors:
    $$X = (X_i)_{i=1}^{n}.$$
  - Y, Y_i, y, or y_i can represent one label.
  - Y or y can represent all the labels:
    $$Y = (Y_i)_{i=1}^{n}.$$
- Upper and lower case can mean different things:
  - Upper case = matrix (2-dimensional table), lower case = vector.
    - (X, y) denotes a complete data set. (We'll see this later in our code!)
  - Upper case = random variable, lower case = constant.

Feature Types

- **Numerical**
  - **Continuous**: Features that can take any value in a range, like temperature or velocity.
  - **Discrete**: Features that take a countable number of distinct values, like the number of cats a person owns. (**Binary** features are a special case.)
- **Categorical** (discrete, but not numbers)
  - **Nominal**: Unordered categories like colors (red, green, blue) or genre (drama, comedy, science fiction, etc.).
  - **Ordinal**: Categories with a specific order like educational level (high school, bachelor's, master's) or military rank (private, specialist, corporal, etc.)
- **Text/String**
- **Image**
- Others?

Feature Types

- Non-numerical features are often converted into numerical features to make them easier to work with.
  - Categorical features map to integers: “Sunday”→0, “Monday”→1, “Tuesday”→2, etc.
  - Images can be converted to sequences of (r,g,b) values describing each pixel.
  - Text can be converted to discrete or continuous features
    - Discrete: Each word (or part of a word) maps to a unique integer.
      - Each basic unit of text (word, character, or subword) is called a **token**.
    - Continuous: Each word can be mapped to a vector of real numbers. This is called a **word embedding**. Ideally, similar words are mapped to similar vectors of numbers. Word embeddings are themselves learned from data.

DATA

5 tensors found
Word2Vec 10K

Label by
word

Color by
No color map

Edit by
word

Tag selection as

Load | Publish | Download | Label

Sphereize data

Checkpoint: Demo datasets

Metadata: oss_data/word2vec_10000_200d_labels.tsv

UMAP | T-SNE | PCA | CUSTOM

Points: 10000 | Dimension: 200 | Selected 101 points

rescue

word rescue
count 291

Show All Data | Isolate 101 points | Clear selection

Search .* by word

neighbors 100

distance COSINE EUCLIDEAN

Nearest points in the original space:

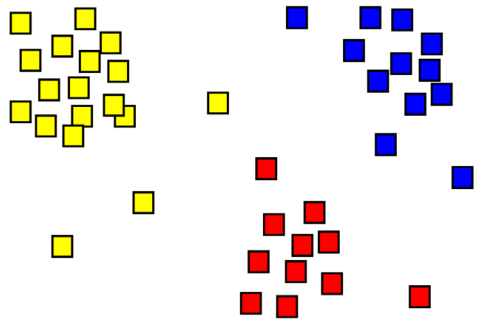
search	0.650
destroy	0.654
crew	0.660
help	0.674
aid	0.679
save	0.694
enemy	0.704
desperate	0.708
mission	0.709
boat	0.713
attack	0.713
disaster	0.713
pilots	0.715
survivors	0.716
jaguar	0.716
kill	0.719
humanitarian	0.719
landing	0.721
assist	0.721
restore	0.732
repair	0.732
launch	0.737
clean	0.739
combat	0.740
training	0.741
shore	0.741
supplies	0.741
aboard	0.741
relief	0.742

Why “Supervised”?

- In **supervised learning**, each data point includes a label Y indicating what the ML algorithm should provide at output when presented with input X.
  - This label provides supervision for the ML algorithm, telling it what it should do.
- In **unsupervised learning**, data points do not have labels.
  - The ML algorithm sees inputs, but has no supervision telling it what it should or should not do when presented with different inputs.
- In **reinforcement learning**, the ML algorithm is told how good its outputs were, but not what the correct outputs would have been.

Unsupervised Learning

- Learning word embeddings is one example of unsupervised learning.
- **Clustering** is another common example of unsupervised learning.
- Clustering algorithms try to identify groups of similar inputs.
- Example: Given images of hand-written letters, we may want to identify the number of different letters in the alphabet and learn to distinguish between them.



Regression and Classification

- Within supervised learning, recall that a data set is a set of input-output pairs (X, Y).
- **Regression**: Y is a continuous number.
  - Multivariate Regression: Y is a vector. That is, $Y \in \mathbb{R}^m$ and $m > 1$.
- **Classification**: Y is categorical (mapped to an integer).
  - Binary Classification: $Y \in \{0,1\}$ or $Y \in \{-1,1\}$.
  - Multi-Class Classification: $Y \in \{0,1, \ldots, k\}$.

Regression ($Y \in \mathbb{R}$) or Classification ($Y \in \mathbb{Z}$)?

- Predict the location of the nearest pedestrian from an image or video taken from a car.
  - Multivariate regression
- Predict how long a person will live based on their age, gender, address, and other health indicators.
  - Regression or classification
- Predict whether a person will repay a loan.
  - Binary classification
- Predict the rating that a person would give to a movie.
  - Depends on the rating scale.

Data Set Storage

- There is no agreed upon format for storing data sets.
  - Sometimes they are in plaintext, other times they are not.
  - When in plaintext, they are often in CSV (comma separated values) files.
    - In other cases, they use semicolons or other symbols to separate values.
  - Sometimes separate files store headers saying what each feature is, other times this header is included at the start of the file.

```
physics_exam,biology_exam,history_exam,second_language_exam,geography_exam,literature_exam,portuguese_essay_exam,math_exam,chemistry_exam,gpa
622.6,491.56,439.93,707.64,663.65,557.09,711.37,731.31,509.8,1.33333
```

```
39, State-gov, 77516, Bachelors, 13, Never-married, Adm-clerical, Not-in-family, White, Male, 2174, 0, 40, United-States, <=50K
50, Self-emp-not-inc, 83311, Bachelors, 13, Married-civ-spouse, Exec-managerial, Husband, White, Male, 0, 0, 13, United-States, <=50K
```

Data Set Representation

- There is no agreed upon way of storing data in software.
  - The entire data set could be one large matrix (two-dimensional array).
  - The data set could be stored as an array of points, each having an X component and a Y component.
  - More commonly, the X values can be stored separately from the Y values.
    - The X values can be stored as a matrix.
    - The X values can be stored as an array of arrays (vector of vectors).
    - These structures could be built in structures in your programming language, or structures built for efficient linear algebra operations.
- One *common* way in python is using the **pandas** library.

See “2.1 Pandas and Datasets.ipynb”

Intermission

- Class will resume in 5 minutes.
- Feel free to:
  - Stand up and stretch.
  - Leave the room.
  - Talk to those around you.
  - **Write a question on a notecard and add it to the stack at the front of the room.**