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# 6.390 Intro to Machine Learning

Midterm Review

Shen Shen

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# Outline

- Rundown
- Past Exam
- Q&A

# Week 1 - IntroML

- Terminologies
  - Training, validation, testing
  - Identifying overfitting, underfitting
- Concrete process
  - Learning algorithm
  - Cross-validation
  - Concept of hyperparameter

# Week 2 - Regression

- Problem Setup
- Analytical solution formula  $\theta^* = \left(\tilde{X}^\top \tilde{X}\right)^{-1} \tilde{X}^\top \tilde{Y}$  (what's  $\tilde{X}$ )
- When  $\tilde{X}^\top \tilde{X}$  not invertible (solutions still exist; just not via the "formula")
  - Practically (two scenarios)
  - Visually (obj fun no longer "bowl" shape, "half-pipe" shape)
  - Mathematically (loss of solution uniqueness)
- Regularization
  - Motivation, how to, when to.
- Cross-validation

# Week 3 - Gradient Descent

- Gradient vector
- The algorithm, gradient-descent formula
- How does "stochastic" gradient descent differ
- (Convex + small-enough step-size + gradient descent) guarantees convergence to global min (when global min exists)
  - If not convex, can e.g. get stuck in local min
  - If step-size too big, can diverge
  - If stochastic gradient descent, can be "wild"

# Week 4 - Classification

- (Binary) linear classifier (sign based)
- (Binary) Linear logistic classifier
  - Sigmoid
  - NLL loss
- Linear separator (equation form, pictorial form with normal vector)
- Linear separability
- How to handle multiple classes
  - Softmax generalization
  - Multiple sigmoids
  - One-vs-one, one-vs-all

# Week 5 - Features

- Feature transformations
  - Applying a fixed feature transformation
  - Hand-design a good feature transformation (e.g. towards getting linear separability)
  - Interplay between number of features, quality of features, and quality of learning algorithms
- Feature encoding
  - One-hot, thermometer, factored, numerical, standardization

# Week 6 - Neural Networks

- Forward-pass (for evaluation)
- Backward-pass (via backpropagation, for optimization)
- Source of expressiveness
- Output layer design
  - dimension, activation, loss
- Hand-design weights
  - to match some given function form
  - achieve some goal (e.g. separate a given data set)



```
1 import random
2 terms= ["fall2023", "spring2023", "fall2022", "spring2022",
3         "fall2021", "fall2019", "fall2018", "fall2018"]
4 qunums = range(1,9)
5 base_URL = "https://introml.mit.edu/_static/spring24/midterm/review/midterm-"
6
7 term = random.choice(terms)
8 num = random.choice(qunums)
9 print("term:", term)
10 print("question number:", num)
11 print(f"Link: {base_URL+term}.pdf")
```

## Review Question Sampler

# General problem-solving tips

## **Polya's Problem Solving Techniques**

In 1945 George Polya published the book *How To Solve It* which quickly became his most prized publication. It sold over one million copies and has been translated into 17 languages. In this book he identifies four basic principles of problem solving.

## **Polya's First Principle: Understand the problem**

This seems so obvious that it is often not even mentioned, yet students are often stymied in their efforts to solve problems simply because they don't understand it fully, or even in part. Polya taught teachers to ask students questions such as:

- Do you understand all the words used in stating the problem?
- What are you asked to find or show?
- Can you restate the problem in your own words?
- Can you think of a picture or diagram that might help you understand the problem?
- Is there enough information to enable you to find a solution?

## Polya's Second Principle: Devise a plan

Polya mentions that there are many reasonable ways to solve problems. The skill at choosing an appropriate strategy is best learned by solving many problems. You will find choosing a strategy increasingly easy. A partial list of strategies is included:

- Guess and check
- Make an orderly list
- Eliminate possibilities
- Use symmetry
- Consider special cases
- Use direct reasoning
- Solve an equation
- Look for a pattern
- Draw a picture
- Solve a simpler problem
- Use a model
- Work backwards
- Use a formula
- Be ingenious

## **Polya's Third Principle: Carry out the plan**

This step is usually easier than devising the plan. In general, all you need is care and patience, given that you have the necessary skills. Persist with the plan that you have chosen. If it continues not to work discard it and choose another. Don't be misled, this is how mathematics is done, even by professionals.

## **Polya's Fourth Principle: Look back**

Polya mentions that much can be gained by taking the time to reflect and look back at what you have done, what worked, and what didn't. Doing this will enable you to predict what strategy to use to solve future problems.

More detailed [CliffsNotes](#)

# General exam tips

- Arrive 5min early to get settled in.
- Bring a watch.
- Bring a pencil (and **eraser**).
- Look over whole exam and strategize for the order you do problems.
- Bring some water.

Good luck!