Overview

Jong-Han Kim

LEO6006 Data Science and Machine Learning for Aerospace Systems

Inha University

Machine learning overview

Overview

- we describe here the general ideas and methods used in machine learning, at a high level
- we will go over all of these topics later, in much more detail
- don't worry if some of this seems abstract at this point, or there are terms you don't know yet

Artificial intelligence approaches

- we would like computers to perform complicated tasks, e.g., medical diagnosis
- distinguish two approaches
  - *knowledge-based*: a computer program whose logic encodes a large number of properties of the world, usually developed by a team of experts over many years
  - *machine learning*: extract information directly from historical data and extrapolate to make predictions
- this class is about machine learning

Machine learning tasks

generic tasks:

- build a *model* from some *data*
  - choose how to map raw data to feature vectors
  - choose a model form
  - choose parameter values in the model
- *test* or *validate* the model
  - evaluate the model on unseen data to assess its performance

model can mean several things, depending on context

Machine learning model taxonomy: supervised vs. unsupervised

- supervised learning models *predict something, given some other things*
  - called a *prediction model*
  - called *regression* when we predict a real scalar or vector value
  - called *classification* when we predict a value from a finite set such as {True; False}
  - called *forecasting* when you predict a future value, given current and past values
- unsupervised learning models just create a model of the data
  - called a *data model*
- the lines between these can be blurred

Machine learning model taxonomy: point vs. probability

- a *point estimate* predicts a single value
- a *probability estimate* predicts a distribution of values
- a *confidence band estimate* predicts a confidence band or interval of values
- a *generative model* generates samples from an estimated distribution

- the lines between these can be blurred

Examples

what kind of models would each of these tasks use?

- predict tomorrow's rainfall, given the date and the last 10 days of rainfall data
- determine from a photo of a face if the user is who she claims to be
- estimate the probability of 10 possible diagnoses, given some patient data, test results
- cluster customers into 22 different groups with similar buying habits
- estimate the risk (probability) of an auto accident at a location given the hour and weather
- build an *anomaly detector*, that rates how suspicious some new data is
- build a *simulator* that generates fake new data that 'looks like' the given data
- build a *recommendation engine* that suggests products a customer might be interested in

Performance metrics

- we judge performance of a model on some data using a *metric* such as
  - mean-square or RMS prediction error (for regression)
  - error rate (for classification)
  - log likelihood (for probabilistic models)
- examples:
  - our predictor predicts tomorrow's maximum temperature with an RMS error of 1.3°C
  - our classifier predicts the topic of a newspaper article (from a set of 50 choices) with an error rate of 5%

Training and validation

- our goal is to develop a model that performs well for *new, unseen data*
- standard practice is to divide the given data set into two parts
  - a *training* data set, used to choose or train the model
  - a *test* or *validation* data set, used to evaluate tentative models
- we can look at the performance metrics on the *training* and *test* data sets
- if the model performs well on the training set, but poorly on the test set, it is *overfit* (and probably useless in practice)
- if the model performs well on the test set, it's likely going to perform well on new unseen data

Learning a model

a common method of choosing a model:

- choose the *model structure* or *form* or *type*
- the model contains a number of *model parameters*
- choose a *loss function* that rates how badly the model performs on a single data point or example
- choose the parameter value by minimizing an average loss over the training data

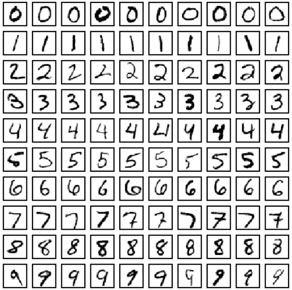
this general scheme, called *empirical risk minimization*, is used to fit a wide variety of models

Examples

Example: diagnosis

- goal is to predict if a patient has a disease, based on whether or not she exhibits 10 symptoms
- historical data consists of a large number of *patient records*
- each record contains
  - 10 Booleans, specifying the presence or absence of the 10 symptoms
  - a Boolean specifying whether that patient had the disease
- machine learning algorithm observes these data, produces a *predictor*
- predictor takes as input 10 Booleans, returns a single Boolean prediction
- this is a *classifier*, since we are predicting an outcome that takes only two values
- we will judge model by its error rate on a separate test set of data, not used to develop the model
- a *probabilistic model* returns a probability that the patient has the disease, not just a Boolean

Example: digit recognition



- 8-bit grayscale images of handwritten digits, 28×28 pixels
- goal is to guess the digit (*i.e.*, $0, \ldots, 9$) from the image
- 60,000 training images, 10,000 test images
- preprocessed by antialiasing, scaling and centering
- data originally by NIST, modified by Le Cun, 1998

Data

- Kaggle: datasets and competitions
- ImageNet dataset: 14m images
- Street view house numbers: 600,000 digit images
- Waymo open dataset: self-driving car data
- many other large datasets

Software

- PyTorch, Keras, TensorFlow, JAX, and many others, . . .
- Scikit-Learn, Spark/MLlib
- Flux, in Julia
- generic packages in R, Matlab, Python, Java, Julia . . .

Core topics

The major parts of the course

1. *regression* — to predict one or more real values
2. *classification* — to predict one of a finite number of possible outcomes
3. *probabilistic supervised learning* — to predict a distribution of outcomes
4. *unsupervised learning* — to develop a data model
5. *optimization* — to fit or choose parameters in all of the models above