CSE 5523: Lecture Notes 1
Introduction and Background

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1.1 Course overview

In the past, computers were used for **solving** equations:

- what trajectory does a rocket need to reach orbit?
- how profitable are each of our stores?
- etc.

Now, computers are used for **finding** equations (and then also solving them):

- what is the distinction between faces and other images / 'ee' sounds and other sounds?
- what is the distinction between products customers buy and products they don't?
- what kinds of customers do we have?
- how should I invest in order to retire rich?
- etc.

That's machine learning!

There are several different kinds of learning we will look at, based on feedback (labels) in training:

- **supervised** learning: find equations to distinguish **familiar outcomes** (products bought/not)

  This requires training data with labels (may be expensive).
- **unsupervised** learning: find equations to distinguish **new clusters** in data (customer types)

  This uses unlabeled training data.
- **reinforcement** learning (if time): find equations for decisions to maximize some **reward**

  This requires training data with rewards (a type of label).

1.2 Background: some math notation (in case you don't know)

Set notation, involving **sets** S, S' and **entities** $x, x', x'', x_1, x_2, x_3, \ldots$:

pair	$\langle x_1, x_2 \rangle$
tuple	$\langle x_1, x_2, x_3, ... \rangle$
set	$S = \{x \mid ...\}$ e.g. $\{x_1, x_2, x_3\}$
empty/null set	$\emptyset$ or $\{\}$
element	$x \in S$ e.g. $x_2 \in \{x_1, x_2\}$, $x_3 \notin \{x_1, x_2\}$
subset (or equal)	$S \subset S'$ e.g. $\{x_1, x_2\} \subset \{x_1, x_2, x_3\}$, $\{x_1, x_2\} \subseteq \{x_1, x_2\}$
union	$S \cup S'$ e.g. $\{x_1, x_2\} \cup \{x_2, x_3\} = \{x_1, x_2, x_3\}$
intersection	$S \cap S'$ e.g. $\{x_1, x_2\} \cap \{x_2, x_3\} = \{x_2\}$
exclusion or complementation	$S - S'$ e.g. $\{x_1, x_2\} - \{x_2, x_3\} = \{x_1\}$
Cartesian product	$S \times S'$ e.g. $\{x_1, x_2\} \times \{x_3, x_4\} = \{\langle x_1, x_3\rangle, \langle x_1, x_4\rangle, \langle x_2, x_3\rangle, \langle x_2, x_4\rangle\}$
power set	$\mathcal{P}(S)$ or 2^S e.g. $\mathcal{P}(\{x_1, x_2\}) = \{\emptyset, \{x_1\}, \{x_2\}, \{x_1, x_2\}\}$
relation	$R \subseteq S \times S' = \{\langle x, x' \rangle \mid ...\}$ e.g. $R = \{\langle x_1, x_3\rangle, \langle x_2, x_3\rangle, \langle x_2, x_4\rangle\}$
function	$F : S \to S' \subseteq S \times S'$ s.t. if $\langle x, x'\rangle, \langle x, x''\rangle \in F$ then $x' = x''$
cardinality	$\lvert S \rvert$ = number of elements in S
integers	$\mathbb{Z}$: the countably infinite set of integers
integer ranges	$\mathbb{Z}_m^n$: the set of integers between m and n (inclusive)
integer tuples	$\mathbb{Z}^n$: the countably infinite set of n-tuples of integers
real numbers	$\mathbb{R}$: the uncountably infinite set of real numbers
real ranges	$\mathbb{R}_m^n$: the real numbers between m and n (inclusive)
real tuples	$\mathbb{R}^n$: the uncountably infinite set of n-tuples of reals

First-order logic notation, involving **propositions** p, p' – e.g. that $1<2$ (true) or $1=2$ (false):

conjunction	$p \wedge p'$ or p, p' e.g. $1<2 \wedge 2<3$ or $1<2, 2<3$
disjunction	$p \vee p'$ e.g. $1<2 \vee 1>2$
negation	$\neg p$ or '/' e.g. $\neg 1=2$ or $1 \neq 2$
existential quantifier	$\exists_{x \in S} \ldots x \ldots$: disjunction over all x of proposition $\ldots x \ldots$
universal quantifier	$\forall_{x \in S} \ldots x \ldots$: conjunction over all x of proposition $\ldots x \ldots$
indicator	$[\![p]\!]$: 1 if p is true, 0 otherwise

Limit notation, involving **sets** S and **entities** x:

existential quantifier	$\bigvee_{x \in S} \ldots x \ldots$:	disjunction over all x of proposition $\ldots x \ldots$
universal quantifier	$\bigwedge_{x \in S} \ldots x \ldots$:	conjunction over all x of proposition $\ldots x \ldots$
limit union	$\bigcup_{x \in S} \ldots x \ldots$:	union over all x of set $\ldots x \ldots$
limit intersection	$\bigcap_{x \in S} \ldots x \ldots$:	intersection over all x of set $\ldots x \ldots$
limit Cartesian product	$\bigtimes_{x \in S} \ldots x \ldots$:	Cartesian product over all x of set $\ldots x \ldots$
limit sum	$\sum_{x \in S} \ldots x \ldots$:	sum over all x of number $\ldots x \ldots$
limit product	$\prod_{x \in S} \ldots x \ldots$:	product over all x of number $\ldots x \ldots$
maximum	$\max_{x \in S} \ldots x \ldots$:	maximum over all x in S of number $\ldots x \ldots$
minimum	$\min_{x \in S} \ldots x \ldots$:	minimum over all x in S of number $\ldots x \ldots$
maximizing argument	$\operatorname{argmax}_{x \in S} \ldots x \ldots$:	value of x in S that maximizes number $\ldots x \ldots$
minimizing argument	$\operatorname{argmin}_{x \in S} \ldots x \ldots$:	value of x in S that minimizes number $\ldots x \ldots$