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## Table of Notations

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| $\cap$ Intersection of sets $A - B, A \setminus B$ Set difference $\overline{A}$ The complement of set $A$ $\oslash$ The complement of set $A$ $\oslash$ The empty set $2^A, \mathcal{P}(A)$ The power set of $A$ $ A $ Cardinality of a set $\Sigma$ Sum $\Pi$ Product $p \Rightarrow q$ $p$ implies $q$ (logical inference) $p \Rightarrow q$ $p$ and $q$ are logically equivalent $\coprod$ Defined to be equal to (only used if "=" is ambiguous) $\mathbb{R}$ The set of real numbers $n!$ The factorial of $n$ $\infty$ Infinity $ x $ Absolute value of a number $\ll$ Much smaller than $\gg$ Much greater than $p \Rightarrow A$ The naximum value of $f$  | U                         | Union of sets  |
|---|---------------------------|--|
| $\overline{A}$ The complement of set $A$ $\varnothing$ The empty set $2^A, \mathcal{P}(A)$ The power set of $A$ $ A $ Cardinality of a set $\sum$ Sum $\prod$ Product $p \Rightarrow q$ $p$ implies $q$ (logical inference) $p \Rightarrow q$ $p$ and $q$ are logically equivalent $\coprod$ Defined to be equal to (only used if "=" is ambiguous) $\mathbb{R}$ The set of real numbers $N$ The set of natural numbers $n!$ The factorial of $n$ $\infty$ Infinity $ x $ Absolute value of a number $\ll$ Much smaller than $\gg$ Much greater than $\Rightarrow$ A function $f$ from values in $A$ to $B$   | $\cap$                    | Intersection of sets                                   |
| $\varnothing$ The empty set $2^A, \mathcal{P}(A)$ The power set of $A$ $ A $ Cardinality of a set $\Sigma$ Sum $\Pi$ Product $p \Rightarrow q$ $p$ implies $q$ (logical inference) $p \Leftrightarrow q$ $p$ and $q$ are logically equivalent $\stackrel{\earrow}{=}$ Defined to be equal to (only used if "=" is ambiguous) $\mathbb{R}$ The set of real numbers $\mathbb{N}$ The set of natural numbers $n!$ The factorial of $n$ $\infty$ Infinity $ x $ Absolute value of a number $\ll$ Much smaller than $\gg$ Much greater than $f: A \rightarrow B$ A function $f$ from values in $A$ to $B$  | $A - B$ , $A \setminus B$ | Set difference   |
| $2^A, \mathcal{P}(A)$ The power set of $A$ $ A $ Cardinality of a set $\Sigma$ Sum $\Pi$ Product $p \Rightarrow q$ $p$ implies $q$ (logical inference) $p \Leftrightarrow q$ $p$ and $q$ are logically equivalent $\underline{\underline{\#}}$ Defined to be equal to (only used if "=" is ambiguous) $\mathbb{R}$ The set of real numbers $\mathbb{N}$ The set of natural numbers $n!$ The factorial of $n$ $\infty$ Infinity $ x $ Absolute value of a number $\ll$ Much smaller than $\gg$ Much greater than $f: A \rightarrow B$ A function $f$ from values in $A$ to $B$   | $\overline{A}$            | The complement of set <i>A</i>                         |
| $ A $ Cardinality of a set $\Sigma$ Sum $\Pi$ Product $p \Rightarrow q$ $p$ implies $q$ (logical inference) $p \Rightarrow q$ $p$ and $q$ are logically equivalent $\cong$ Defined to be equal to (only used if "=" is ambiguous) $\mathbb{R}$ The set of real numbers $\mathbb{N}$ The set of natural numbers $n!$ The factorial of $n$ $\infty$ Infinity $ x $ Absolute value of a number $\ll$ Much smaller than $\gg$ Much greater than $f: A \rightarrow B$ A function $f$ from values in $A$ to $B$   | Ø                         | The empty set  |
| $\sum$ Sum $\prod$ Product $p \Rightarrow q$ $p$ implies $q$ (logical inference) $p \Rightarrow q$ $p$ and $q$ are logically equivalent   | $2^A$ , $\mathcal{P}(A)$  | The power set of A                                     |
| $\square$ Product $p \Rightarrow q$ $p$ implies $q$ (logical inference) $p \Rightarrow q$ $p$ and $q$ are logically equivalent $\blacksquare$ $p$ and $q$ are logically equivalent $\blacksquare$ Defined to be equal to (only used if "=" is ambiguous) $\mathbb{R}$ The set of real numbers $\mathbb{N}$ The set of natural numbers $n!$ The factorial of $n$ $\infty$ Infinity $ x $ Absolute value of a number $\ll$ Much smaller than $\gg$ Much greater than $f: A \rightarrow B$ A function $f$ from values in $A$ to $B$  | A                         | Cardinality of a set                                   |
| $p \Rightarrow q$ $p$ implies $q$ (logical inference) $p \Rightarrow q$ $p$ and $q$ are logically equivalent $factorialp and q are logically equivalentfactorialp are logical numberfactorialp are lo$ | Σ                         | Sum  |
| $p \Leftrightarrow q$ $p$ and $q$ are logically equivalent  | П                         | Product  |
| $\underline{*}$ Defined to be equal to (only used if "=" is ambiguous) $\mathbb{R}$ The set of real numbers $\mathbb{N}$ The set of natural numbers $n!$ The factorial of $n$ $\infty$ Infinity $ x $ Absolute value of a number $\ll$ Much smaller than $\gg$ Much greater than $f: A \rightarrow B$ A function $f$ from values in $A$ to $B$  | $p \Rightarrow q$         | p implies $q$ (logical inference)                      |
| $\mathbb{R}$ The set of real numbers $\mathbb{N}$ The set of natural numbers $n!$ The factorial of $n$ $\infty$ Infinity $ x $ Absolute value of a number $\ll$ Much smaller than $\gg$ Much greater than $f: A \rightarrow B$ A function $f$ from values in $A$ to $B$   | $p \Leftrightarrow q$     | p and $q$ are logically equivalent                     |
| $\mathbb{N}$ The set of natural numbers $n!$ The factorial of $n$ $\infty$ Infinity $ x $ Absolute value of a number $\ll$ Much smaller than $\gg$ Much greater than $f: A \rightarrow B$ A function $f$ from values in $A$ to $B$  | def                       | Defined to be equal to (only used if "=" is ambiguous) |
| $n!$ The factorial of $n$ $\infty$ Infinity $ x $ Absolute value of a number $\ll$ Much smaller than $\gg$ Much greater than $f: A \rightarrow B$ A function $f$ from values in $A$ to $B$  | R                         | The set of real numbers                                |
| $\infty$ Infinity $ x $ Absolute value of a number $\ll$ Much smaller than $\gg$ Much greater than $f: A \rightarrow B$ A function f from values in A to B  | $\bowtie$                 | The set of natural numbers                             |
| $ x $ Absolute value of a number $\ll$ Much smaller than $\gg$ Much greater than $f: A \rightarrow B$ A function f from values in A to B  | <i>n</i> !                | The factorial of <i>n</i>                              |
| $\ll$ Much smaller than $\gg$ Much greater than $f: A \rightarrow B$ A function f from values in A to B   | $\infty$                  | Infinity   |
| >>Much greater than $f: A \rightarrow B$ A function f from values in A to B   | <i>x</i>                  | Absolute value of a number                             |
| $f: A \to B$ A function $f$ from values in $A$ to $B$   | «                         | Much smaller than                                      |
|   | >>                        | Much greater than                                      |
| $\max f$ The maximum value of $f$   | $f: A \to B$              | A function $f$ from values in $A$ to $B$               |
|   | $\max f$                  | The maximum value of $f$                               |

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| $\min f$                            | The minimum value of $f$   |
|-------------------------------------|--|
| $\arg \max f$                       | The argument for which $f$ has its maximum value   |
| arg min f                           | The argument for which $f$ has its minimum value   |
| $\lim_{x\to\infty}f(x)$             | The limit of $f$ as $x$ tends to infinity  |
| $f \propto g$                       | f is proportional to $g$   |
| 9                                   | Partial derivative   |
| ſ                                   | Integral   |
| $\log a$                            | The logarithm of <i>a</i>  |
| $\exp(x), e^x$                      | The exponential function   |
| [ <i>a</i> ]                        | The smallest integer <i>i</i> s.t. $i \ge a$   |
| x                                   | A real-valued vector: $\vec{x} \in \mathbb{R}^n$   |
| $ \vec{x} $                         | Euclidean length of $\vec{x}$  |
| $\vec{x} \cdot \vec{y}$             | The dot product of $\vec{x}$ and $\vec{y}$   |
| $\cos(\vec{x}, \vec{y})$            | The cosine of the angle between $\vec{x}$ and $\vec{y}$                                    |
| $C_{ij}$                            | Element in row $i$ and column $j$ of matrix $C$  |
| $C^{\mathrm{T}}$                    | Transpose of matrix <i>C</i>   |
| $\hat{X}$                           | Estimate of <i>X</i>   |
| E(X)                                | Expectation of <i>X</i>  |
| Var(X)                              | Variance of <i>X</i>   |
| μ                                   | Mean   |
| $\sigma$                            | Standard deviation   |
| <i>X</i>                            | Sample mean  |
| $s^2$                               | Sample variance  |
| P(A B)                              | The probability of <i>A</i> conditional on <i>B</i>  |
| $X \sim \mathbf{p}(\mathbf{x})$     | Random variable $X$ is distributed according to p  |
| b( <i>r</i> ; <i>n</i> , <i>p</i> ) | The binomial distribution  |
| $\binom{n}{r}$                      | Combination or binomial coefficient (the number of ways of choosing $r$ objects from $n$ ) |
| n(x; $\mu, \sigma$ )                | The normal distribution  |
| H(X)                                | Entropy  |

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*Table of Notations* 

| I(X; Y)                              | Mutual information  |
|--------------------------------------|---|
| $D(\mathbf{p} \parallel \mathbf{q})$ | Kullback-Leibler (KL) divergence                                |
| $C(\cdot)$                           | Count of the entity in parentheses                              |
| fu                                   | The relative frequency of <i>u</i> .                            |
| $W_{ij}, W_{(i)(j)}$                 | The words $w_i, w_{i+1}, \ldots, w_j$                           |
| $W_{i,j}$                            | The same as $w_{ij}$  |
| $W_i,\ldots,W_j$                     | The same as $w_{ij}$  |
| O(n)                                 | Time complexity of an algorithm                                 |
| *                                    | Ungrammatical sentence or phrase or ill-formed word             |
| ?                                    | Marginally grammatical sentence or marginally acceptable phrase |

**Note.** Some chapters have separate notation tables for symbols that are used locally: table 6.2 (Statistical Inference), table 7.1 (Word Sense Disambiguation), table 9.1 (Markov Models), table 10.2 (Tagging), table 11.1 (Probabilistic Context-Free Grammars), and table 14.2 (Clustering).

xxvii

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