

Statistical and Causal Models

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Probability Theory and Statistics

- Probability Theory: Reason about the outcomes of random experiments, given the preceding mathematical structure.
- Statistical Learning: Given the outcomes of experiments, infer properties of the underlying mathematical structure.

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Difference

- Infer structure rather than distribution
- Different training and testing distributions

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Relationship

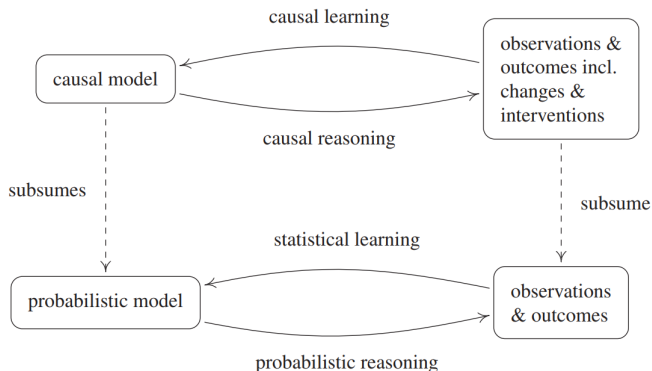


Figure 1.1: Terminology used by the present book for various **probabilistic inference** problems (bottom) and **causal inference** problems (top); see Section 1.3. Note that we use the term “inference” to include both learning and reasoning.

Reichenbach's common cause principle

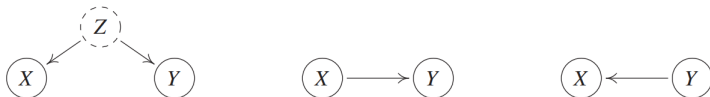


Figure 1.2: Reichenbach's common cause principle establishes a link between statistical properties and causal structures. A *statistical* dependence between two observables X and Y indicates that they are *caused* by a variable Z , often referred to as a **confounder** (left). Here, Z may coincide with either X or Y , in which case the figure simplifies (middle/right). The principle further argues that X and Y are statistically independent, conditional on Z . In this figure, direct causation is indicated by arrows; see Chapters 3 and 6.

Principle 1.1 (Reichenbach's common cause principle) *If two random variables X and Y are statistically dependent ($X \not\perp Y$), then there exists a third variable Z that causally influences both. (As a special case, Z may coincide with either X or Y .) Furthermore, this variable Z screens X and Y from each other in the sense that given Z , they become independent, $X \perp Y | Z$.*

Correlation does not imply causation.

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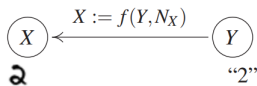
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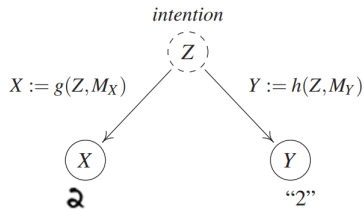
Causal Modeling and Learning

Example

Optical Character Recognition



Model (i); Y, N_X independent



Model (ii); Z, M_X, M_Y independent