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Placement of the \neg operator is very important!

$$\neg \exists x \in P : \text{IsCarOwner}(x)$$

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$\neg \exists x \in P : IsCarOwner(x)$ It is not the case that someone has a car.

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$\neg \exists x \in P : \neg IsCarOwner(x)$ No one is without a car.

Multiple Quantifiers

If a predicate has more than 1 variable, we might apply more than 1 quantifier.

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Every integer has a square that is a positive integer:

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Define predicate isPerfectSquare:

$$\forall x \in \mathcal{I} : \text{IsPerfectSquare}(x) \leftrightarrow (\exists y \in \mathcal{I} : x = y^2)$$

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Formulas

- ▶ If p is an n -argument predicate, and each of a_1, \dots, a_n is either an element of a domain \mathcal{U} , or a variable over a domain, then $p(a_1, \dots, a_n)$ is a formula. By convention, a predicate with $n = 0$ arguments is a simple Boolean variable.
- ▶ If α is a formula and β is a formula, then $\neg\alpha$, $(\alpha \vee \beta)$ and $(\alpha \wedge \beta)$ are formulas.
- ▶ If α is a formula and x is a variable over a domain, then $(\exists x : \alpha)$ and $(\forall x : \alpha)$ are formulas.

More Examples: Character Arrays

Let $A = (a_1, \dots, a_n)$ and $B = (b_1, \dots, b_n)$ be sequences of characters.

\prec : predicate meaning x comes before y lexicographically. E.g. $b \prec d \equiv \text{True}$.

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What does the following formula mean (in English)?

$$\forall i \in \mathcal{I}_{n-1} : a_i \prec a_{i+1}$$

More Examples: Graphs

Undirected Graph $G = (V, E)$:

V is a set of vertices, and

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Give a formula for the following English sentence:

Every pair of vertices has a path of length 2.

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$\forall x \in V : \forall y \in V : \exists z \in V : ((x, z) \in E) \wedge ((y, z) \in E)$

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Exercise

Let $V = \{a, b, c, d\}$

Case a) $\text{Edge}(a,b) = \text{Edge}(b,c) = \text{Edge}(b,d) = \text{TRUE}$

Case b) $\text{Edge}(a,b) = \text{Edge}(b,c) = \text{Edge}(c,d) = \text{TRUE}$

$\forall x \in V : \forall y \in V : (x \neq y) \rightarrow \text{Edge}(x,y)$

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