

mat.1 Expressing the Size of Structures

fol:mat:siz:
sec

There are some properties of structures we can express even without using the non-logical symbols of a language. For instance, there are sentences which are true in a structure iff the domain of the structure has at least, at most, or exactly a certain number n of elements. explanation

Proposition mat.1. *The sentence*

$$\begin{aligned} \varphi_{\geq n} \equiv \exists x_1 \exists x_2 \dots \exists x_n \quad & (x_1 \neq x_2 \wedge x_1 \neq x_3 \wedge x_1 \neq x_4 \wedge \dots \wedge x_1 \neq x_n \wedge \\ & x_2 \neq x_3 \wedge x_2 \neq x_4 \wedge \dots \wedge x_2 \neq x_n \wedge \\ & \vdots \\ & x_{n-1} \neq x_n) \end{aligned}$$

is true in a structure \mathfrak{M} iff $|\mathfrak{M}|$ contains at least n elements. Consequently, $\mathfrak{M} \models \neg\varphi_{\geq n+1}$ iff $|\mathfrak{M}|$ contains at most n elements.

Proposition mat.2. *The sentence*

$$\begin{aligned} \varphi_{=n} \equiv \exists x_1 \exists x_2 \dots \exists x_n \quad & (x_1 \neq x_2 \wedge x_1 \neq x_3 \wedge x_1 \neq x_4 \wedge \dots \wedge x_1 \neq x_n \wedge \\ & x_2 \neq x_3 \wedge x_2 \neq x_4 \wedge \dots \wedge x_2 \neq x_n \wedge \\ & \vdots \\ & x_{n-1} \neq x_n \wedge \\ & \forall y (y = x_1 \vee \dots \vee y = x_n) \dots) \end{aligned}$$

is true in a structure \mathfrak{M} iff $|\mathfrak{M}|$ contains exactly n elements.

Proposition mat.3. *A structure is infinite iff it is a model of*

$$\{\varphi_{\geq 1}, \varphi_{\geq 2}, \varphi_{\geq 3}, \dots\}$$

There is no single purely logical sentence which is true in \mathfrak{M} iff $|\mathfrak{M}|$ is infinite. However, one can give sentences with non-logical predicate symbols which only have infinite models (although not every infinite structure is a model of them). The property of being a finite structure, and the property of being a non-enumerable structure cannot even be expressed with an infinite set of sentences. These facts follow from the compactness and Löwenheim-Skolem theorems.

Photo Credits

Bibliography