

int.1 λ -Definable Arithmetical Functions

lam:int:rep:
sec How can the lambda calculus serve as a model of computation? At first, it is not even clear how to make sense of this statement. To talk about computability on the natural numbers, we need to find a suitable representation for such numbers. Here is one that works surprisingly well.

Definition int.1. For each natural number n , define the *Church numeral* \bar{n} to be the lambda term $\lambda x. \lambda y. (x(x(x(\dots x(y))))))$, where there are n x 's in all.

The terms \bar{n} are “iterators”: on input f , \bar{n} returns the function mapping y to $f^n(y)$. Note that each numeral is normal. We can now say what it means for a lambda term to “compute” a function on the natural numbers.

Definition int.2. Let $f(x_0, \dots, x_{k-1})$ be an n -ary partial function from \mathbb{N} to \mathbb{N} . We say a λ -term F *λ -defines* f iff for every sequence of natural numbers n_0, \dots, n_{k-1} ,

$$F \overline{n_0} \overline{n_1} \dots \overline{n_{k-1}} \twoheadrightarrow \overline{f(n_0, n_1, \dots, n_{k-1})}$$

if $f(n_0, \dots, n_{k-1})$ is defined, and $F, \overline{n_0} \overline{n_1} \dots \overline{n_{k-1}}$ has no normal form otherwise.

lam:int:rep:
thm:lambda-def **Theorem int.3.** *A function f is a partial computable function if and only if it is λ -defined by a lambda term.*

This theorem is somewhat striking. As a model of computation, the lambda explanation calculus is a rather simple calculus; the only operations are lambda abstraction and application! From these meager resources, however, it is possible to implement any computational procedure.

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Bibliography