

PAPER

A general framework for the semantics of type theory

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Abstract

We propose an abstract notion of a type theory to unify the semantics of various type theories including Martin-Lof type theory, two-level type theory, and cubical type theory. We establish basic results in the semantics of type theory: every type theory has a bi-initial model; every model of a type theory has its internal language; the category of theories over a type theory is bi-equivalent to a full sub-2-category of the 2-category of models of the type theory.

Keywords: Dependent type theory; Natural model; Category with families; Logical framework; Representable map; Representable map category

1. Introduction

One of the key steps in the semantics of type theory and logic is to establish a correspondence between theories and models. Every theory generates a model called its syntactic model, and every model has a theory called its internal language. Classical examples are simply typed λ-calculi and cartesian closed categories (Lambek and Scott 1986); generalized algebraic theories and contextual categories (Cartmell 1978); extensional Martin−Löf theories and locally cartesian closed categories (Seely 1984); first-order theories and hyperdoctrines (Seely 1983); higher order theories and elementary toposes (Lambek and Scott 1986). Recently, homotopy type theory (The Univalent Foundations Program 2013) is expected to provide an internal language for what should be called "elementary (∞, 1)-toposes." As a first step, Kapulkin and Szumiło (2019) showed that there is an equivalence between intensional Martin−Löf theories and finitely complete (∞, 1)-categories.

As there exist correspondences between theories and models for almost all type theories and logics, it is natural to ask if one can define a general notion of a type theory or logic and establish correspondences between theories and models uniformly. First, we clarify what we informally mean by "type theory," "logic," "theory," and "model". By a type theory or logic, we mean a formal system for deriving judgments which is specified by a collection of inference rules. For example, first-order logic is a logic and has inference rules for logical connectives and quantifiers such as \land and \lor . For a type theory or logic \Tau , by a \Tau -theory or theory over \Tau we mean a set of constants and axioms written in \Tau , while by a model of \Tau we mean a mathematical structure that admits an interpretation of the inference rules of \Tau . For example, a first-order theory is a theory over first-order logic and consists of type constants, term constants, predicate constants, and axioms, while a hyperdoctrine is a model of first-order logic and interprets, for instance, the universal quantifier \lor as a right adjoint.

A successful syntactic approach to defining general type theories and logics is a logical framework such as the Edinburgh Logical Framework (Harper et al. 1993) and Martin-Löf's logical

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designing the user interface The following section examines those issues in the AI field that are currently of greatest interest to designers and human factors specialists including such problems as natural language interface and methods for knowledge acquisition The last section includes social aspects in computer usage the impact on work organizations and work General Semantics Bulletin Harry L Weinberg, 1996-10 The SAGE Encyclopedia of Communication Research Methods Mike Allen, 2017-04-11 Communication research is evolving and changing in a world of online journals open access and new ways of obtaining data and conducting experiments via the Internet Although there are generic encyclopedias describing basic social science research methodologies in general until now there has been no comprehensive A to Z reference work exploring methods specific to communication and media studies Our entries authored by key figures in the field focus on special considerations when applied specifically to communication research accompanied by engaging examples from the literature of communication journalism and media studies Entries cover every step of the research process from the creative development of research topics and questions to literature reviews selection of best methods whether quantitative qualitative or mixed for analyzing research results and publishing research findings whether in traditional media or via new media outlets In addition to expected entries covering the basics of theories and methods traditionally used in communication research other entries discuss important trends influencing the future of that research including contemporary practical issues students will face in communication professions the influences of globalization on research use of new recording technologies in fieldwork and the challenges and opportunities related to studying online multi media environments Email texting cellphone video and blogging are shown not only as topics of research but also as means of collecting and analyzing data Still other entries delve into considerations of accountability copyright confidentiality data ownership and security privacy and other aspects of conducting an ethical research program Features 652 signed entries are contained in an authoritative work spanning four volumes available in choice of electronic or print formats Although organized A to Z front matter includes a Reader's Guide grouping entries thematically to help students interested in a specific aspect of communication research to more easily locate directly related entries Back matter includes a Chronology of the development of the field of communication research a Resource Guide to classic books journals and associations a Glossary introducing the terminology of the field and a detailed Index Entries conclude with References Further Readings and Cross References to related entries to guide students further in their research journeys The Index Reader's Guide themes and Cross References combine to provide robust search and browse in the e version **Resources in Education** ,1998-07 Catalog of Copyright Entries. Third Series Library of Congress. Copyright Office, 1976 **Oualitative** Research Methods Sarah J. Tracy, 2012-11-05 Qualitative Research Methods is a comprehensive all inclusive resource for the theory and practice of qualitative ethnographic research methodology Serves as a how to guide for qualitative ethnographic research detailing how to design a project conduct interviews and focus groups interpret and analyze data and represent it in

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