

CSCI-B619 Topics in Applied Logic: Modern Dependent Types

Carlo Angiuli

Spring 2024

Location: Mondays and Wednesdays, 1:15pm–2:30pm, Ballantine Hall 006.

Instructor: Carlo Angiuli (cangiuli@indiana.edu), Luddy Hall 3008.

Office hours: Wednesdays, 2:45pm–4:00pm, or by appointment, or by finding me.

Website: carloangiuli.com/courses/b619-sp24

Course description

This is a graduate seminar on the modern design of full-spectrum dependent type theories, such as the core calculi of proof assistants like Agda, Coq, and Lean. The goal of this course is to prepare students to engage with current research on dependent type theory and to understand the motivations behind recent extensions of these systems. Topics include extensional, intensional, homotopy, and cubical type theory.

By the end of the course, students will understand:

- What is (full-spectrum dependent) type theory?
- What makes a good type theory, and why are there so many?
- Why is equality so central to type theory, and what is the state of the art?

Research projects may naturally arise during the semester for interested students.

The course will be structured in three parts:

- Extensional type theory: substitution calculus and connectives.
- Intensional type theory: implementation considerations and equality.
- Post-intensional type theories: homotopy and cubical type theory.

Prerequisites This course has no formal prerequisites, but I anticipate that most students will start the semester with *at least one* of:

- Basic familiarity with dependent types in practice, e.g., some (perhaps not much) experience using a system such as Agda, Coq, Lean, or Pie.

- CSCI-B522 or familiarity with concepts from programming language theory, particularly λ -calculus, typing judgments, inference rules, β -equivalence, etc.

I will review these topics in class but not in great depth.

Sibling course Lars Birkedal and Daniel Gratzer are concurrently teaching a sibling course on modern dependent type theory at Aarhus University (<https://jozefg.github.io/courses/type-theory-s-2024>).

Course materials

Lecture notes My collaborator Daniel Gratzer and I are writing lecture notes to be posted on the course website and continually updated throughout the semester. These lecture notes are the best reference for what we will cover in class, but they are in early draft form and should be considered experimental. Comments and corrections are very welcome.

There is no textbook, although the lecture notes include many references (including books) that you may wish to consult on occasion. In general, these will be freely available online or at least accessible on campus behind publishers' paywalls.

Agda It may be helpful to have access to a computer with a recent version of Agda installed. I strongly recommend using an editor with good Agda support, which currently means one of Emacs, Neovim, or Visual Studio Code. (If you don't know what these are, use Visual Studio Code.)

Course policies

These policies are subject to change.

Communication Most information will be posted to the course website, but I will send any time-sensitive announcements by email using Canvas. Anyone auditing or informally attending the course should contact me at the beginning of the semester to ensure they receive these announcements. The best ways to contact me are by email, in person after class, or in my office when my door is open.

Attendance Lectures will be primarily conducted at the blackboard and will not be recorded; in addition, many of the perspectives I present may be difficult to find in the literature. It is therefore crucial that you attend lecture. While I am lecturing, I encourage you to stop me whenever you have a question.

Assignments The only way to learn theory is by doing it. No more than weekly, I will assign written problem sets that you will have one week to complete (preferably typeset using \LaTeX). I encourage you to think about these problems by yourself at first, but you are welcome to then discuss them with other students.

The problem sets will be graded, but their main purpose is to force you to think in depth about the topics we have discussed, and to give me a chance to correct any misunderstandings. Toward the end of the semester, I may also ask you to write and/or present a short report on a research paper.

Exams There will be no exams.

Grading Your grade will be based on your participation and assignments.

Because this course is not required for anybody, my expectation is that you are here because you are interested in learning the material; if you demonstrate an understanding of the primary course objectives, you can expect to earn a satisfactory grade.

University policies

Academic integrity Students at IU are expected to adhere to the standards contained in the Code of Student Rights, Responsibilities, & Conduct available at <https://policies.iu.edu/policies/student-code/>. Academic misconduct is defined as any activity that tends to undermine the academic integrity of the institution, including but not limited to cheating, fabrication, plagiarism, interference, violation of course rules, and facilitating academic dishonesty.

Accommodations Every attempt will be made to provide accessibility measures to students with qualifying medical conditions (e.g. mental health, learning, chronic health, physical, hearing, vision, neurological, etc.), under the Americans with Disabilities Act. You must have established your eligibility for support services through Accessible Educational Services (AES) for qualifying medical conditions. Note that services are confidential, may take time to put in place, and are forward moving. Captions and alternate media for print materials may take three or more weeks to get produced. Please contact AES (iubaes@iu.edu) as soon as possible if accessibility measures are needed.

Bias incident reporting Bias-based incident reports can be made by students, faculty, and staff. Any act of discrimination or harassment based on race, ethnicity, religious affiliation, gender, gender identity, sexual orientation or disability can be reported through any of the options:

- fill out an online report at <https://reportincident.iu.edu/>;
- call the Dean of Students Office at (812) 855-8187.

Reports can be made anonymously at <https://reportincident.iu.edu>.

Sexual misconduct & Title IX IU policy prohibits sexual misconduct in any form, including sexual harassment, sexual assault, stalking, sexual exploitation, and dating and domestic violence. If you have experienced sexual misconduct, or know someone who has, the University can help. If you are seeking help and would like to speak to

someone confidentially, you can make an appointment with the IU Sexual Assault Crisis Services at (812) 855-8900, or contact a Confidential Victim Advocate at (812) 856-2469 or cva@indiana.edu.

University policy requires me to share certain information brought to my attention about potential sexual misconduct with the campus Deputy Sexual Misconduct & Title IX Coordinator or the University Sexual Misconduct & Title IX Coordinator. In that event, those individuals will work to ensure that appropriate measures are taken and resources are made available. Protecting student privacy is of utmost concern, and information will only be shared with those that need to know to ensure the University can respond and assist. I encourage you to visit <http://stopsexualviolence.iu.edu/index.html> to learn more.