

Computational Higher Inductive Types

Computing with Custom Equalities

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Properties of Equality

Warm Up: Linked Lists

Example: Unordered Sets
Canonical Inhabitants
Higher Inductive Types

Computing with Higher Inductive Types

Thank you

Properties of Equality

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- ▶ Transitivity: if $x = y$ and $y = z$, then $x = z$
- ▶ Leibniz rule: if $x = y$, then $f(x) = f(y)$

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- ▶ Equality is defined on an element-by-element basis
 - ▶ $[] = []$
 - ▶ $[] \neq [a, \dots]$
 - ▶ $[a, \dots] \neq []$
 - ▶ $[x_0, x_1, \dots, x_n] = [y_0, y_1, \dots, y_m]$ iff $[x_1, \dots, x_n] = [y_1, \dots, y_m]$ and $x_0 = y_0$

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- ▶ Fairly easy to prove the properties of equality
 - ▶ In Coq, Agda, and Idris, you get all of these properties for free

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- ▶ In Haskell, Agda, Coq, and Idris, the Leibniz rule is false! (or at least not internally provable)
 - ▶ The problem is that either you don’t have private fields, or you can’t make use of the fact that everything is defined in terms of your public methods.

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- ▶ Is this really what we wanted? We asked for unordered sets, and instead made sorted lists.

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 - ▶ Take the reflexive symmetric transitive closure of the given relation
- ▶ How do we get Leibniz for free?
 - ▶ Require proving it each time you define a particular function
 - ▶ To define a function that deals with unordered sets, you have to simultaneously prove that your function is invariant under permutations

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- ▶ Equality in Coq and Agda (`--without-K`) actually has a rich structure
- ▶ If you look at proofs of equality, and equality of these proofs, and you iterate this process, you get enough math to do topology!
- ▶ This is Homotopy Type Theory

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Questions?

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- ▶ Very hard to do!
- ▶ Can probably be done by way of parametricity (aka “theorems for free”), or a generalization of it
- ▶ Parametricity can be given a computational interpretation, but it’s very non-trivial to do so