Formal specification of the Cardano ledger, mechanized in Agda

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Intro

‘ Some quotes are worth more than others. ’

—someone

Motivation

- Explore another point in the design space
- Provide a constructive perspective on nominal techniques
- Do this without changing the system itself — as an Agda library
- Make it ergonomic for the user to use the library as a tool for dealing with names (e.g. working on some syntax with binding)
- Mechanise existing (but also new?) meta-theoretical results

Agda Preliminaries

Separation of concerns

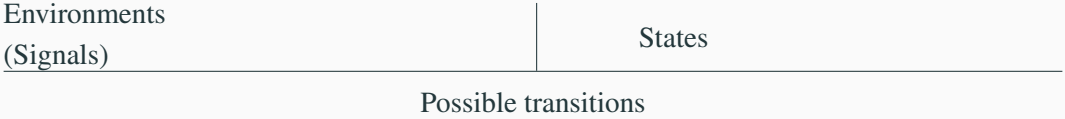
- Networking: deals with sending messages across the internet.
- Consensus: establishes a common order of valid blocks.
- Ledger: decides whether a sequence of blocks is valid.

State transitions

$$\Gamma \vdash s \xrightarrow[X]{b} s'$$

```
_⊢_-⟨_⟩_ : Env → State → Signal → State → Type
```

Triptychs



Reflexive-transitive closure

```
data _⊢_→⟨_⟩*_ : Env → State → List Signal → State → Type where

  base :
    ──────────────────────
    Γ ⊢ s →⟨ [] ⟩* s

  step :
    • Γ ⊢ s  →⟨ b  ⟩ s'
    • Γ ⊢ s' →⟨ bs ⟩* s''
    ──────────────────────
    Γ ⊢ s  →⟨ b :: bs ⟩* s''
```

Set theory

```
_⊆_ _≡ᵉ_ : {A : Type} → ℙ A → ℙ A → Type
X ⊆  Y = ∀ {x} → x ∈ X → x ∈ Y
X ≡ᵉ Y = X ⊆ Y × Y ⊆ X
```

```
_→_ : Type → Type → Type
A → B = ∃ λ (ℛ : ℙ (A × B)) →
  ∀ {a b b'} → (a , b) ∈ ℛ → (a , b') ∈ ℛ → b ≡ b
```

Future Work

- More meta-programming automation to minimise overhead
  - corresponding laws and equivariance lemmas follow the same type-directed structure as the swap operation itself
- Another case study on cut elimination for first-order logic
  - need to work with entities that are not finitely supported
  - also includes name abstraction over proof trees
- Formalise the constructive total concretion function, which seems novel

Questions?

https://omelkonian.github.io/nominal-agda