EuroProofNet WG6 meeting 2025

Controlling computation in type theory, *locally*

Théo Winterhalter

INRIA Saclay

Computation in type theory ✨

Proofs by computation

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refl : 2 + 2 = 4
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Definitional proof irrelevance without K
Gilbert, Cockx, Tabareau
2019
Agda ROCQ

and more!

Controlling and extending computation in ITPs

Coq modulo theory

Strub

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cooltt

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This one is local! 😎

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ROCQ

Why locality matters

Example: exceptions

```
symb raise : ∀ {A}, A
rule if raise then t else f ↦ raise
defn nth_exn : list A → ℕ → A := …
```

Agda ROCQ

Computation rules must be assumed **forever**

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Agda · ROCQ

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lemma something_unrelated : …
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No way to ensure the rules aren't used here
(unlike axioms, there is no `Print Assumptions`)

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Rules extend the trusted computing base

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Overall, not very modular
(or type-theoretic)

The elephant in the room: why not use extensional type theory?

Equality reflection

$$\frac{\Gamma \vdash p : u =_A v}{\Gamma \vdash u \equiv v}$$

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Conservative over ITT + UIP + funext

Extensional concepts in intensional type theory
Hofmann
1995

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Effective translation to ITT

Extensionality in the calculus of constructions

Oury

2005

Eliminating reflection from type theory

Winterhalter, Sozeau, Tabareau

2019

Terribly inefficient!

My proposal

Prenex quantification over (directed) equations

```
interface Bool
  assumes
    bool : Type
    true, false : bool
    ifte : ∀ (P : bool → Type). P true → P false → ∀ b. P b
  where
    ifte P t f true ↦ t
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My proposal

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  assumes
    sum : Type → Type → Type
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    elim :
      ∀ {A B} (P : sum A B → Type).
        (∀ a, P (inl a)) →
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    elim P l r (inl a) ↦  l a
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Equations are verified implicitly → `ifte P t f := S.elim P (U.elim _ t) (U.elim _ f)`

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Equations are verified implicitly (→ `ifte P t f := ...`)

You can exploit the encoding without having to work directly with it!

Other examples include…

Hiding implementation details
while retaining computation

```
interface Shift
  assumes
    shift : list ℕ → list ℕ
  where
    shift (x :: l) ↦ suc x :: shift l
    shift [] ↦ []
```

```
instance ShiftasMap
  shift := map suc
```

This way, `map` never appears in goals out of nowhere
useful for automatically generated functions (eg. Equations in Rocq)
for controlling unfolding (like in `cooltt`)
or for strictifications

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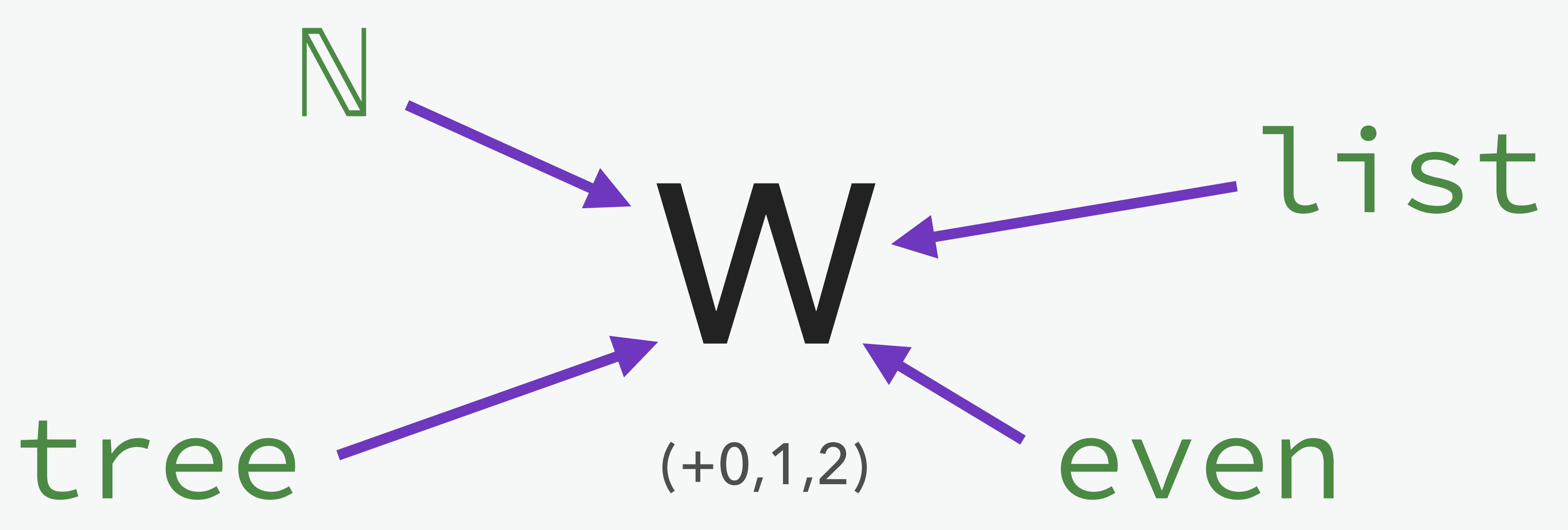

Why not W?
Hugunin
2021

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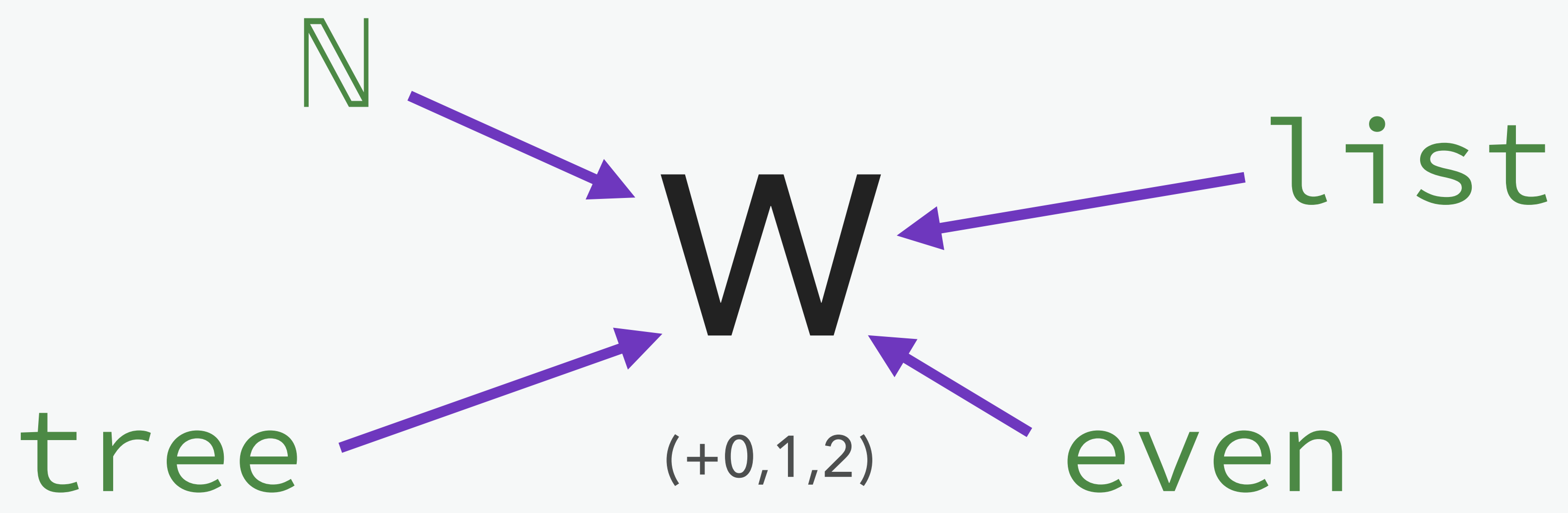

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Use effects locally, eg. exceptions

The type theory

$$\Sigma \mid \Xi \mid \Gamma \vdash t : A$$

The type theory

```
interface E⟨ Ξ’ ⟩ assumes Δ where R
```

```
def f⟨ Ξ’ ⟩ : A := t
```

Global environment

$$\Sigma \mid \Xi \mid \Gamma \vdash t : A$$

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Global environment

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M : E⟨ ξ ⟩
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Extension environment

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Basically regular MLTT

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Global environment — Extension environment — Basically regular MLTT

$$\Sigma \mid \Xi \mid \Gamma \vdash t : A$$

Computation rule (simplified)

```
(interface E⟨ Ξ’ ⟩ assumes Δ where R) ∈ Σ
  (M : E⟨ ξ ⟩) ∈ Ξ              (l ↦ r) ∈ R
─────────────────────────────────────────────
          Σ | Ξ | Γ ⊢ lξσ ≡ rξσ
```

The type theory

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interface E⟨ Ξ’ ⟩ assumes Δ where R
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```
M : E⟨ ξ ⟩
```

Global environment — Extension environment — Basically regular MLTT

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Computation rule (simplified)

$$\frac{(\texttt{interface } E\langle\ \Xi'\ \rangle \texttt{ assumes } \Delta \texttt{ where } R) \in \Sigma \qquad (M : E\langle\ \xi\ \rangle) \in \Xi \qquad (l \mapsto r) \in R}{\Sigma \mid \Xi \mid \Gamma \vdash l\xi\sigma \equiv r\xi\sigma}$$

Unfolding rule

$$\frac{(\texttt{def } f\langle\ \Xi'\ \rangle : A := t) \in \Sigma \qquad \Sigma \mid \Xi \mid \Gamma \vdash \xi : \Xi'}{\Sigma \mid \Xi \mid \Gamma \vdash f\langle\xi\rangle \equiv t\xi}$$

Meta-theory

mostly usual

Environment weakening (Σ, Ξ, Γ), **substitution, instantiation, validity**

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Σ | Ξ | Γ ⊢ ξ : Ξ' →
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Consistency

A given by embedding into ETT

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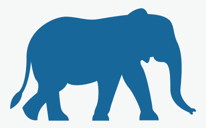
A given by embedding into ETT 

more interesting:

Conservativity over MLTT

```
· | · | · ⊢ A : Type →
Σ | · | · ⊢ t : A →
∃ t'. · | · | · ⊢ t' : A
```

Obtained by **inlining** definitions

Inlining

if $\Sigma \mid \Xi \mid \Gamma \vdash t : A$

then $[\![\Sigma]\!] \mid [\![\Xi]\!]\langle \kappa \rangle \mid [\![\Gamma]\!]\langle \kappa \rangle \vdash [\![t]\!]\langle \kappa \rangle : [\![A]\!]\langle \kappa \rangle$

where κ interprets the definitions of Σ

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removes all definitions
and unfolds them in extensions

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with κ fixed (and abstract):

$[\![x]\!] := x$

$[\![\lambda\ (x : A).\ t]\!] := \lambda\ (x : [\![A]\!]).\ [\![t]\!]$

$[\![u\ v]\!] := [\![u]\!]\ [\![v]\!]$

$[\![M.x]\!] := M.x$

$[\![f\langle \xi \rangle]\!] := (\kappa\ f)[\![\xi]\!]$

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κ is then defined by induction on ⊢ Σ such that

when `(def f⟨ Ξ' ⟩ : A := t) ∈ Σ` we have `κ f := ⟦ t ⟧⟨ κ_rec ⟩`

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Inlining

Compared to conservativity, we need full generality here

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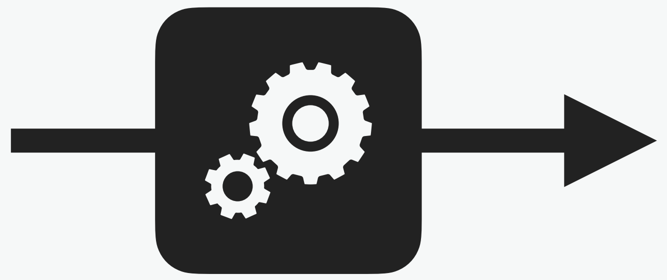
Conclusion

Conservative extension of MLTT with **local computation**

Conclusion



hide implementation details

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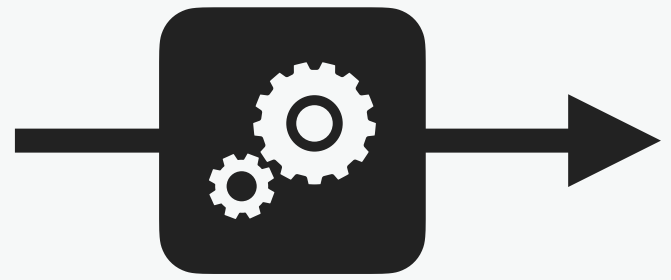
Conclusion



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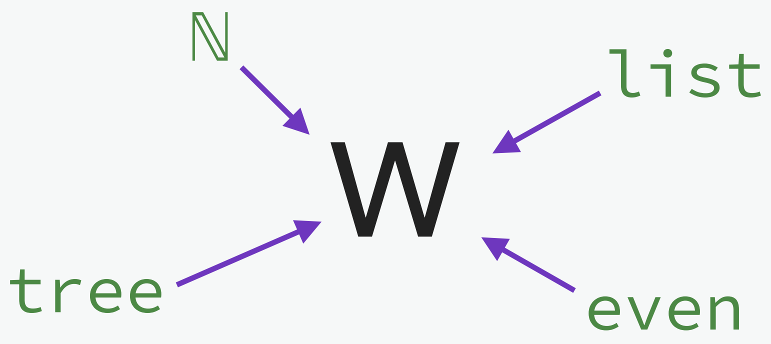

encode features

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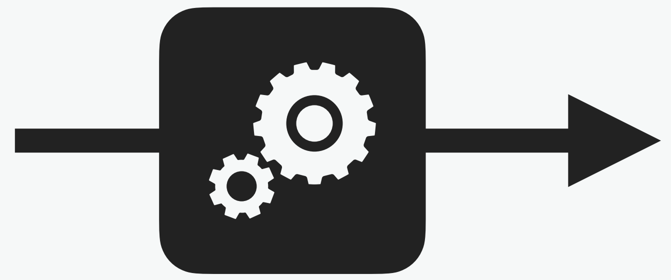

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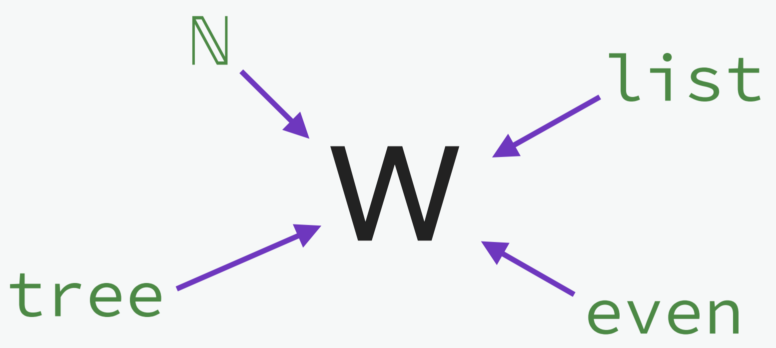

encode features

contained extensions (safer)

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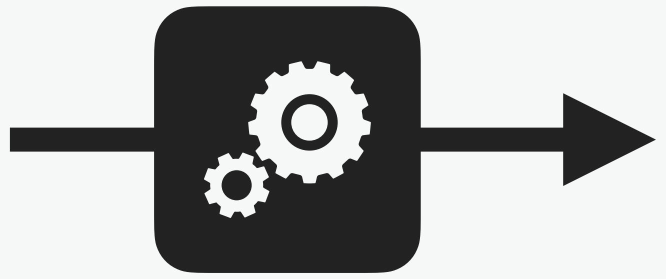
Conclusion



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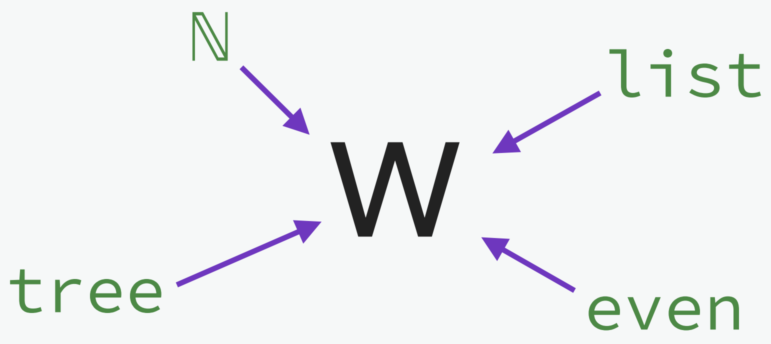

encode features

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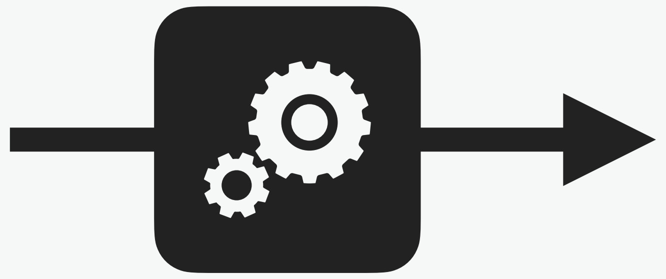
Conservative extension of MLTT with **local computation**

ROCQ APPROVED

/TheoWinterhalter/local-comp

Conclusion



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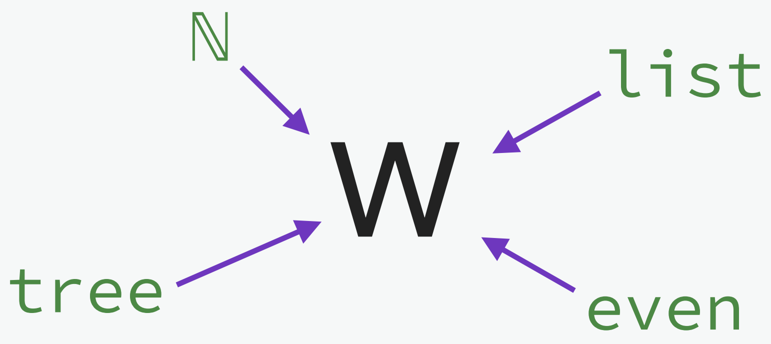

encode features

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Conservative extension of MLTT with **local computation**

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Perspectives

Agda ROCQ

Concrete implementation

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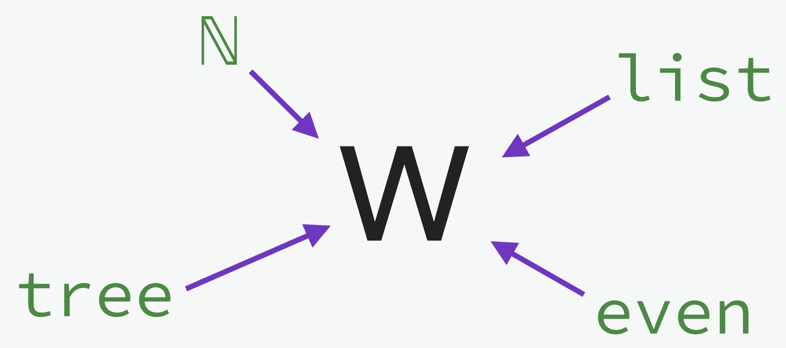
hide implementation details



encode features

contained extensions (safer)

Conservative extension of MLTT with **local computation**

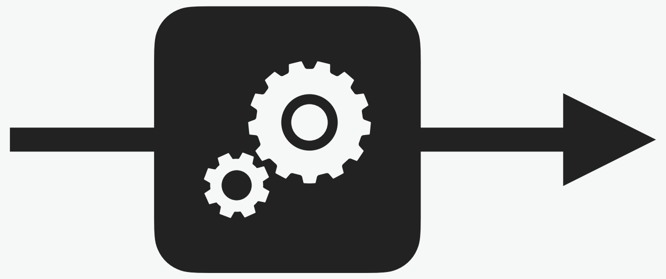
/TheoWinterhalter/local-comp

Perspectives

Concrete implementation

Decidability of type checking

Conclusion



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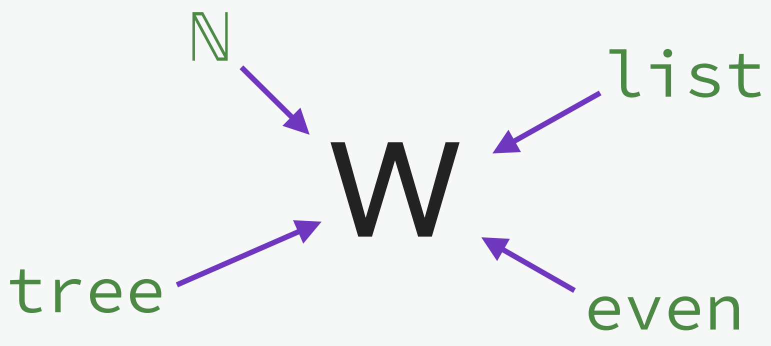

encode features

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Conservative extension of MLTT with **local computation**

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Decidability of type checking

Propositional instances

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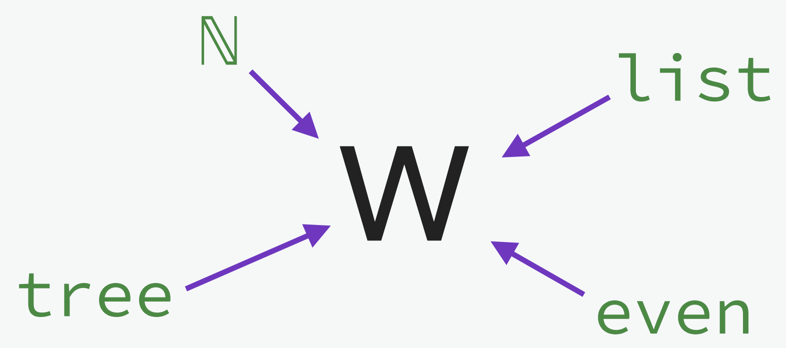
hide implementation details



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Thank you!