Agda Backends: A survey and a UHC backend prototype

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Agda Introduction

- Why dependent types?

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  head :: forall a . List a -> a
  head (x:xs) = x
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  ```
  ```

Agda Introduction

- Why dependent types?
- ```
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  ```
- Runtime crashes are possible in Haskell!
  ```

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      zero : Nat
      succ : Nat → Nat
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    ```

Agda Introduction

- How to make sure at compile time that this doesn't happen?
- We need to encode the length of lists in the type
  - data Nat : Set where
    zero : Nat
    succ : Nat → Nat
  - data Vec : (A : Set) → (n : Nat) → Set where
    nil : ∀ {A} → Vec A zero
    cons : ∀ {A n} → A → Vec A n → Vec A (succ n)

Cont.

- We can now write the head function in Agda
  - $\text{head1} : \forall \{A\ n\} \to \text{Vec}\ A\ n \to A$
    $\text{head1}\ (\text{cons}\ x\ xs) = x$
    $\text{head1}\ \text{nil} = ????$

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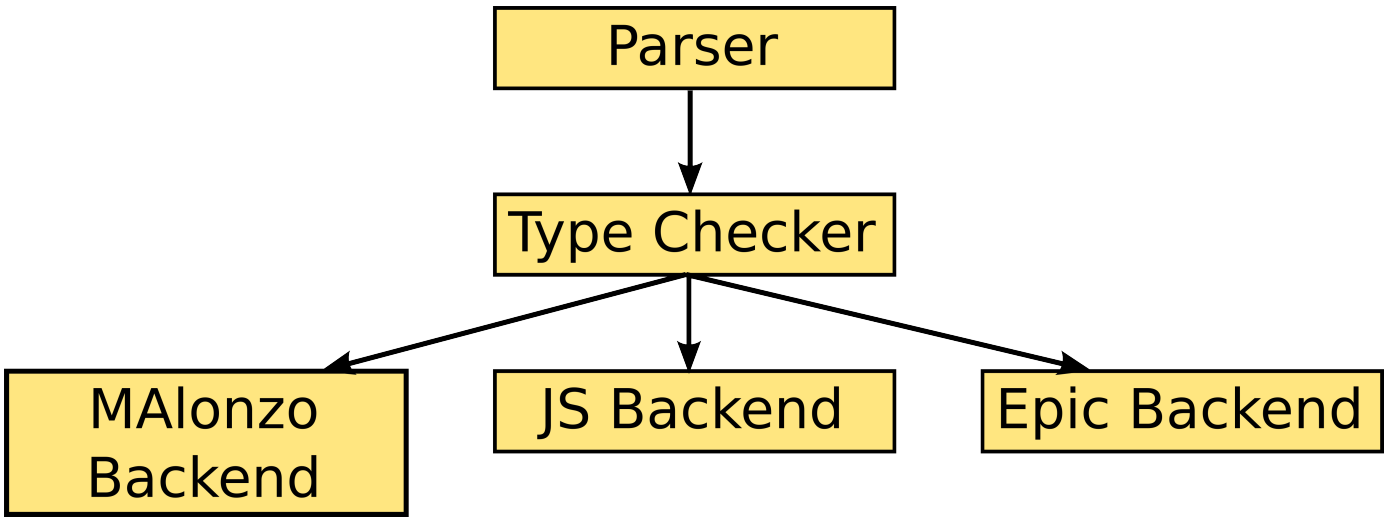
    $\text{head1}\ \text{nil} = ????$
- This will not type check!
  - $\text{head2} : \forall \{A\ n\} \to \text{Vec}\ A\ (\text{succ}\ n) \to A$
    $\text{head2}\ (\text{cons}\ x\ xs) = x$
- The typechecker now knows that the nil-case cannot happen!

Agda Summary

- Values can be used as types
- Types cannot influence value of an expression
- Functions need to be total

Agda Architecture



MAlonzo backend

MAlonzo backend

- Targets Haskell
- Maintained
- Relies on GHC for optimizations

MAlonzo - FFI

- Provides simple FFI to haskell
- Very limited
  - No class support
  - Can't export Agda datatypes
  - Not automatic

MAlonzo - FFI

```
{-# IMPORT Data.List #-}

data List : (A : Set) -> Set where
  nil : ∀ {A} → List A
  cons : ∀ {A} → A → List A → List A
{-# COMPILED_DATA List Data.List nil cons #-}

postulate
  head : ∀ {A} → List A -> A
{-# COMPILED head Data.List.head #-}
```

MAlonzo - Code Generation

```
vecToStr : ∀ {A m} → (A → String)
    → Vec A m → String
vecToStr f [] = ""
vecToStr f (x :: xs) = ", " ++ ((f x)
    ++ (vecToStr f xs))
```

MAlonzo - Code Generation

```
d55 v0 v1 v2 v3
  = MAlonzo.RTE.mazCoerce
      (d_1_55 (MAlonzo.RTE.mazCoerce v0)
        (MAlonzo.RTE.mazCoerce v1)
        (MAlonzo.RTE.mazCoerce v2)
        (MAlonzo.RTE.mazCoerce v3))
  where d_1_55 v0 v1 v2 (C51 v3 v4 v5)
          = MAlonzo.RTE.mazCoerce
              (d33 (MAlonzo.RTE.mazCoerce ", ")
                (MAlonzo.RTE.mazCoerce
(d33 (MAlonzo.RTE.mazCoerce (v2 (MAlonzo.RTE.mazCoerce v4)))
    (MAlonzo.RTE.mazCoerce
      (d55 (MAlonzo.RTE.mazCoerce v0) (MAlonzo.RTE.mazCoerce v3)
        (MAlonzo.RTE.mazCoerce v2)
        (MAlonzo.RTE.mazCoerce v5))))))
        d_1_55 v0 v1 v2 v3 = MAlonzo.RTE.mazIncompleteMatch name55
```

MAlonzo - Summary

- Produces 'strange' haskell code
- Can lead to size blow-up
  - 84 lines Agda - 250'000 lines Haskell - 300 Mb executable (CITE)

JS backend

JS backend

- Targets Javascript
- Not maintained
- Very similar to MAlonzo

Epic backend

Epic backend

- Targets Epic
- Not maintained

Epic

- Untyped-lambda calculus with some extensions
- Intended as building block for compilers
- Also not maintained

Epic Language

Epic Language

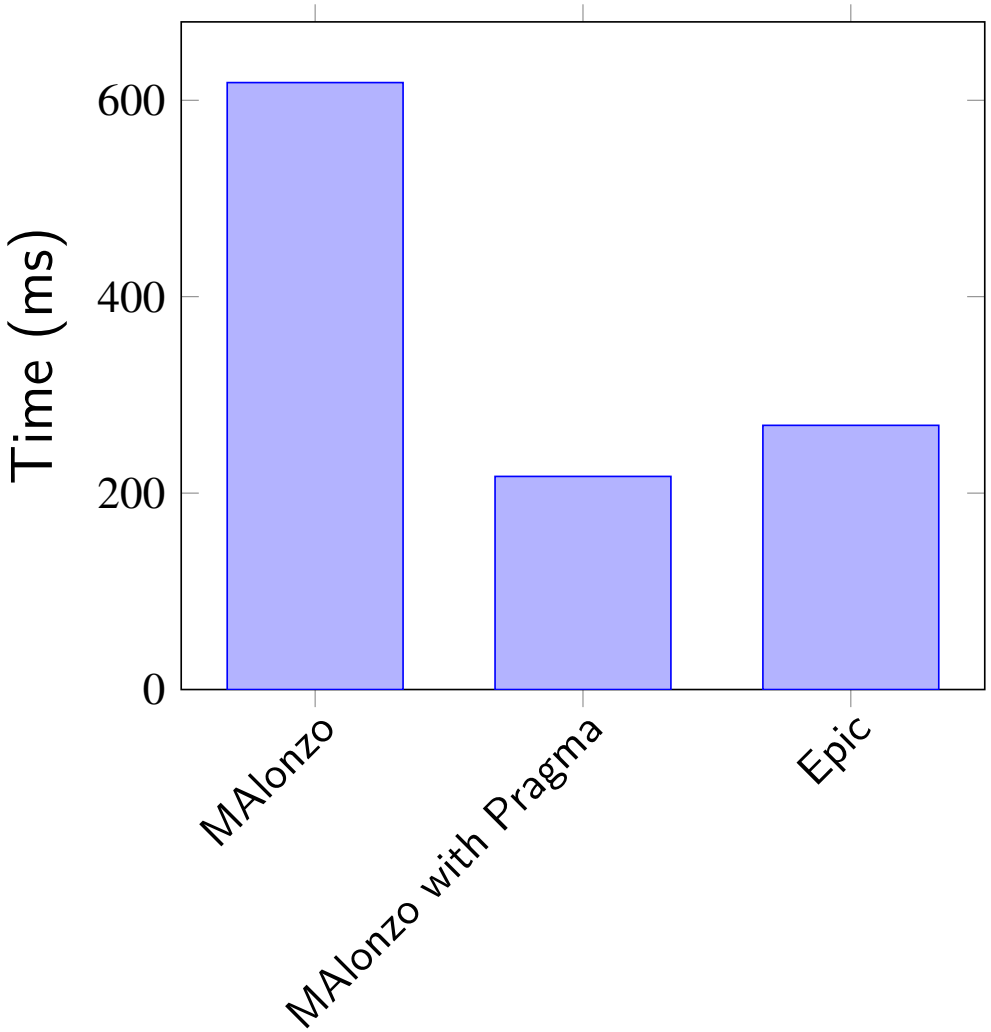
$$
\begin{array}{lcl}
t & ::= & x \\
& | & t\ \vec{t} \\
& | & \lambda x \to t \\
& | & \text{Con}\ i\ \vec{t} \\
& | & \text{if}\ t\ \text{then}\ t\ \text{else}\ t \\
& | & \text{case}\ t\ \text{of}\ \vec{alt} \\
& | & \text{let}\ x = t\ \text{in}\ t \\
& | & \\
& | & \text{lazy}\ t \\
& | & t\ !\ i \\
& | & i
\end{array}
$$

Epic - Nat Optimizations

- ```
  data Nat : Set where
    zero : Nat
    succ : Nat -> Nat
  {-# BUILTIN NATURAL Nat #-}
  ```

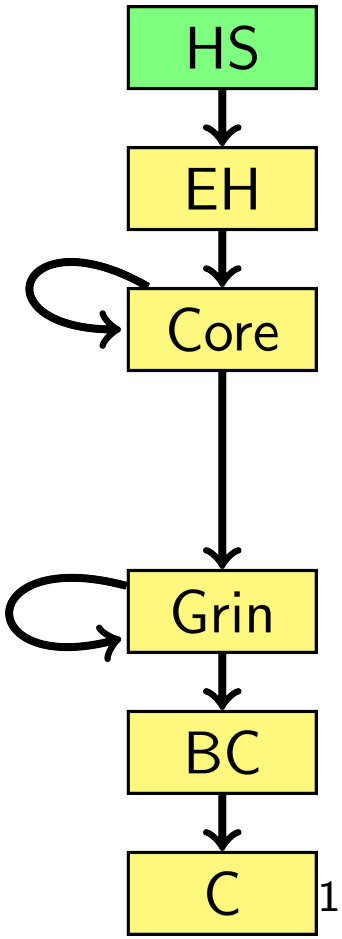
- Naive translation is horribly slow
- Can be transformed into arbitrary precision Integers
- Automatic detection of Nat-like datatypes
  ```

Nat Performance



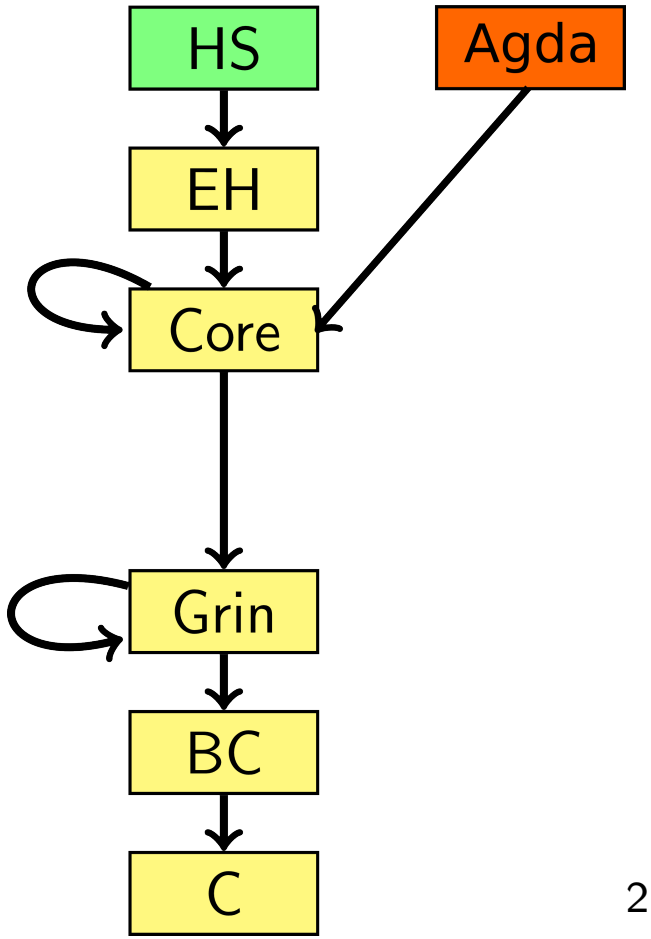
Comparison

UHC Compiler



[1]Dijkstra, Fokker, and Swierstra, 2009.

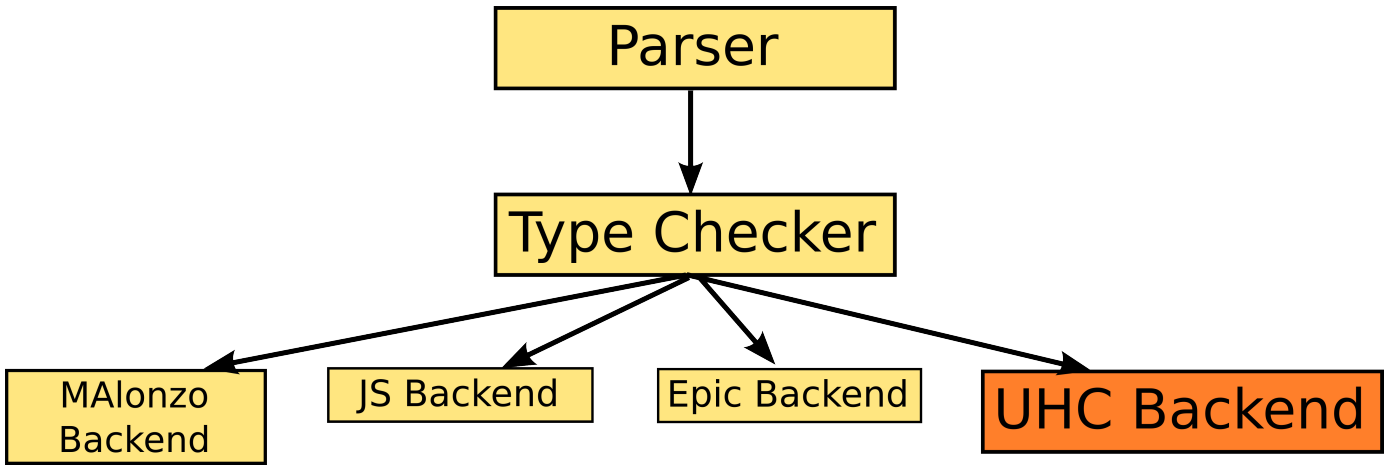
UHC Compiler



[2]

[2] Dijkstra et al., 2009.

UHC Backend


Parser
Type Checker
MAlonzo Backend
JS Backend
Epic Backend
UHC Backend

Epic vs UHC Core

Epic Language			UHC Core		
t	$::=$	x	t	$::=$	x
	$\mid$	$t\ \vec{t}$		$\mid$	$t\ t$
	$\mid$	$\lambda x \to t$		$\mid$	$\lambda x \to t$
	$\mid$	Con $i\ \vec{t}$		$\mid$	Con $i\ \vec{t}$
	$\mid$	if t then t else t			
	$\mid$	case t of $\vec{alt}$		$\mid$	case t of $\vec{alt}$
	$\mid$	let $x = t$ in t		$\mid$	let $x = t$ in t
				$\mid$	let! $x = t$ in t
	$\mid$	lazy t			
	$\mid$	i		$\mid$	i

UHC Backend - Challenges

- Agda is a moving target
- UHC Core was not intended as public API
- Undocumented assumptions inside UHC

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- Agda is a moving target
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- Undocumented assumptions inside UHC

```
case x of
  []     -> a
  (x:xs) -> b
```

is not the same as

```
case x of
  (x:xs) -> b
  []     -> a
```

UHC Backend - What works?

- (Dependent) dataypes, functions
- Compiling single Agda modules
- Agda - Haskell FFI, but involves manual work

Demonstration

UHC Backend - Future work

- Support whole Agda language
  - Multiple modules
  - Complete IO bindings
  - Agda Standard Library
- Optimizations
- Improve Agda - Haskell FFI
- Agda support for Cabal
- Contracts for FFI

Thank you!

Questions?

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