Tiny Idris Program Synthesis

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03-2021

Introduction

Introduce Functional programs and the TinyIdris system.

Project aim

Related work

Implementation

Evaluation

Functional Programming

Defines the structure of data.

Functions transform data by inspecting the structure, and deciding how to proceed.

Abstractions lead to concise code and encourages reuse.

Similar structures can lead to repetitive code.

Repetitive boilerplate can be tedious and lead to simple errors.

TinyIdris

Tiny Idris is a dependently typed functional language.

Not compiled, runs as an evaluator.

```
Processed Nat
processed type add
Processed add
> add (Suc (Suc Zero)) (Suc Zero)
Checked: (add (Suc (Suc Zero)) (Suc Zero))
Type: Nat
Evaluated: (Suc (Suc (Suc Zero)))
>
```

Project Aim

Extend the TinyIdris system with program synthesis functionality.

Constructing a function definition from a type signature, local environment and global context.

Specialised Systems

Specialised tools such as Leon, Myth, Synquid, ReSyn.

No use of available type information initially, use general constraint solving approach.

Utilised specifications such as input / output examples and counterexamples.

Extend languages with constraints and type refinements.

Greatly improved performance when enough type information is available.

Can require verbose specifications.

Built in to Languages

Developed from automatic proof search tools.

Use more hardcoded knowledge.

Agda and Coq have more hard-coded information to define tactics.

Packaged in a more useful manner than specialised systems.

Idris uses a more general, though limited approach.

More focus on quick definitions using time limits.

TinyIdris Processing

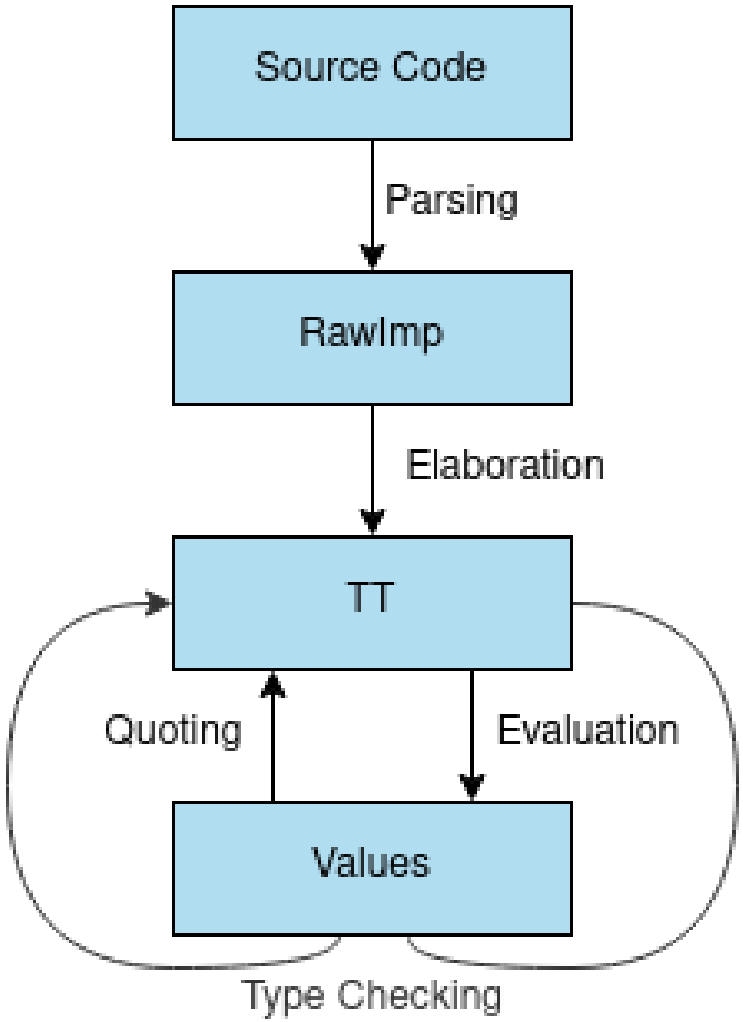
Code is parsed into the high level representation, RawImp.

RawImp is elaborated to the core language, TT.

Elaboration performs type checking and strips down terms.

Unification checks a type of equality between terms.

Resulting terms are stored in the context.



Implementation

Language extended with holes '?hole_name'.

Synthesise individual terms or full pattern matching definitons.

Repl extended with 'auto' command for interaction.

Testing functionality using pre-defined answer files and 't, test' commands.

Attempts full context enumeration unlike other dependently typed systems.

Term Synthesis

Local environment is searched first.

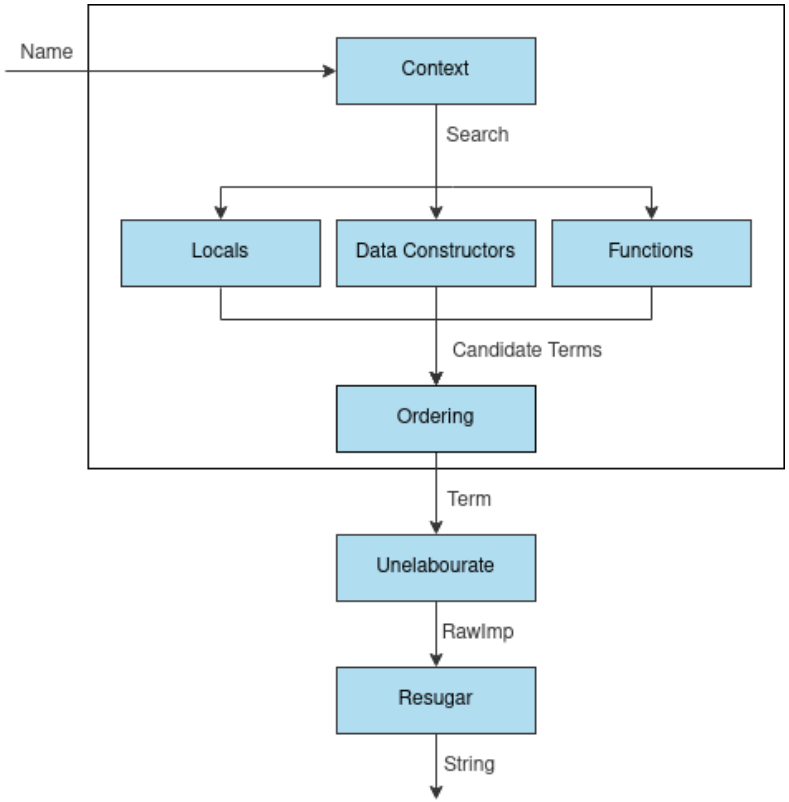
Data Constructors second.

Finally function definitions.

Arguments are synthesised in a depth first traversal.

Returns a list of results to be ordered.

Order of synthesis is a heuristic.



Definition Synthesis

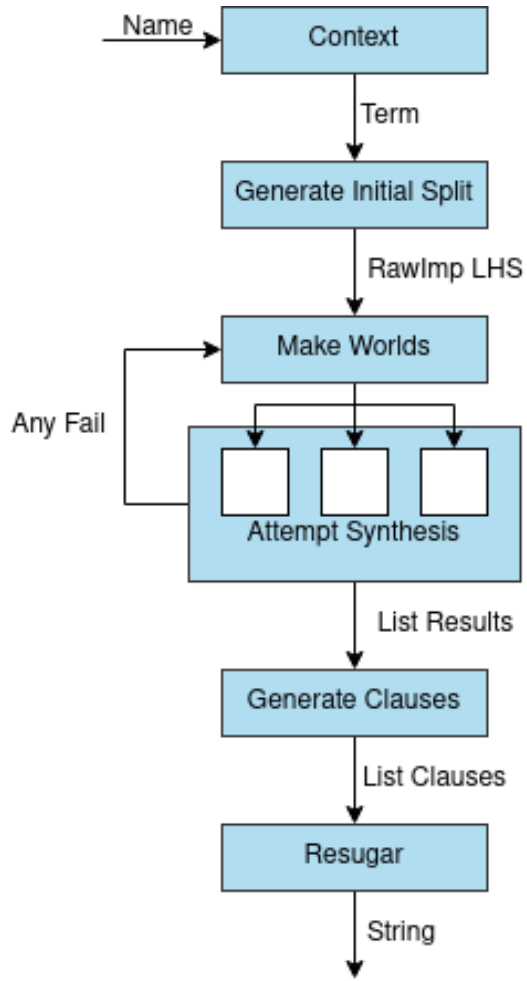
Given a type signature, construct a left hand side term to be split.

Alternates between splitting on arguments and attempting synthesis.

Synthesis attempted for each left hand side.

If all are successful the results are combined.

If any fail the process attempts further splitting.



Case Splitting

An Initial split is performed on the leftmost type constructor.

Splitting on all names that depend on the split argument is attempted.

If the split results in only one case, new names are added and the process repeats until no names are left.

```
pat a : Type, n : Nat, m : Nat,
      xs : Vec n a, ys : Vec m a =>
```

```
pat a : Type, m : Nat, ys : Vec m a =>
  append a Z m (Nil a) ys
pat a : Type, n : Nat, m : Nat, x : a, xs : Vec n a,
                                ys : Vec m a =>
  append a (S n) m (Cons a n x xs) ys
```

Case Splitting

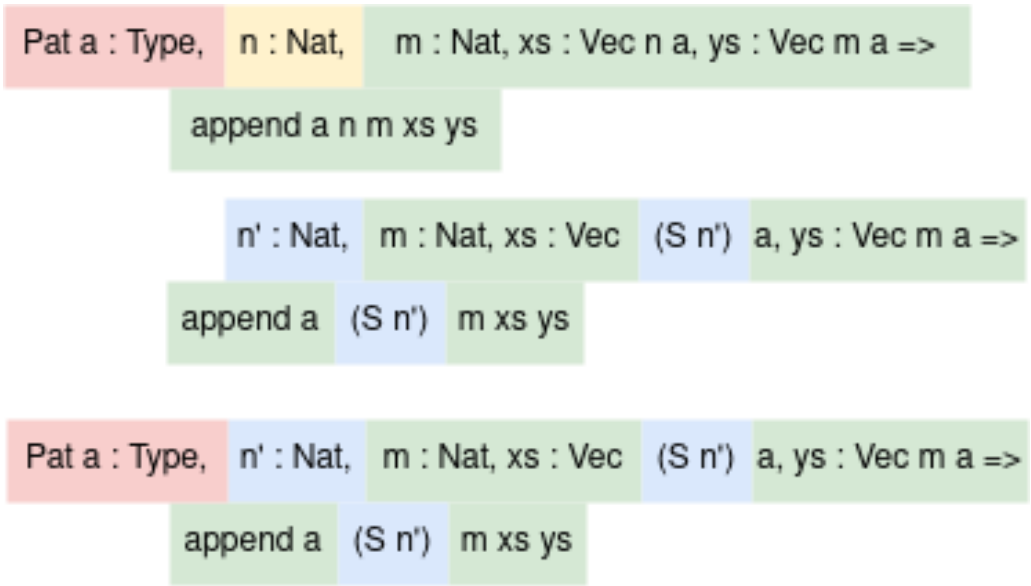
LHS split into patterns before the split argument, and the scope.

Identify which patterns for the constructor have already been introduced.

Generate unique pattern variables for those which have not.

Replace references to the term with the application of the constructor.

Put the term back together and attempt to fill in any implicits generated.



Evaluation

Tested with varying levels of type information.

Compared to other similar systems.

Idris, Idris2, Agda, Synquid.

Evaluated based on the correctness of synthesised definitions.

On each input returns the expected output.

Evaluation - Lists

Problem	TinyIdris	Idris	Idris2	Agda	Synquid
append			Pass		
map			Pass		
replicate			Pass		
drop					
foldr					
is empty					
is elem					
duplicate					
zip					
i'th elem					
index					

Evaluation - Vectors

Problem	TinyIdris	Idris	Idris2	Agda	Synquid
append	Pass	Pass	Pass	Pass	Pass
map	Pass	Pass	Pass	Pass	Pass
replicate	Pass	Pass			Pass
drop			Pass	Pass	Pass
foldr					Pass
is empty					Pass
is elem					Pass
duplicate	Pass				Pass
zip		Pass	Pass	Pass	Pass
i'th elem					Pass
index					Pass

Equalities

Problem	TinyIdris	Idris	Idris2	Agda	Synquid
andSymmetric	Pass	Pass	Pass	Pass	Pass
orSymmetric	Pass	Pass	Pass	Pass	Pass
plus commutes					-
plus Suc					-
symmetry		Pass	Pass	Pass	
transitivity		Pass	Pass	Pass	
congruence		Pass	Pass	Pass	-
list(vec(list)) = list		Pass	Pass	Pass	-
vec(list(list)) = vec			Pass		-
disjoint union apply				Pass	Pass
a = not not a					-
not not not a = not a			Pass	Pass	-

Heuristics

Problem	Loc-> DCon -> Func	Max Args	Rec + Max Arg	Functions Only
append	Pass	Pass	Pass	Pass
map	Pass			Pass
replicate	Pass			Pass
drop				
foldr				
is empty				
is elem				
duplicate	Pass	Pass	Pass	Pass
zip				
i'th elem				
index				

Conclusions

Effectiveness limited due to the lack of constraint solving.

Performance hindered by full enumeration.

Heuristic less effective with full enumeration of the context.

Prioritising language constructs that requires more built in knowledge may perform better than context enumeration.

Type system extensions could provide more powerful definitions, as seen in Synquid.