

Clafer Type System and Attributes



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Recent Progress

Recent Progress

Many people involved

Language

Applications and ecosystem

Documentation and promotion

Recent Progress: Language

Defaults (Leo)

Type system (Jimmy)

Intermediate representation - XML (Jimmy)

Translator (Jimmy, Kacper)

Test suite (Michal, Kacper)

Visualization: CVL and Class-like (Seyi)

Natural language syntax proposal (Michal)

Recent Progress: Applications

Lightweight methodology (Krzysztof, Michal)

Multiobjective optimization (Bo, Derek)

Usability empirical evaluation (Dina)

Future: financial domain (Marko), security (with Mahesh)

Recent Progress: Documentation

Tutorial (Michał)

Clafer wiki: github.com/gsdlab/ciafer/wiki/ (Michał, Kacper)

Website: ciafer.org (Michał, Kacper)

Type System

Motivation

Why does Clafer need a type system?

Type check

Free and automatic sanity check.

```
abstract Y  
  x : string  
  y : int  
  [x + y = 3]
```

Clafer reports that “+” cannot be applied on x and y.

Semantics

The type of an expression affects the semantics (output Alloy code). Also, needed for code optimization.

```
computer
  dualCpu ?
    speed : integer
    totalSpeed : integer
```

What does the expression *speed* mean?

Two cases

```
computer
  dualCpu ?
    speed : integer
  extraSpeed : integer
  [extraSpeed = (speed  $\Rightarrow$  speed else 0)]
```

The expression *speed* refers 1) presence of clafer, 2) to its integer value.

Semantics OO-analogy

```
class MemberAge {  
    int value;  
}  
class CentenarianClub {  
    MemberAge[] memberAge;  
}
```

The expression *memberAge* can refer to

- the *MemberAge* object(s)
- or its *value* field

The inferred type of the expression implicitly determines which of the two case applies.

Type system

A Clafer model consists of two parts.

- Clafer definitions
- Constraints

The type system performs two tasks in parallel.

- Type check the expressions in the constraints.
- Infer the types of expressions in the constraints.

Notation & Definition 1

Definition

$::$ is shorthand for “is type”.

example: “ $x :: \textit{integer}$ ” is read as “ x is type *integer*”.

Definition

\vdash is shorthand for “entails”.

example: “ $\Gamma \vdash x :: \textit{integer}$ ” is read as “ Γ entails $x :: \textit{integer}$ ”.
Sometimes it is clearer to read it as “ $x :: \textit{integer}$ given Γ ”.

Notation & Definition 2

Definition

The letter “*x*” is a Clafer reference.

In the expression below, “*speed*” is a Clafer reference.

[speed > 80]

Notation & Definition 3

Definition

The letters “ E, F, G ” are expressions.

2 leaf expressions: “ $speed$ ” and “ 80 ”.

1 super expression: “ $speed > 80$ ”.

[$speed > 80$]

Less frequent notations will be explained as they come.

Notation & Definition 4

Definition

A type environment (Γ) is a mapping from Clafer definition to the type of its value.

```
abstract Y : string
```

```
  a : integer
```

```
  b
```

```
X : Y
```

$$\Gamma = \{Y :: \textit{string}, \quad a :: \textit{integer}, \quad b :: \textit{clafer}, \quad X :: \textit{string}\}$$

Type rule

$$\text{name of rule} \frac{\textit{statementA} \quad \textit{statementB}}{\textit{statementC}}$$

If A and B holds then C follows.

The type system is specified through a series of type rules.

Clafer type rule 1

$$\text{intconst} \frac{}{\Gamma \vdash \text{INTEGER} :: \textit{integer}}$$

Clafer type rule 2

$$\text{eq} \frac{\Gamma \vdash E :: \tau \quad \Gamma \vdash F :: \tau}{\Gamma \vdash E = F :: \text{boolean}}$$

Clafer type rule 3

Can we prove that the following model passes type checking?
What is the type of each expression?

```
abstract Y  
  [0 = 1]
```

$$\Gamma = \{Y :: \textit{clafer}\}$$

Clafer type rule 4

$$\Gamma = \{Y :: \textit{clafer}\}$$

Proof.

$$\text{intconst} \frac{}{\Gamma \vdash 0 :: \textit{integer}} \quad \text{intconst} \frac{}{\Gamma \vdash 1 :: \textit{integer}} \\ \text{eq} \frac{}{\Gamma \vdash 0 = 1 :: \textit{boolean}}$$

Clafer type rule 5

$$\text{value} \frac{(x :: \tau) \in \Gamma}{\Gamma \vdash x :: \tau}$$

Clafer type rule 6

Prove that the following model is type correct.

```
abstract Y  
  a : integer  
  [a = 1]
```

$$\Gamma = \{Y :: \textit{clafer}, \quad a :: \textit{integer}\}$$

Clafer type rule 7

$$\Gamma = \{Y :: \textit{clafer}, \quad a :: \textit{integer}\}$$

Proof.

$$\text{value} \frac{(a :: \textit{integer}) \in \Gamma}{\Gamma \vdash a :: \textit{integer}} \quad \text{intconst} \frac{}{\Gamma \vdash 1 :: \textit{integer}} \\ \text{eq} \frac{}{\Gamma \vdash a = 1 :: \textit{boolean}}$$

Clafer type rule 8

$$\text{clafer} \frac{}{\Gamma \vdash x :: \textit{clafer}}$$

Clafer type rule 9

Prove that the following model is type correct.

```
abstract Y  
  a : integer  
  b  
  [a = b]
```

$$\Gamma = \{Y :: \textit{clafer}, \quad a :: \textit{integer}, \quad b :: \textit{clafer}\}$$

Clafer type rule 10

$$\Gamma = \{Y :: \textit{clafer}, \quad a :: \textit{integer}, \quad b :: \textit{clafer}\}$$

Proof.

$$\text{eq} \frac{\text{clafer} \frac{}{\Gamma \vdash a :: \textit{clafer}} \quad \text{clafer} \frac{}{\Gamma \vdash b :: \textit{clafer}}}{\Gamma \vdash a = b :: \textit{boolean}}$$

Clafer type rule precedence

abstract Y

a : integer

b : integer

[a = b]

Integer equality or clafer equality?

Clafer type rule casting 1

abstract Y

a : real

b : integer

[a = b]

Clafer type rule casting 2

$$\text{eqcast1} \frac{\Gamma \vdash E :: \text{real} \quad \Gamma \vdash F :: \text{integer}}{\Gamma \vdash E = F :: \text{boolean}}$$

$$\text{eqcast2} \frac{\Gamma \vdash E :: \text{integer} \quad \Gamma \vdash F :: \text{real}}{\Gamma \vdash E = F :: \text{boolean}}$$

Attributes

Primitive Types

```
Version : int *  
[Version + 2 > 0]
```

What is the value of Version?

Is the constraint satisfied? When?

Is the meaning of “+” purely arithmetic?

Does “+” handle sets?

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Semantic Variants

Sum

```
Version : int *  
[Version + 2 > 0]
```

Semantics: $\text{sum}(\text{Version}) + 2 > 0$

Version 0: returns 0. OK

Version 1: OK

Version +: Set sum. Confusing

```
abstract comp  
  version : int  
[comp.version = 1]
```

Used by Alloy and CDL

Sum

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[Version + 2 > 0]
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[Version + 2 > 0]

Semantics: [sum(Version) + 2 > 0]

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abstract comp
version : int
[comp.version = 1]

Used by Alloy and CDL

Universal Quantification

Version : int *
[Version + 2 > 0]

Semantics: [all a : Version | a + 2 > 0]

Version 0: ignores constraint

Version 1: OK

Version +: OK

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Version : int *
[Version + 2 > 0]

Semantics: [all a : Version | a + 2 > 0]

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Enforced Presence

Version : int *
[Version + 2 > 0]

Semantics: [some Version && Version + 2 > 0]

Version 0: constraint unsatisfied (as in OCL)

Version 1: OK

Version +: unclear. Sum or universal quantification.

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[Version + 2 > 0]

Semantics: [some Version && Version + 2 > 0]

Version 0: constraint unsatisfied (as in OCL)

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Version +: unclear. Sum or universal quantification.

Explicit Guards

Version : int *
[Version + 2 > 0]

Semantics: [(Version ? Version : 0) + 2 > 0]

Version 0: OK

Version 1: OK

Version +: unclear. Sum or universal quantification.

Explicit Guards

Version : int *
[Version + 2 > 0]

Semantics: [(Version ? Version : 0) + 2 > 0]

Version 0: OK

Version 1: OK

Version +: unclear. Sum or universal quantification.

Vector Operations

Version : int *
[Version + 2 > 0]

Semantics: [Version(0) + 2 > 0, Version(1) + 2 > 0, ...]

Version 0: unclear

Version 1: OK

Version +: OK, but complex.

Vector Operations

Version : int *
[Version + 2 > 0]

Semantics: [Version(0) + 2 > 0, Version(1) + 2 > 0, ...]

Version 0: unclear

Version 1: OK

Version +: OK, but complex.

No good semantics!

Proposed Solution

Version : int *
[Version + 2 > 0]

Use the sum semantics. Covers 0 and 1 cardinality.

For higher cardinalities, enforce using quantifiers.

Complex but makes intuitive sense.

Discussion:

github.com/gsdlab/clafer/wiki/Experimental:-Attributes

Conclusion

Conclusion

Clafer entered new evolution phase

Type system clarifies semantics

Experiments with design choices

Evaluation needed

Upcoming applications

Thanks for listening!

Questions?

clafer.org