Algebraic Subtyping for Algebraic Effects and Handlers

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Introduction

Algebraic effect handlers

A feature for side effects and exception handlers on steroids [1, 4, 5]

Implemented in Eff programming language [6, 7]

Algebraic subtyping

A form of subtyping used in type inference systems [2]

let twice f x =
 f (f x)

With subtyping

twice : $(\beta \rightarrow \gamma) \rightarrow \alpha \rightarrow \gamma \mid \alpha \leq \beta, \gamma \leq \beta$

With algebraic subtyping

twice: $(\alpha \rightarrow \alpha \& \beta) \rightarrow \alpha \rightarrow \beta$

```
effect Op : unit -> int

let someFun b =
    handle (
    if (b == 0) then
        let a = #Op ()
        print a
    else
        print b
) with
        | #Op () cont -> cont 1
```

Research problem

Too many constraints

Constraints keep stacking and they become unwieldy.

Algebraic Subtyping

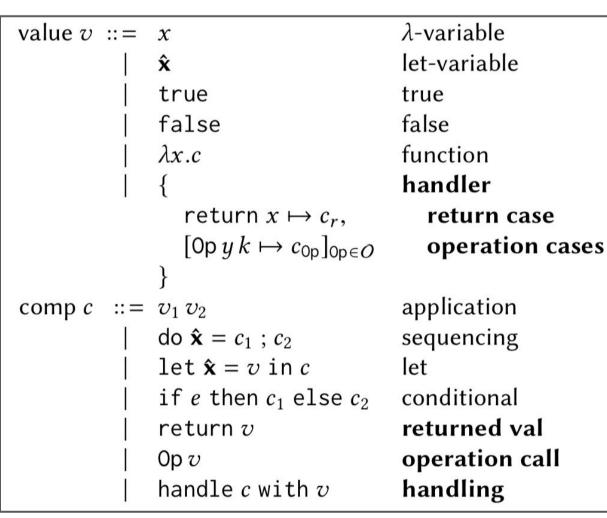
Does not use effect information.

Optimisations

Implementing effect-aware optimizing compiler is error-prone due to the many different constraints that remain unsolved in traditional subtyping systems.

How can effects be introduced within algebraic subtyping? How can such a system be implemented in the Eff programming language?

Extension



| 100-71 | | 101 100 100 |
|---|---|----------------|
| | | |
| (pure) type $A, B ::=$ | bool | bool type |
| | $A \rightarrow \underline{C}$ | function type |
| | $\underline{C} \Rightarrow \underline{D}$ | handler type |
| | α | type variable |
| ĺ | $\mu\alpha.A$ | recursive type |
| | Т | top |
| | 上 | bottom |
| ĺ | $A \sqcap B$ | intersection |
| | $A \sqcup B$ | union |
| dirty type $\underline{C}, \underline{D} ::=$ | $A \mid \Delta$ | |
| $dirt\ \Delta\ ::=$ | Ор | operation |
| | δ | dirt variable |
| ĺ | Ø | empty dirt |
| 1 | $\Delta_1 \sqcap \Delta_2$ | intersection |

 $(A_1 \to \underline{C}_1) \sqcup (A_2 \to \underline{C}_2) \equiv (A_1 \sqcap A_2) \to (\underline{C}_1 \sqcup \underline{C}_2)$

union

 $\Delta_1 \sqcup \Delta_2$

Formulation of typing rules

Relationship to subtyping

Biunification algorithm input <-> output

Type inference algorithm

Type simplification algorithm
Construct type automata
Convert to NFA
Minimization algorithm

Semantics of the dirt

Set operations?

(Op ∐ Op2) ∏ (Op ∐ Op3) => Op

Input vs Output

☐ for outputs☐ for inputs

 $\Delta_1 \leqslant \Delta_2 \leftrightarrow \Delta_1 \sqcup \Delta_2 \equiv \Delta_2$

 $\Delta_1 \leqslant \Delta_2 \leftrightarrow \Delta_1 \equiv \Delta_1 \sqcap \Delta_2$

Evaluation

Implementation

Eff programming language Fully featured

Replace type inference engine ~2900 loc ⇔ ~5800

Proofs

Algorithms have been proven to be correct_(see thesis appendix for the proofs)

| N | | |
|----------------|------------------------|-----------------------|
| System Program | Algebraic Subtyping | Standard Subtyping |
| Interpreter | 1.550 | 1.740 |
| Loop | 1.285 | 2.859 |
| Parser | 171.887 | 11.791 |
| N-Queens | 35.377 | 5.362 |
| Range | 0.642 | 1.058 |

Future Work

Optimizations engine

Adapting the effect-aware optimizing compiler for the algebraic-subtyping based system.

Simplification of types and effects
Implementing the extended algorithm
to simplify types and effects using
type automata.

Summary

Algebraic effects and handlers

These are a very active area of research. An important aspect is the development of an optimising compiler.

Research problem

Compilation is a slow process with difficult to read types due to the constraints without a strong, reliable type-&-effect system.

This thesis simplifies constraint generation for types *AND EFFECTS* by providing a new core language based upon extended **algebraic subtyping**.

References

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[2] Stephen Dolan and Alan Mycroft. 2017. Polymorphism, Subtyping, and Type Inference in MLsub. In Proceedings of the 44th ACM SIGPLAN Symposium on Principles of Programming Languages (POPL 2017). ACM, New York, NY, USA, 60–72.

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