Assignment iect Exam Help er.com Concepts of Programming Longuages Add Welchatspowcoder

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Motivation

Suppose we added Float to MinHS. Ideal Atte Sanging Port Description of the Ip

4 + 6 :: Int

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Similarly, a numeric literal should take on whatever type is inferred from context.

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sin(5 :: Float)

Without Overloading

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```
\underset{(+_{\mathtt{Float}}) :: \mathtt{Float} \to \mathtt{Float}}{(+_{\mathtt{Float}}) :: \mathtt{Float} \to \mathtt{Float}} \to \mathtt{Int}
```

Such type-directed name resolution is called *ad-hoc polymorphism* or *overloading*.

Type Classes

Type Asses in granne and to be the former by and exist it is languages under different names:

- Type Classes in Haskell
- Traits in Pattps://powcoder.com
- Implicits in Scala
- Protocols in Swift
- Contracts i Acad We Chat powcoder
- Concepts in C++
- Other languages approximate with *subtype polymorphism* (coming)

Type Classes

A type series functions, called methods.

Example (Numeric Types)

In Haskell, the present of the state of the

In Haskell, the Eq type class contains methods (=) and (/=) for computable equality.

In Haskell, the Eq type class contains methods (=) and (/=) for computable equality. What types cannot be an instance of Eq?

¹Nothing to do with OO methods.

Notation

We write: Assignment Project Exam Help

To indicate that f has the type τ where a can be instantiated to any type under the

condition that the constraint P is satisfied.

Typically, P is hittopstance powered and common conditions are satisfied.

Example

- (+) :: $\forall a$. (Num a) $\Rightarrow a \rightarrow a \rightarrow a$ that powcoder
- Is (1 :: Int) + 4.4 a well-typed expression?

No. The type of (+) requires its arguments to have the same type.

Extending MinHS

Extendes in the Exam Help

```
Predicates P ::= C \tau
Polytypes \pi ::= \tau \mid \forall a, \pi \mid P \Rightarrow \pi
Class names C
```

Our typing judgement The exprove includes a set of type class axiom schema: Powcoder

This set contains predicates for all type class instances known to the compiler.

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Typing Rules

The existing rules now just thread through.
In order is set to be the first through the known axioms:

Right now,
$$A \Vdash P$$
 iff $P \in A$, but we will complicate this situation later.

If, adding a predicate to the known axioms, we can conclude a typing judgement, then we can overload the expressive with that predicate OWCOCCT

$$\frac{P, \mathcal{A} \mid \Gamma \vdash e : \pi}{\mathcal{A} \mid \Gamma \vdash e : P \Rightarrow \pi} GEN$$

Example

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- Num Float
 Using ALLE (from previous lecture), we can conclude
 - Using ALLE (from previous fecture), we can conclude $(+)::(\texttt{Num Float})\Rightarrow \texttt{Float} \rightarrow \texttt{Float} \rightarrow \texttt{Float}.$
- Using Inst (on previous slide) and 10, we can conclude (+) :: Float Code at WF foat nat powcoder
- \bullet By the function application rule, we can conclude 3.2 + 4.4 :: Float as required.

Dictionaries and Resolution

This is called ad-hoc polymorphism because the type checker removes it — it is not a fundamental incorporation to parametric polymorphism. Type classes are converted to types:

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$$(/=): a \rightarrow a \rightarrow Bool$$

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type EqDict
$$a = (a \rightarrow a \rightarrow Bool \times a \rightarrow a \rightarrow Bool)$$

A *dictionary* contains all the method implementations of a type class for a specific type.

Dictionaries and Resolution

Instances become values of the dictionary type:

Assignmente Project Exam Help False == False = True https://powcoden.com

becomes

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False
$$==_{Bool}$$
 False True
 $==_{Bool}$ = False
 $a \neq_{Bool}$ $b = not (a ==_{Bool} b)$

$$eqBoolDict = ((==_{Bool}), (/=_{Bool}))$$

Dictionaries and Resolution

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same ::
$$\forall a$$
. (Eq a) \Rightarrow [a] \rightarrow Bool same [] = True
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Becomes:

```
same eq (x : []) = True
same eq (x : y : xs) = (fst eq) x y \land same eq (y : xs)
```

Generative Instances

Such instances are transformed into Continues: powcoder

 $eqList :: EqDict a \rightarrow EqDict [a]$

Our set of axiom schema \mathcal{A} now includes implications, like (Eq a) \Rightarrow (Eq [a]). This makes the relation $\mathcal{A} \Vdash P$ much more complex to solve.

Coherence

Som Anguste gaining that and kits) is that they and ore that per class per type in the entire program. It achieves this by requiring that all instances are either:

- Defined along with the definition of the type llass or COM
 Defined along with the definition of the type.

This rules out so-called *orphan* instances.

There are a number of that addising the line of the li

- Modularity has been compromised but.
- Types like Data. Set can exploit this coherence to enforce invariants.

Static Dispatch

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Typically, the compiler can *inline* all dictionaries to their usage sites, thus eliminating all run-time cost of the stype deserving the compiler can inline all dictionaries to their usage sites, thus eliminating all run-time cost of the compiler can inline all dictionaries to their usage sites, thus eliminating all run-time cost of the compiler can inline all dictionaries to their usage sites, thus eliminating all run-time cost of the compiler can inline all dictionaries to their usage sites, thus eliminating all run-time cost of the compiler can inline all dictionaries to their usage sites, thus eliminating all run-time cost of the cost of the

This is only not possible if the exact type being used cannot be determined at compile-time, such as with polymorphic recursion etc.

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Subtyping

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ob-ject: to feel distaste for something

Webster's Dictionary

Subtyping

To a substitution. To a substitution of substitution.

 $\Gamma \vdash e : \tau \qquad \tau \leq \rho$

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To aid in type inference (as type inference with subtyping is undecidable in general),

To aid in type inference (as type-inference with subtyping is undecidable in general), sometimes subsumptions (called *upcasts*) are made explicit (e.g. in OCaml):

Add We Chat powcoder $\Gamma \vdash \text{upcast } \rho \in \Gamma$

²Remember discrete maths, or check the glossary.

What is Subtyping?

What this partia order Project Exam Help main approaches:

- Most common: where upcasts do not have dynamic behaviour, i.e. upcast ν A LL pisregumes that which the Collasso be judged to have type ρ. If types are viewed as sets, this could be viewed as a subset relation.
- Uncommon: where upcasts cause a coercion to occur, actually converting the value from Atom of runtine Chat powcoder

 Observation: By using an identity function as a coercion, the coercion view is more

general.

Desirable Properties

The coercion is the most Peroject Fxam Helpsults.

Example

Suppose Int String and Int to a string. String and Int to a string.

- O Directly: "3"
- via Float: A3.0 WeChat powcoder

 Typically, we would enforce that the subtype coercions are coherent, such that no

Typically, we would enforce that the subtype coelcions are coherent, such that no matter which coercion is chosen, the same result is produced.

Behavioural Subtyping

Another Soft grant Christian Projects by The Another Soft grant Corresponds to the Corresponding Something Semantically. In other words, if we know $\tau \leq \rho$, then it should be reasonable to replace any value of type ρ with an value of type τ without any observable

difference. https://powcoder.com

Let $\varphi(x)$ be a property provable about objects x of type ρ . Then $\varphi(y)$ should be true for objects y of Aped whele We Chat powcoder

Languages such as Java and C++, which allow for user-defined subtyping relationships (inheritance), put the onus on the user to ensure this condition is met.

Product Types

Assurance pieg 1947 14 Projectine support of the pond data types?

What is the relationship between these types?

- $\underset{\bullet \text{ (Float} \times \text{Float)}}{\bullet \text{ (Float} \times \text{Float)}} s: //powcoder.com$
- (Float × Int)
- $\bullet \text{ (Int} \times \text{F1} \text{(At)} dd \text{ WeChat powcoder} \\ \tau_1 \leq \rho_1 \\ \tau_2 \leq \rho_2 \\$

$$\frac{\tau_1 \le \rho_1}{(\tau_1 \times \tau_2) \le (\rho_1 \times \rho_2)}$$

Sum Types

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- (Int + Int)
- (Float + host) ps://powcoder.com
- (Int + Float)

Any other compound types?



Functions

What Assignment Heroject Exam Help

- $\bullet \ (\mathtt{Int} \to \mathtt{Int})$
- (Float \rightarrow Float)
- (Float -) https://powcoder.com
- ullet (Int o Float)

The relation is flipped on the left hand side!
$$\underbrace{Add}_{\rho_1 \leq \tau_1} \underbrace{\underbrace{p_0}_{\rho_2}}_{\tau_2 \geq \rho_2} wcoder$$



Variance

The Avs significant appropriate by the property of the proper

- If $C \tau \le C \rho$, then C is covariant. **Examples** Products (both arguments). Sumi (both arguments), Function return type, ...
- If $C \rho \le C \tau$, then C is contravariant. Examples: Aundio are went typical powcoder
- If it is neither covariant nor contravariant then it is (confusingly) called *invariant*. **Examples**: data Endo $a = E(a \rightarrow a)$

Stuffing it up

Many languages have famously stuffed this up, at the expense of type safety.

¹⁹Assignment Project Exam Help

Dart supports optional typing based on interface types.

The type system is unsound, due to the covariance of generic types. This is a deliberate choice (and undoubtedly controversial). Experience has shown that sound type rules for the Sily in the condition of the form of the form of the form of the covariance of generic types. This is a deliberate choice has shown that sound type rules for tools to provide a sound type analysis if they choose, which may be useful for tasks like refactoring.

Add We few prattarpowcoder Language and libraries

- · Dart's type system is now sound.
 - Fixing common type problems

Java too

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Java (and its Stattle based cousin 6) also broke type safety with incorrect variance in arrays.

We will demonstrate how this violates preservation, time permitting.

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