CS450

Structure of Higher Level Languages

Lecture 34: Generic methods

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Today we will learn...

- contrasting match and generic

Generic methods versus match

Example: serialization

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Let us implement a serialization function

```
#lang racket
(require rackunit)
(require racket/generic)
(provide (all-defined-out))
;; Values
(define (r:value? v) (r:number? v))
(struct r:number (value) #:transparent)
;; Expressions
(define (r:expression? e) (or (r:value? e) (r:variable? e) (r:apply? e)))
(struct r:variable (name) #:transparent)
(struct r:apply (func args) #:transparent)
```

Specification

```
(check-equal? (r:quote (r:apply (r:variable '+) (list (r:number 1) (r:number 2))))  '(+ 1 2
```

Implementing `r:quote` with `match`

File: `example1.rkt`

> Copy/paste the AST and implement `r:quote`.

Solution

```
(define (r:quote exp)
```

Implementing `r:quote` with `match`

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> Copy/paste the AST and implement `r:quote`.

Solution

```
(define (r:quote exp)

  (match exp
    [(r:number n) n]
    [(r:variable x) x]
    [(r:apply ef ea) (cons (r:quote ef) (map r:quote ea))]))
```

Revisiting racket/generic

File: example2.rkt

> We can use **racket/generic** to represent abstract interfaces that are satisfied dynamically by the argument. A generic interface may have one or more functions.

```
(define-generics quotable
   (r:quote quotable))

(define (r:value? v) (r:number? v))
(struct r:number (value) #:transparent
  #:methods gen:quotable
  [(define (r:quote n) (r:number-value n))])

(check-equal? (r:quote (r:number 10)) 10)
```

racket/generic and recursive calls

> When a method needs to do a ***generic*** recursive call, we need to access the "***main***" generic method, and not the current method. To do so, we need to use `define/generic` to access the main generic method.

```
(struct r:apply (func args) #:transparent
  #:methods gen:quotable
  [
    (define/generic rec-quote r:quote)
    (define (r:quote app)
      (cons (rec-quote (r:apply-func app))
            (map rec-quote (r:apply-args app))))])
```

In contrast with

```
    [(r:apply ef ea) (cons (r:quote ef) (map r:quote ea))]))
```

Generic interface summary

`define-generics` defines an interface

- A generic interface has a name, in this example it is `fruit`
- We specify which methods are generic and provide the list of formal parameters. Exactly one parameter must have the name of the interface.

```
(define-generics fruit
  (pick x fruit)
  (pluck fruit x))
; (foo fruit fruit) ⟵ incorrect because fruit shows up more than once
; (bar x y)         ⟵ incorrect because fruit does not show up
```

More

- `define/generic` accesses the generic method
- We can check if a value is of a given interface with `(fruit? x)`

Introducing booleans

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```
;; Values
(define (r:value? v) (or (r:number? v) (r:bool? v)))
(struct r:number (value) #:transparent)
(struct r:bool (value) #:transparent)

(check-equal? (r:quote (r:apply (r:variable 'and) (list (r:bool #t) (r:bool #f))))
  '(and #t #f))
```

What is the impact of adding a new kind of AST node?

Match version

File: `example1-v2.rkt`

> We must go through each function that has a `match` and add a branch to handle our new AST node.

```
(define (r:quote exp)
  (match exp
    [(r:number n) n]
    [(r:variable x) x]
    [(r:bool b) b]
    [(r:apply ef ea) (cons (r:quote ef) (map r:quote ea))]))
```

Generic version

File: `example2-v2.rkt`

> We must update our AST to implement the generic interface.

```
(struct r:bool (value) #:transparent
  #:methods gen:quotable
  [(define (r:quote b) (r:bool-val b))])
```

Generic is open-ended

File: `example3.rkt`

> A benefit of `generic` is that it is dynamically extensible. With `match` you may need to change a 3rd-party code.

```
#lang racket
(require rackunit)
(require "example2.rkt")

(struct r:bool (val) #:super struct:r:value
  #:methods gen:quotable
  [(define (r:quote b) (r:bool-val b))])

(check-equal? (r:quote (r:apply (r:variable 'and) (list (r:bool #t) (r:bool #f))))
  '(and #t #f))
```

Contrasting `match` with `generic`

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What are the main differences between `match` and `generic`?

Code impact in adding a new kind of node

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Match

- Code is centralized in a function

Dispatch

- Code is split across structs

Extension points

Contrasting `match` with `generic`

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Code impact in adding a new kind of node

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Dispatch

- Code is split across structs

Extension points

Match

- Not possible

Dispatch

- Any code may add a branch

Quiz: `match` versus `dispatch`

Q1: Which of the code is centralized?

Q2: Each of which allows for extension points?

Implementing generic

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1. Declare a generic function

```
(define-generic quotable (r:quote quotable))
```

2. Register an instance of said function

```
  #:methods gen:quotable
  [(define (r:quote b) (r:bool-val b))])
```

3. Call a generic function

```
(r:apply (r:variable 'and) (list (r:bool #t) (r:bool #f)))
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2. Register an instance of said function

> Registering an instance should add one entry to the registry. It should register the type as the key.

3. Call a generic function

> Calling a generic function should lookup the registry for the right instance according to the type.

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- Which argument is being dispatched on?
- How many arguments does the function have?
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```
(struct generic (index instances))
(define (make-generic index)
  (generic index (list)))
(struct instance (type? func))
```

Example

```
(define g
  (generic 0 ; dispatch on the first argument
    (list (instance r:bool? (lambda (b) (r:bool-val b))))))
```

Original

```
#:methods gen:quotable
[(define (r:quote b)
   (r:bool-val b))]
```

2. Registering an instance

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Registration takes a predicate and a function, and updates a generic.

```
(define (generic-register gen prec? func)
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```
(define (generic-register gen prec? func)

  (generic
    (generic-index gen)
    (cons (instance prec? func) (generic-instances gen))))
```

3. Call a generic function

- We want to implement `(generic-apply gen . args)`

3. Call a generic function

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We want to implement `(generic-apply gen . args)`

1. Let the list of instances be `l`
2. Let the the index being dispatched be `n`
3. Load the `n`-th argument
4. Let the the instance that matches the `n`-th argument be `f`
5. Call `f` with arguments `args`

Implementing instance lookup

> Given a `generic` and a value, return the instance callback. Function `(memf f l)` finds an element using `f`; an element is found when `f` applied to the element returns a true value.

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```
(define (generic-lookup gen elem)
  (memf
    (lambda (inst) ((instance-type? inst) elem))
    (generic-instances gen)))
```

Implementing `generic-apply`

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We can load the `n`-th element of a list with function `(list-ref list index)`.

```
(define (generic-apply gen . args)
```

Implementing `generic-apply`

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- We can load the `n`-th element of a list with function `(list-ref list index)`.

```
(define (generic-apply gen . args)

  (define elem (list-ref args (generic-index gen)))
  (apply (generic-lookup gen elem) args))
```

Example

```
(define g
  (generic 0 ; dispatch on the first argument
    (list (instance r:bool? (lambda (b) (r:bool-val b))))))
(check-true (generic-apply g (r:bool #t)))
```

Limitations

- Lookup is linear with the number of instances
- No error reporting:
  - Instance with 1 arguments, but we are dispatching on the 2nd argument
  - Do we want to enforce that all instances have the same number of arguments?