EOPL3 Notes

# Inductive Sets of Data

# Data Abstraction

## Specifying Data via Interfaces

### 编程练习

#### Exercise 2.3 diff-tree

##### 树的构造

**zero表示:**(diff (one) (one))

zero = 1 - 1

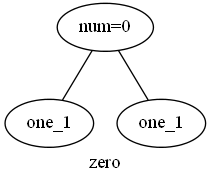


图 1 zero表示

**inc\_one/dec\_one的表示：**

|  |  |
| --- | --- |
| inc\_one = (diff (one) (diff (one) (one))) | dec\_one = (diff (diff (one) (one)) (one)) |
|  |  |

**子树相加：**设n(t)为两颗树相加的结果，现在求子树t1与t2如何组成t， n(t) = n(t1) + n(t2)

|  |  |  |
| --- | --- | --- |
| n(t) | = | n(t1) + n(t2) |
|  | = | n(t1) – (-n(t2)) |
|  | = | n(t1) – (0 – n(t2)) |
|  | = | n(t1) – ((1 - 1) – n(t2)) |

**diff-tree表示 =**

|  |
| --- |
| diff-tree = (diff **t1**  (diff (diff (one) (one))  **t2**)) |

**successor** = t + inc\_one

**predecessor** = t + dec\_one

successor与predecessor可以基于diff-tree加法实现

##### 接口编写

|  |
| --- |
| #lang eopl  (require "lib/eopl\_comm.rkt")  *;Diff-tree ::= (one) | (diff Diff-tree Diff-tree)*  (define one '(one))  (define inc-one '(diff (one) (diff (one) (one))))  (define dec-one '(diff (diff (one) (one)) (one)))  *;zero*  (define zero '(diff (one) (one)))  *;tree->num: Diff-tree -> Int*  (define (**tree->num** tree)  (if (equal? tree one) 1  (- (tree->num (lson tree))  (tree->num (rson tree)))))  *(display (tree->num inc-one)) (newline)*  *(display (tree->num dec-one)) (newline)*  ;is-zero?:Diff-tree -> boolean  (define (**is-zero?** tree)  (zero? (- (tree->num (lson tree))  (tree->num (rson tree)))))  *(display (is-zero? inc-one)) (newline)*  *(display (is-zero? dec-one)) (newline)*  ;diff-tree-plus:Diff-tree x Diff-tree -> Diff-Tree(n(t1) + n(t2))  ;usage:return n(t1) + n(t2) in constant time  (define (**diff-tree-plus** t1 t2)  (interior-node 'diff  t1  (interior-node 'diff  (interior-node 'diff one one)  t2)))  ;successor:Diff-tree -> Diff-tree(n + 1)  (define (**successor** tree) (diff-tree-plus tree inc-one))  *(display (tree->num (successor zero))) (newline)*  *(display (tree->num (successor one))) (newline)*  *(display (tree->num (successor inc-one))) (newline)*  *(display (tree->num (successor dec-one))) (newline)*  ;predecessor:Diff-tree -> Diff-tree(n - 1)  (define (**predecessor** tree) (diff-tree-plus tree dec-one))    *(display (tree->num (predecessor zero))) (newline)*  *(display (tree->num (predecessor one))) (newline)*  *(display (tree->num (predecessor inc-one))) (newline)*  *(display (tree->num (predecessor dec-one))) (newline)*  ;num->tree:Int(n) -> Diff-tree(n)  (define (**num->tree** n)  (if (zero? n) zero  (successor (num->tree (- n 1)))))  *(display (num->tree 3)) (newline)*  *(display (tree->num (num->tree 3))) (newline)*  ;diff-tree-plus test  (display (tree->num (diff-tree-plus (num->tree 10) (num->tree 20)))) (newline) |

## 数据类型的表示策略

**程序不依赖具体数据类型:** 当抽象数据类型被使用后，程序可以不依赖数据的具体表现形式。可以在不修改程序的情况下,重新定义抽象数据类型的部分接口实现.

### Environment接口

**environment定义:**变量的有限集合，变量可以是所有的Scheme值。

**表示形式：**{(var1, val1), . . ., (varn, valn)},

* vari是互不相同的变量, vali是任何Schem值。
* 称var的值与env绑定

**environment接口定义**

|  |  |  |
| --- | --- | --- |
| (empty-env) | = | ⌈∅⌉ |
| (apply-env *f*  *var*) | = | *f* (*var*) |
| (extend-env *var v* ⌈ *f* ⌉) | = | ⌈g⌉, 当*var1=var*时，*g(var1) = v；其它情况,g(var1)=f(var1)* |

**说明：**

* empty-env:没有参数，产生一个空的environment数据类型表示。
* (apply-env env var):查看env中var对应的值
* (extend-env *var val env*):生成一个新的env, var对应的值变更为val,没有var时新增。
* empty-env / extend-env为constructor，apply-env为observer

#### Exercise 2.4 stacks的接口定义

stack表示形式：{var1, var2, ... , varn}

|  |  |  |
| --- | --- | --- |
| (empty-stack) | = | ⌈∅⌉ |
| (push ⌈ *f* ⌉  *var*) | = | ⌈*g*⌉, ⌈*g*⌉ = {var, var1, var2, ... , varn} |
| (pop ⌈ *f* ⌉) | = | ⌈*g*⌉, ⌈*g*⌉ = {var2, var3, ... varn} |
| (top ⌈ *f* ⌉) | = | var1 |
| (empty-stack? ⌈ *f* ⌉) | = | ⌈ *f* ⌉ == ⌈∅⌉ |

### Environment数据结构的表示

**env的构造：**可以从empty-env开始，通过n次extend-env构成

|  |
| --- |
| (extend-env varn valn  ...  (extend-env var1 val1  (empty-env))...) |

从env的构造特点，提取出构造语法： empty-env/extend-env直接作为env的组成部分

|  |  |  |
| --- | --- | --- |
| Env-exp | ::= | (empty-env) |
|  | ::= | (extend-env Identifier Scheme-value Env-exp) |

Env-exp的语法与list语法是一样的，所以可以参考list来实现env

|  |
| --- |
| Env = (empty-env) | (extend-env Var SchemeVal Env) Var = Sym |

**apply-env：**如果env为空，报错。如果env由extend-env构造,则检查var是否在env中绑定。如果是，则返回env保存的值；否则继续在保存的env中寻找变量。

**iinterpreter模式：**按apply-env这种模式的代码

1. 检查一块数据
2. 判断它表示的是什么类型的数据
3. 抽取数据的组成部分，并进行合适的处理。

#### env的接口的实现

通过env的构造过程，直接转换为表示形式：

* empty: (empty-env)
* non-empty: (extend-env 'a 1 (extend-env 'b 2 (empty-env)))

**说明：**

var的惟一绑定和覆盖之前绑定值 这一特性，是指通过env接口表现出来的。而实现时env中可以有多个var对应不同的值，但只有满足取出最新的值就OK。

|  |
| --- |
| #lang eopl  (require racket/trace)  *;environment representation:*  *;empty: (empty-env)*  *;non-empty: (extend-env 'a 1 (extend-env 'b 2 (empty-env)))*  **;Grammer:**  **;Env-exp ::= (empty-env)**  **; ::= (extend-env Identifier Scheme-value Env-exp)**  *;report-no-binding-found: SchemeVal -> ErrorMsg*  (define (report-no-binding-found search-var)  (eopl:error 'apply-env "No Binding for ~s" search-var))  *;report-invalid-env: Env -> ErrorMsg*  (define (report-invalid-env env)  (eopl:error 'apply-env "Bad environment: ~s" env))  *; this way, define a variable not a function.*  *;(define empty-env '(empty-env))*  *;empty-env: () -> List; return '(empty-env)*  (define empty-env  (lambda () '(empty-env)))  (display (empty-env)) (newline)  *;empty-env?: Env -> boolean*  (define (empty-env? env)  (equal? env (empty-env)))  (display (empty-env? (empty-env))) (newline)  *;extend-env:Var × SchemeVal × Env → Env*  (define (extend-env var val env)  (list 'extend-env var val env))  *;apply-env:Env x Var -> SchemeVal*  (define (apply-env env search-var)  (cond ((null? env) (report-invalid-env env))  ((empty-env? env) (report-no-binding-found search-var))  ((not (equal? (car env) 'extend-env)) (report-invalid-env env))  ((not (eqv? 4 (length env))) (report-invalid-env env))  ((equal? search-var (cadr env)) (caddr env))  (else (apply-env (cadddr env) search-var))))  (display (apply-env '(extend-env a 1 (extend-env b 2 (empty-env)))  'b)) (newline) |

#### 编程练习

##### Exercise 2.6 01\_environment

**Grammar:**

|  |
| --- |
| Env ::= () | (env-element\*)  env-element ::= (Symbol SchemeVal) |

|  |
| --- |
| #lang eopl  *;environment representation:*  *;empty -> '()*  *;non-empty -> '(('a 1) ('b 2))*  *;empty-env: -> '()*  (define empty-env '())  *;extend-env: Var x SchemeVal x Env -> Env*  *;usage:return distinct var of Env*  (define (extend-env var val env)  (cond ((equal? env empty-env) (list (list var val)))  ((equal? var (caar env)) (cons (list (caar env) val) (cdr env)))  (else (cons (car env) (extend-env var val (cdr env))))))  (display (cons '(1 2) '((2 3)))) (newline)  (display (extend-env 'a 1 empty-env)) (newline)  (display (extend-env 'b 2 '((a 1)))) (newline)  (display (extend-env 'a 2 '((a 1)))) (newline)  *;apply-env: Env x Var -> SchemeVal*  (define (apply-env env search-var)  (cond ((null? env) (report-no-binding-found search-var))  ((not (= 2 (length (car env)))) (report-invalid-env env) )  ((equal? search-var (caar env)) (cadar env))  (else (apply-env (cdr env) search-var))))  *;(display (apply-env '() 'a)) (newline)*  (display (apply-env '((a 1)) 'a)) (newline)  (display (apply-env '((a 1) (a 2)) 'a)) (newline)  (display (apply-env '((a 1) (b 2)) 'b)) (newline) |

##### Exercise 2.6 02\_environment

Grammer: 在单层list中实现

|  |
| --- |
| env ::= () | ({var val}\*) |

**接口实现：**

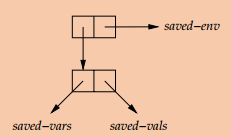
|  |
| --- |
| ;environment representation:  ;empty -> '()  ;non-empty -> '((a 1) (b 2))  ;empty-env: -> '()  (define empty-env (lambda () '()))  ;empty-env?: Env -> Boolean  (define (empty-env? env) (equal? env (empty-env)))  ;extend-env: Var x SchemeVal x Env -> Env  (define (extend-env var val env)  (append (list var val) env))  (display (extend-env 'a 1 (extend-env 'b 2 (empty-env)))) (newline)  ;apply-env: Env x SearchVar -> Val  (define (apply-env env search-var)  (cond ((empty-env? env) (report-no-binding-found search-var))  ((< (length env) 2) (report-invalid-env env))  ((equal? (car env) search-var) (cadr env))  (else (apply-env (cddr env) search-var))))  (display (apply-env '(a 1 b 2) 'b)) (newline) |

##### Exercise 2.6& 2.8 03\_environment

**Grammar:**

|  |
| --- |
| Env ::= () | (Env-element Env)  Env-element ::= (Symbol SchemeVal) |

示例：((a 1) ((b 2) ((c 3)))



**接口实现：**

|  |
| --- |
| ;environment representation:  *;empty -> '()*  *;non-empty -> '((a 1) ((b 2) ()))*  *;empty-env: -> '()*  (define empty-env (lambda () '()))  *;empty-env?: Env -> Boolean*  (define (empty-env? env) (equal? env (empty-env)))  *;extend-env: Var x SchemeVal x Env -> Env*  (define (extend-env var val env)  (list (list var val) env))  (display (extend-env 'a 1 (extend-env 'b 2 (empty-env)))) (newline)  *;apply-env: Env x SearchVar -> Val*  (define (apply-env env search-var)  (cond ((empty-env? env) (report-no-binding-found search-var))  ((< (length env) 2) (report-invalid-env env))  ((< (length (car env)) 2) (report-invalid-env env))  ((equal? (caar env) search-var) (cadar env))  (else (apply-env (cadr env) search-var))))  (display (apply-env '((a 1) ((b 2) ())) 'b )) (newline) |

## Interfaces for Recursive Data Types

#### Exercise 2.18 NodeInSequence

**语法：**

|  |
| --- |
| NodeInSequence ::= (Int Left-Listof(Int) Right-Listof(Int2)) |

说明：

(1 2 3 4 5 6 7 8 9)使用(6 (5 4 3 2 1) (7 8 9))表示，以6为轴。左移/右移是相对于轴来说的。

**接口：**

|  |  |  |
| --- | --- | --- |
| number->sequence | Int -> NodeInSequence | > (number->sequence 7) (7 () ()) |
| current-element | NodeInSequence –> Int | > (current-element ’(6 (5 4 3 2 1) (7 8 9))) 6 |
| move-to-left | Left-ListOf(Int)中的数据往左移，当前元素放到右边 | (move-to-left ’(6 (5 4 3 2 1) (7 8 9))) (5 (4 3 2 1) (6 7 8 9)) |
| move-to-right | Right-ListOf(int)中的数据往左移，当前元素放到左边 | > (move-to-right ’(6 (5 4 3 2 1) (7 8 9))) (7 (6 5 4 3 2 1) (8 9)) |
| insert-to-left | Int x NodeInSequence –> NodeInSequence  往Left-ListOf(Int)的开头插入 | > (insert-to-left 13 ’(6 (5 4 3 2 1) (7 8 9))) (6 (13 5 4 3 2 1) (7 8 9)) |
| insert-to-right | 往Right-ListOf(Int)的开头插入 | > (insert-to-right 13 ’(6 (5 4 3 2 1) (7 8 9))) (6 (5 4 3 2 1) (13 7 8 9)) |

**接口实现：**

|  |
| --- |
| #lang eopl  (require racket/pretty)  (require "../lib/eopl\_comm.rkt")  *;NodeInSequence ::= (Int Listof(Int) Listof(Int))*  *;(number->sequence 7) -> (7 () ())*  (define (number->sequence int)  `(,int () ()))  (pretty-print (number->sequence 7))  *;(current-element '(6 (5 4 3 2 1) (7 8 9))) -> 6*  (define (current-element node)  (car node))  (pretty-print (current-element '(6 (5 4 3 2 1) (7 8 9))))  *;(move-to-left ’(6 (5 4 3 2 1) (7 8 9)))*  *;->(5 (4 3 2 1) (6 7 8 9))*  (define (move-to-left node)  (if (null? (lson node))  (display "Out-of-Range")  (interior-node (car (lson node))  (cdr (lson node))  (cons (current-element node) (rson node)))))  (pretty-print (move-to-left '(7 () (8))))  (pretty-print (move-to-left '(6 (5 4 3 2 1) (7 8 9))))  *;(move-to-right '(6 (5 4 3 2 1) (7 8 9)))*  *;-> (7 (6 5 4 3 2 1) (8 9))*  (define (move-to-right node)  (if (null? (rson node))  (display "Out-of-Range")  (interior-node (car (rson node))  (cons (current-element node) (lson node))  (cdr (rson node)))))  (pretty-print (move-to-right '(6 (5 4 3 2 1) (7 8 9))))  *;(insert-to-left 13 '(6 (5 4 3 2 1) (7 8 9)))*  *;->(6 (13 5 4 3 2 1) (7 8 9))*  (define (insert-to-left int node)  (interior-node (current-element node)  (cons int (lson node))  (rson node)))  (pretty-print (insert-to-left 13 '(6 (5 4 3 2 1) (7 8 9))))  *;(insert-to-right 13 '(6 (5 4 3 2 1) (7 8 9)))*  *;->(6 (5 4 3 2 1) (13 7 8 9))*  (define (insert-to-right int node)  (interior-node (current-element node)  (lson node)  (cons int (rson node))))  (pretty-print (insert-to-right 13 '(6 (5 4 3 2 1) (7 8 9)))) |

#### Exercise 2.19 *Bintree*

**语法：**

|  |
| --- |
| Bintree ::= () | (Int Bintree Bintree) |

**接口：**

|  |  |  |
| --- | --- | --- |
| number->bintree | Int -> Bintree | (number->bintree 13) -> (13 () ()) |
| current-element | Bintree -> Int |  |
| move-to-left | 取左子树 |  |
| move-to-right | 取右子树 |  |
| at-leaf? | ()为叶节点 |  |
| insert-to-left | 插入左子树，作为原左子树的根 |  |
| insert-to-right | 插入右子树，作为原右子树的根 |  |

**接口实现：**使用racket的单元测框架**rackunit**

|  |
| --- |
| #lang eopl  **(require rackunit)**  (require "../lib/eopl\_comm.rkt")  (define (number->bintree int) `(,int () ()))  (define (current-element bintree) (contents-of bintree))  (define (move-to-left bintree) (lson bintree))  (define (move-to-right bintree) (rson bintree))  (define (at-leaf? bintree) (null? bintree))  (define (insert-to-left int bintree)  (interior-node (contents-of bintree)  (interior-node int  (lson bintree)  '())  (rson bintree)))  (define (insert-to-right int bintree)  (interior-node (contents-of bintree)  (lson bintree)  (interior-node int  (rson bintree)  '())))  (define t0 (number->bintree 13))  (define t1 (insert-to-right 14 (insert-to-left 12 t0)))  (check-equal? t0 '(13 () ()))  (check-equal? (current-element t1) 13)  (check-equal? t1 '(13 (12 () ()) (14 () ())))  (check-equal? (move-to-left t1) '(12 () ()))  (check-equal? (move-to-right t1) '(14 () ()))  (check-equal? (at-leaf? (move-to-right (move-to-left t1))) #t)  (check-equal? (insert-to-left 15 t1) '(13  (15  (12 () ())  ())  (14 () ()))) |

#### Exercise 2.20 bintree – zipper

https://wiki.haskell.org/Zipper

附录

# Mathematcial Symbol

向上取整：⌈...⌉

# graphViz

参考：<http://graphs.grevian.org/example>

## 无向图

|  |  |
| --- | --- |
| graph {  rankdir=LR  a -- b;  a -- c;  a -- e;    b -- c;  e -- c;    c -- d;  } |  |

**说明：**

* **--：** 无向图连线，可指定 节点集合 到 节点集合的连线，实现批量指定连线。
* **rankdir=LR:**指定图形排布方式，**TB:**从上到下, **BT:**从下到上; **LR:**从左到右; **RL:**从右到左。默认为TB
* **位置：**图形和连线出现的位置与图形元素的声明顺序有关

## 带标签加权无向图

|  |
| --- |
| graph {  rankdir=LR  a [label="start",**color**=red,**style**=filled]  d [label="end",**color**=black,**fontcolor**=white,**style**=filled]  a -- b[**label**="10",**weight**="10"];  a -- c[label="1",weight="1"];  a -- e[label="1",weight="1"];    b -- c[label="4",weight="4"];  e -- c[label="1",weight="1"];    c -- d[label="6",weight="6"];  } |
|  |

**说明：**

* label=”start”:指定节点或连线的标签内容
* color=red:指定节点的颜色
* fontcolor=white:指定节点标签字体的颜色
* style=filled:指定 节点或连线 风格，filled:填充满, 对于线:style=dotted:虚线
* weight:两个节点之间的连线weight越大，则节点靠得更近。

## 有向图

|  |  |
| --- | --- |
| digraph {  a -> b[label="0.2",weight="2"];  a -> c[label="0.4",weight="4"];  c -> b[label="0.6",weight="6"];  c -> e[label="0.6",weight="6"];  e -> e[label="0.1",weight="1"];  e -> b[label="0.7",weight="7"];  } |  |

**说明：**

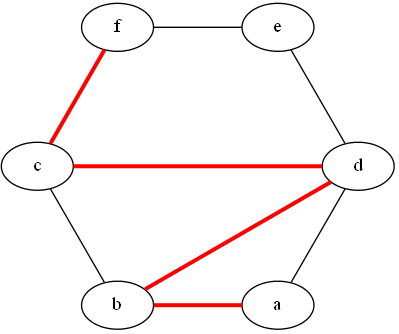
**画图引擎：**要画出右图，需要切换画图引擎为circo.

### 画图引擎

|  |  |
| --- | --- |
| 图形引擎 | 特点 |
| circo | 适合多环路结构的图形 |
| dot |  |
| neato |  |
| fdp |  |
| sfdp |  |
| twopi | 放射状布局 |

## 标注路径

由circo图形引擎生成：



|  |
| --- |
| graph {  a -- b -- d -- c -- f[color=red,penwidth=3.0];  b -- c;  d -- e;  e -- f;  a -- d;  } |

## 子图

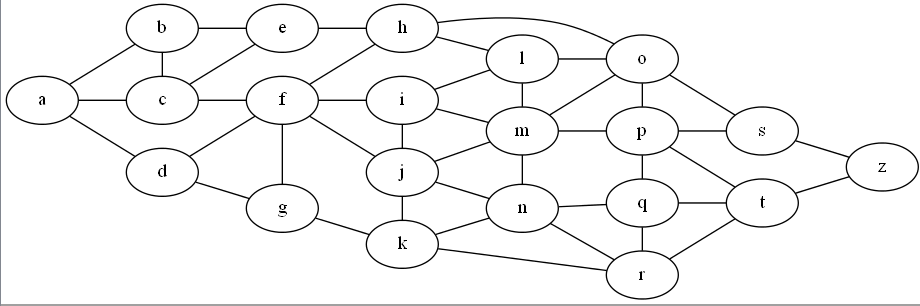
由dot图形引擎生成：

|  |  |
| --- | --- |
| digraph {  **splines=line;**  subgraph **cluster**\_0 {  label="Subgraph A";  a -> b;  b -> c;  c -> d;  }  subgraph cluster\_1 {  label="Subgraph B";  a -> f;  f -> c;  }  } |  |

**说明：**

* splines=line：指定只使用直线
* subgraph clusterXXX: 子图命名必需以cluster开关，否则无法合并到一个框图中。而且只有dot引擎支持。

## 大型图形:rank=same对齐



|  |
| --- |
| graph {  rankdir=LR;  a -- { b c d }; b -- { c e }; c -- { e f }; d -- { f g }; e -- h;  f -- { h i j g }; g -- k; h -- { o l }; i -- { l m j }; j -- { m n k };  k -- { n r }; l -- { o m }; m -- { o p n }; n -- { q r };  o -- { s p }; p -- { s t q }; q -- { t r }; r -- t; s -- z; t -- z;  { rank=same b c d };  { rank=same e f g } ;  { rank=same h i j k };  { rank=same l m n };  { rank=same o p q r };  { rank=same s t };  } |

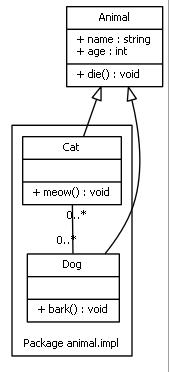
**说明：**

* a -- { b c d }; ： 指定 节点 -> 节点集合 的连线
* rank=same：将节点对齐排列，左右或上下
* ranksep=1：指定两级rank之间的距离,inch. 在上图中ranksep越大，a,c离的越开
* nodesep=1: 指定同级rank之间的距离,inch. 在上图中nodesep越大,a,c,d离的越开

## UML元素

引用：http://www.ffnn.nl/pages/articles/media/uml-diagrams-using-graphviz-dot.php

使用dot引擎生成：如果使用circo引擎，则无法生成子图



|  |
| --- |
| digraph G {  fontname = "Bitstream Vera Sans"  fontsize = 8  node [  fontname = "Bitstream Vera Sans"  fontsize = 8  shape = "record"  ]  edge [  fontname = "Bitstream Vera Sans"  fontsize = 8  ]  Animal [  label = "{Animal|+ name : string\l+ age : int\l|+ die() : void\l}"  ]  subgraph **cluster**AnimalImpl {  label = "Package animal.impl"  Dog [  label = "{Dog||+ bark() : void\l}"  ]  Cat [  label = "{Cat||+ meow() : void\l}"  ]  }  edge [  arrowhead = "empty"  ]  Dog -> Animal  Cat -> Animal  edge [  arrowhead = "none"  headlabel = "0..\*"  taillabel = "0..\*"  ]  Dog -> Cat  } |

### node[..],edge[..]设置节点、连线属性

### node[shape=”record”]

设置节点为record，这样的节点可以被分割，适合构造类图

### 类表示：Animal Class

|  |
| --- |
| Animal [  label = "{Animal|+ name : string\l+ age : int\l|+ die() : void\l}"  ] |
| Animal class UML model |

**说明：**

* "{" and "}"：表示要创建一个record的图形，并带有分隔线。
* "|" ： 代表分隔线。这时用于分隔类名、方法、属性
* "\l" ： 换行，后面的字符左对齐

### 继承关系:edge[arrowhead = "empty"]

|  |  |
| --- | --- |
| edge [  arrowhead = "empty"  ]  Dog -> Animal  Cat -> Animal | Adding the subclass relations to the UML diagram |

### N:M关系:edge[arrowhead=”none”,headlabel=””,taillabel=””]

|  |  |
| --- | --- |
| edge [  arrowhead = "none"  headlabel = "0..\*"  taillabel = "0..\*"  ] | Adding the association between classes |

### 包：使用子图实现subgraph clusterxxx {}

|  |  |
| --- | --- |
| subgraph clusterAnimalImpl {  label = "Package animal.impl"  ... Cat/Dog类  } |  |