Software Testing Assignment 2

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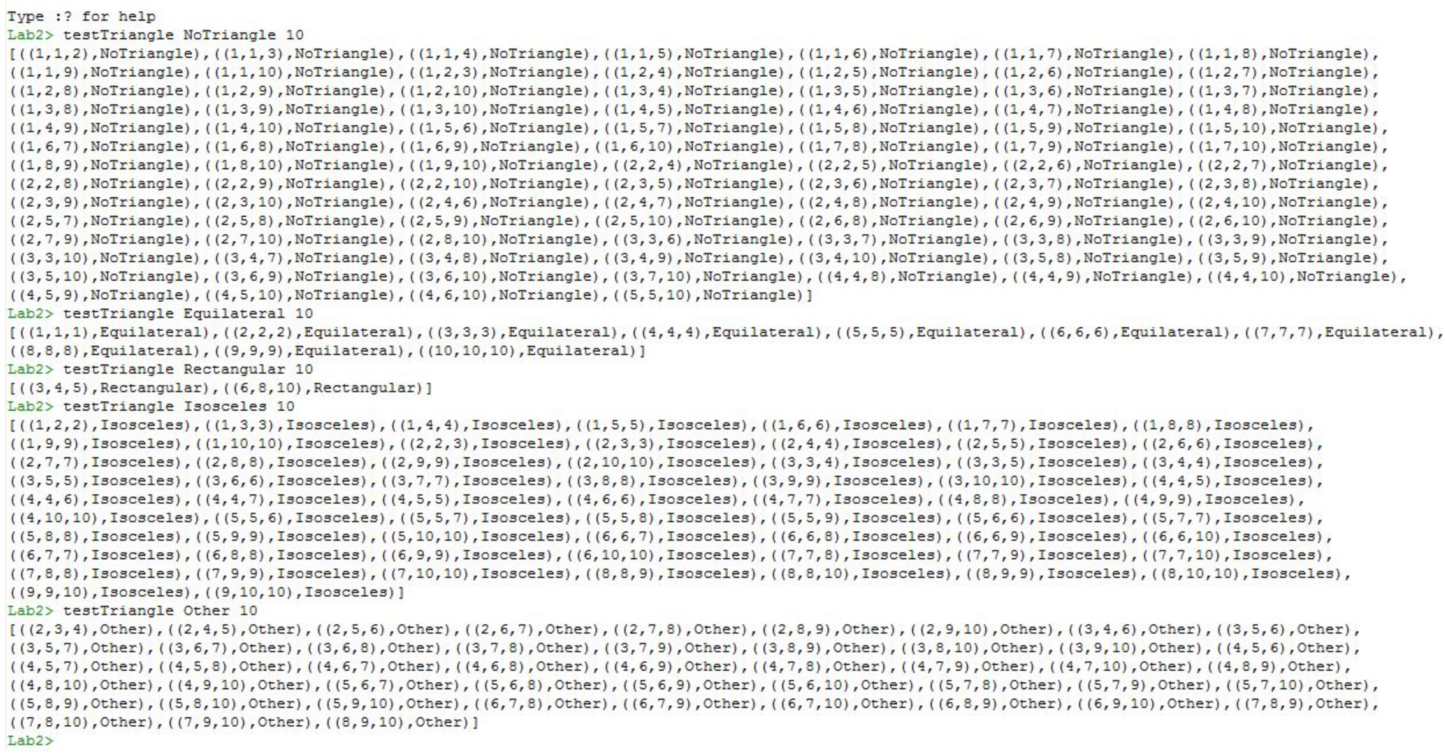
10 September , 2013

Triangle Exercise

```haskell
triangle :: Integer -> Integer -> Integer -> Shape
triangle x y z          | (a + b <= c) || (a <1)        = NoTriangle
                        | (a == b && b == c)            = Equilateral
                        | ((a^2 + b^2) == c^2)          = Rectangular
                        | (a == b) || (b == c)          = Isosceles
                        | otherwise                     = Other
                        where [a, b, c] = sort [x, y, z]

testTriangle :: Shape -> Integer -> [((Integer, Integer, Integer), Shape)]
testTriangle s maxN = [((a, b, c), s)   | a <- [1..maxN],
                                          b <- [a..maxN],
                                          c <- [b..maxN],
                                          triangle a b c == s]
```

The function testTriangle takes two input arguments. The first is the type of triangle and the second is the maximum side length. To avoid permutations (b,c) only range over there value of there predecessor and the maximum value as these permutations are mapped to the same values by the sort algortihm inside the triangle function. 10 was chosen as a maximum value to keep the results acceptable to manual inspection. The results are shown below and where verified to be correct.



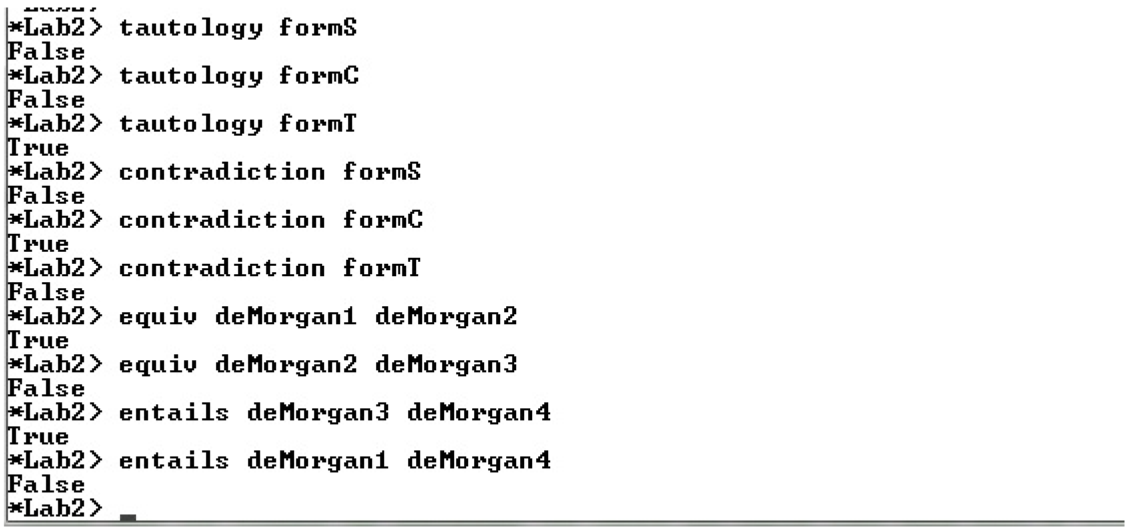
```
Type :? for help
Lab2> testTriangle NoTriangle 10
[((1,1,2),NoTriangle),((1,1,3),NoTriangle),((1,1,4),NoTriangle),((1,1,5),NoTriangle),((1,1,6),NoTriangle),((1,1,7),NoTriangle),((1,1,8),NoTriangle),
((1,1,9),NoTriangle),((1,1,10),NoTriangle),((1,2,3),NoTriangle),((1,2,4),NoTriangle),((1,2,5),NoTriangle),((1,2,6),NoTriangle),((1,2,7),NoTriangle),
((1,2,8),NoTriangle),((1,2,9),NoTriangle),((1,2,10),NoTriangle),((1,3,4),NoTriangle),((1,3,5),NoTriangle),((1,3,6),NoTriangle),((1,3,7),NoTriangle),
((1,3,8),NoTriangle),((1,3,9),NoTriangle),((1,3,10),NoTriangle),((1,4,5),NoTriangle),((1,4,6),NoTriangle),((1,4,7),NoTriangle),((1,4,8),NoTriangle),
((1,4,9),NoTriangle),((1,4,10),NoTriangle),((1,5,6),NoTriangle),((1,5,7),NoTriangle),((1,5,8),NoTriangle),((1,5,9),NoTriangle),((1,5,10),NoTriangle),
((1,6,7),NoTriangle),((1,6,8),NoTriangle),((1,6,9),NoTriangle),((1,6,10),NoTriangle),((1,7,8),NoTriangle),((1,7,9),NoTriangle),((1,7,10),NoTriangle),
((1,8,9),NoTriangle),((1,8,10),NoTriangle),((1,9,10),NoTriangle),((2,2,4),NoTriangle),((2,2,5),NoTriangle),((2,2,6),NoTriangle),((2,2,7),NoTriangle),
((2,2,8),NoTriangle),((2,2,9),NoTriangle),((2,2,10),NoTriangle),((2,3,5),NoTriangle),((2,3,6),NoTriangle),((2,3,7),NoTriangle),((2,3,8),NoTriangle),
((2,3,9),NoTriangle),((2,3,10),NoTriangle),((2,4,6),NoTriangle),((2,4,7),NoTriangle),((2,4,8),NoTriangle),((2,4,9),NoTriangle),((2,4,10),NoTriangle),
((2,5,7),NoTriangle),((2,5,8),NoTriangle),((2,5,9),NoTriangle),((2,5,10),NoTriangle),((2,6,8),NoTriangle),((2,6,9),NoTriangle),((2,6,10),NoTriangle),
((2,7,9),NoTriangle),((2,7,10),NoTriangle),((2,8,10),NoTriangle),((3,3,6),NoTriangle),((3,3,7),NoTriangle),((3,3,8),NoTriangle),((3,3,9),NoTriangle),
((3,3,10),NoTriangle),((3,4,7),NoTriangle),((3,4,8),NoTriangle),((3,4,9),NoTriangle),((3,4,10),NoTriangle),((3,5,8),NoTriangle),((3,5,9),NoTriangle),
((3,5,10),NoTriangle),((3,6,9),NoTriangle),((3,6,10),NoTriangle),((3,7,10),NoTriangle),((4,4,8),NoTriangle),((4,4,9),NoTriangle),((4,4,10),NoTriangle),
((4,5,9),NoTriangle),((4,5,10),NoTriangle),((4,6,10),NoTriangle),((5,5,10),NoTriangle)]
Lab2> testTriangle Equilateral 10
[((1,1,1),Equilateral),((2,2,2),Equilateral),((3,3,3),Equilateral),((4,4,4),Equilateral),((5,5,5),Equilateral),((6,6,6),Equilateral),((7,7,7),Equilateral),
((8,8,8),Equilateral),((9,9,9),Equilateral),((10,10,10),Equilateral)]
Lab2> testTriangle Rectangular 10
[((3,4,5),Rectangular),((6,8,10),Rectangular)]
Lab2> testTriangle Isosceles 10
[((1,2,2),Isosceles),((1,3,3),Isosceles),((1,4,4),Isosceles),((1,5,5),Isosceles),((1,6,6),Isosceles),((1,7,7),Isosceles),((1,8,8),Isosceles),
((1,9,9),Isosceles),((1,10,10),Isosceles),((2,2,3),Isosceles),((2,3,3),Isosceles),((2,4,4),Isosceles),((2,5,5),Isosceles),((2,6,6),Isosceles),
((2,7,7),Isosceles),((2,8,8),Isosceles),((2,9,9),Isosceles),((2,10,10),Isosceles),((3,3,4),Isosceles),((3,3,5),Isosceles),((3,4,4),Isosceles),
((3,5,5),Isosceles),((3,6,6),Isosceles),((3,7,7),Isosceles),((3,8,8),Isosceles),((3,9,9),Isosceles),((3,10,10),Isosceles),((4,4,5),Isosceles),
((4,4,6),Isosceles),((4,4,7),Isosceles),((4,5,5),Isosceles),((4,6,6),Isosceles),((4,7,7),Isosceles),((4,8,8),Isosceles),((4,9,9),Isosceles),
((4,10,10),Isosceles),((5,5,6),Isosceles),((5,5,7),Isosceles),((5,5,8),Isosceles),((5,5,9),Isosceles),((5,6,6),Isosceles),((5,7,7),Isosceles),
((5,8,8),Isosceles),((5,9,9),Isosceles),((5,10,10),Isosceles),((6,6,7),Isosceles),((6,6,8),Isosceles),((6,6,9),Isosceles),((6,6,10),Isosceles),
((6,7,7),Isosceles),((6,8,8),Isosceles),((6,9,9),Isosceles),((6,10,10),Isosceles),((7,7,8),Isosceles),((7,7,9),Isosceles),((7,7,10),Isosceles),
((7,8,8),Isosceles),((7,9,9),Isosceles),((7,10,10),Isosceles),((8,8,9),Isosceles),((8,8,10),Isosceles),((8,9,9),Isosceles),((8,10,10),Isosceles),
((9,9,10),Isosceles),((9,10,10),Isosceles)]
Lab2> testTriangle Other 10
[((2,3,4),Other),((2,4,5),Other),((2,5,6),Other),((2,6,7),Other),((2,7,8),Other),((2,8,9),Other),((2,9,10),Other),((3,4,6),Other),((3,5,6),Other),
((3,5,7),Other),((3,6,7),Other),((3,6,8),Other),((3,7,8),Other),((3,7,9),Other),((3,8,9),Other),((3,8,10),Other),((3,9,10),Other),((4,5,6),Other),
((4,5,7),Other),((4,5,8),Other),((4,6,7),Other),((4,6,8),Other),((4,6,9),Other),((4,7,8),Other),((4,7,9),Other),((4,7,10),Other),((4,8,9),Other),
((4,8,10),Other),((4,9,10),Other),((5,6,7),Other),((5,6,8),Other),((5,6,9),Other),((5,6,10),Other),((5,7,8),Other),((5,7,9),Other),((5,7,10),Other),
((5,8,9),Other),((5,8,10),Other),((5,9,10),Other),((6,7,8),Other),((6,7,9),Other),((6,7,10),Other),((6,8,9),Other),((6,9,10),Other),((7,8,9),Other),
((7,8,10),Other),((7,9,10),Other),((8,9,10),Other)]
Lab2>
```

Logic

```
contradiction :: Form -> Bool
contradiction f = not (satisfiable f)

tautology :: Form -> Bool
tautology f = all (\ v -> eval v f) (allVals f)

entails :: Form -> Form -> Bool
entails a b = all (\ v -> eval v f) (allVals f) where f = (Impl a b)

equiv :: Form -> Form -> Bool
equiv a b = all (\ v -> eval v f) (allVals f) where f = (Equiv a b)
```

Testing can be done by inserting propositions which we have already validated by hand. formC is a contradiction, formT is a tautology and formS is a proposition which is satisfiable. For equiv we can check DeMorgan Law's because we already know they are equivalant. DeMorgan can also be used for the entails function. Because if $\leftrightarrow$ holds than $\rightarrow$ will also hold.

```
formC =  Cnj[p, (Neg p)]
formT = Equiv (Impl p q)(Impl (Neg q)(Neg p))
formS = Dsj[p, (Neg q)]
deMorgan1 = Neg (Cnj[p,q])
deMorgan2 = Dsj[Neg p, Neg q]
deMorgan3 = Neg (Dsj[p,q])
deMorgan4 = Cnj[Neg p, Neg q]
```



```
*Lab2> tautology formS
False
*Lab2> tautology formC
False
*Lab2> tautology formT
True
*Lab2> contradiction formS
False
*Lab2> contradiction formC
True
*Lab2> contradiction formT
False
*Lab2> equiv deMorgan1 deMorgan2
True
*Lab2> equiv deMorgan2 deMorgan3
False
*Lab2> entails deMorgan3 deMorgan4
True
*Lab2> entails deMorgan1 deMorgan4
False
*Lab2> _
```

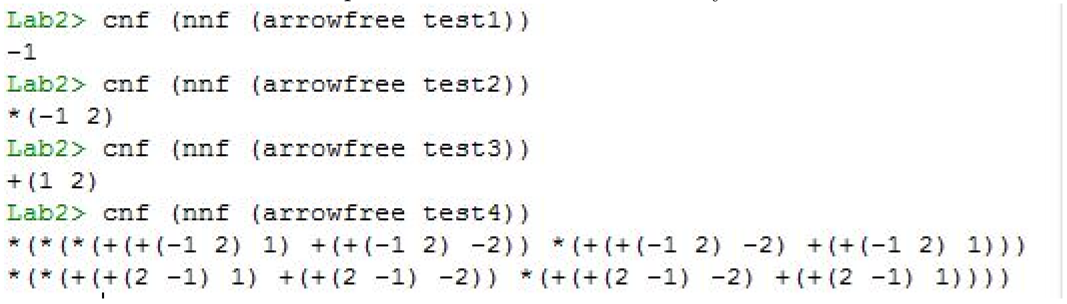
Conjunctive Normal Form (CNF)

```
-- Precondition: Form is arrowfree and in negative normal form
-- Postcondition: Form is in conjunctive normal form
cnf :: Form -> Form
cnf (Prop x)           = Prop x
cnf (Neg (Prop x))     = Neg (Prop x)
cnf (Cnj f)            = Cnj (map cnf f)
cnf (Dsj [f, g])       = dist (cnf f) (cnf g)
cnf (Dsj (f:fs))       = dist (cnf f) (cnf (Dsj fs))

-- Precondition: Forms are in conjunctive normal form
-- Postcondition: Form is the the conjuctive normal form of (form1 v form2)
dist :: Form -> Form -> Form
dist (Cnj fs) g        = Cnj (map (dist g) fs)
dist f (Cnj gs)        = Cnj (map (dist f) gs)
dist f g               = Dsj [f,g]
```

In order to define test cases arbritrary formulas need to be defined first and converted to conjunctive normal form manually. In the workshop four functions were defined and converted to CNF therefore these four functions will be used to test our CNF. The four test cases are:

```
test1 = Neg( Neg (Neg p))
test2 = Neg( Dsj[ p, Neg q])
test3 = Neg( Cnj[Neg p , Neg q])
test4 = Equiv (Impl p q) (Impl (Neg q) (Neg p))
```

The results are stated in the picture below and are verified by hand.



```
Lab2> cnf (nnf (arrowfree test1))
-1
Lab2> cnf (nnf (arrowfree test2))
*(-1 2)
Lab2> cnf (nnf (arrowfree test3))
+(1 2)
Lab2> cnf (nnf (arrowfree test4))
*(*(*(+(+(-1 2) 1) +(+(-1 2) -2)) *(+(+(-1 2) -2) +(+(-1 2) 1)))
*(*(+(+(2 -1) 1) +(+(2 -1) -2)) *(+(+(2 -1) -2) +(+(2 -1) 1))))
```