Numberjack Tutorial

(Adapted from Hebrard et al.'s AAAI 2010 tutorial and parts of the Numberjack website)

CS 275

April 2, 2014

What is Numberjack?

- A platform for constraints
- Written in Python - a front-end to C++-based solvers
- Excellent for rapidly trying out models

Overview of Python

- Scripting language
- Supports classes, objects, etc.

Basic Structures

Variables

```
a = 2
```

Functions

```
def double(a):
    return a * 2
```

Lists

```
foo = [1, 4, 5, 10, 2]
bar = ["this", "is", "a", "list"]
```

Tuples

```
triplet = (1, 2, 3)
```

Control

```
if <boolean_exp>:
    do_stuff()

while <boolean_exp>:
    do_stuff()
```

For Loops

For loops in C/C++/Java

```
for (int i = 0; i < n; ++i) {
    do_stuff(i)
}
```

For loops in Python

```
for i in range(n):
    do_stuff(i)
```

- Based on iterating through an iterable object

For Loops

```
for element in list:
    do_stuff_with(element)

pairs = [(0, "Foo"),
         (1, "Bar"),
         (2, "Baz")]
for id, item in pairs:
    print "ID ", id, ":", item
```

```
ID 0 : Foo
ID 1 : Bar
ID 2 : Baz
```

List Comprehensions

A very useful feature!

```
>>> range(4)
[0, 1, 2, 3]
>>> [x * 2 for x in range(4)]
[0, 2, 4, 6]
>>> [x * 2 for x in range(4) if x >= 2]
[4, 6]
```

Generally,

```
[<expression> for x in <Iterable> (if <condition>)]
```

Overview

- Constructs
  - Variables
  - Constraints
  - Model
- A common API to interface with back-end solvers

Variables

```
# binary variable
Variable()
# domain from 0 to N−1
Variable(N)
# domain from L to U
Variable(L, U)
# domain specified by a list
Variable(list)
```

Useful method (used after a solution has been found)

```
get_value()
```

Variables

More constructors:

```
# create a list of N binary variables
VarArray(N)
# create a list of N variables with domains from 0 to D−1
VarArray(N, D)
# create a list of N variables with domains from L to U
VarArray(N, L, U)
```

Variables

...and even more constructors:

```
# create a matrix of M x N binary variables
m = Matrix(M, N)
# create a matrix of M x N variables with domains from L to U
m = Matrix(M, N, L, U)
```

Special operators

```
# Return a VarArray containing all of the elements of the Matrix
m.flat
# Return a list of VarArrays corresponding to each row
m.row
# Return a list of VarArrays corresponding to each column
m.col
```

Constraints

- Arithmetic operators on variables

```
x > y
x == y + 2
a[1] > b[2]
m[1][4] != n[4][3]
```

- Global constructors

```
AllDiff([a, b, c, d, e])
AllDiff(myVarArray)
AllDiff(myMatrix)
Sum([a, b, c, d]) >= e
```

Model

- Used to collect the constraints together to define a problem
- Constructors

```
# empty model
model = Model()

# model with constraints
model = Model(constraints,...)
```

- Adding more constraints

```
model.add(constraints)
#or
model += constraints
```

Using a Solver

- Different solvers supported
  - SAT: MiniSat, Walksat
  - MIP: Gurobi, CPLEX, SCIP
  - CP: Mistral

Using a Solver

- Methods

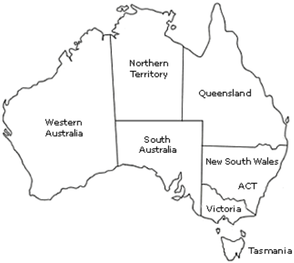
```
# Get a solver to solve the given problem specified
# by the model,
solver = model.load('nameOfSolver')
# attempts to solve the problem
solver.solve()
# for search-based solvers only (to generate multiple solutions)
solver.startNewSearch()
while solver.getNewSolution():
    # do something with solution
```

- Results are stored in the Variable objects

Outline of Usage

- Specify variables
- Specify constraints over those variables
- Construct a model with the constraints
- Construct the solver using that model
- Call solve() and extract results from Variables using get_value()
- Can alternatively use the print statement on Variables directly to output their values

Problem Definition



- Color the map such that no two adjacent territories have the same color.

Problem Definition

	x_0	x_1	x_2	x_3
0				
1				
2				
3				

- Place queens on the chessboard such that no two queens are attacking each other

Problem Definition

1	2	15	16
12	14	3	5
13	7	10	4
8	11	6	9

- Given an $N \times N$ square, place numbers ranging from 1 to N^2 such that each row, column, and diagonal has the same sum

Conclusion

- Rapid prototyping of problems
- Easy to test out different solvers
- Numberjack website: http://numberjack.ucc.ie (also linked from the course page)