İSTANBUL ŞEHİR ÜNİVERSİTY

ENGR 212: Programming Practice

Week 13

Optimization

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- Optimization finds the best solution to a problem by trying many different solutions and scoring them to determine their quality.
- Optimization is typically used in cases where there are too many possible solutions to try them all.
- The simplest but least effective method of searching for solutions is just trying a few thousand random guesses and seeing which one is best.

Group Travel Planning

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- Have you ever planned a trip for a group of people?
- You must have thought about total cost, time spent waiting at airports, and time taken off work.

Group Travel Planning

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- Let's plan a trip for a group of people (the Glass family in this example) from different locations all arriving at NewYork, La Guardia Airport.

Group Travel Planning

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Group Travel Planning

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```
import time
import random
import math

people = [('Seymour','BOS'),
          ('Franny','DAL'),
          ('Zooey','CAK'),
          ('Walt','MIA'),
          ('Buddy','ORD'),
          ('Les','OMA')]

# LaGuardia airport in New York
destination='LGA'
```

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- schedule.txt
  - This file contains origin, destination, departure time, arrival time, and price for a set of flights

```
LGA,MIA,20:27,23:42,169
MIA,LGA,19:53,22:21,173
LGA,BOS,6:39,8:09,86
BOS,LGA,6:17,8:26,89
LGA,BOS,8:23,10:28,149
```

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- Let's prepare a flights dictionary:

```
flights = {}
for line in file('schedule.txt'):
    origin, dest, depart, arrive, price = line.strip().split(',')
    flights.setdefault((origin, dest), [])

    # Add details to the list of possible flights
    flights[(origin, dest)].append((depart, arrive, int(price)))
```

Representing Solutions

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- There may be different alternatives.
- Should be generic enough so that any optimization algorithm may be used.
- List of numbers is a common representation.
  - Each number represents the flight a person takes

Example: `[1,4,3,2,7,3,6,3,2,4,5,3]`

Printing a Solution

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```
def printschedule(r):
    print r
    for d in range(len(r)/2):
        name = people[d][0]
        origin = people[d][1]
        out = flights[(origin,destination)][r[2*d]]
        ret = flights[(destination,origin)][r[2*d+1]]
        print '%10s%10s %5s-%5s $%3s %5s-%5s $%3s' % (name,origin,
                                                      out[0],out[1],out[2],
                                                      ret[0],ret[1],ret[2])
```

Printing a Solution

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```
import optimization
s=[1, 4, 3, 2, 7, 3, 6, 3, 2, 4, 5, 3]
optimization.printschedule(s)
```

Printing a Solution

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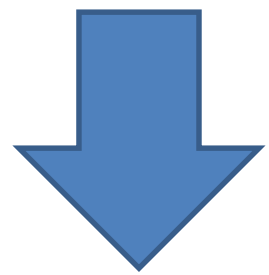
```
import optimization
s=[1, 4, 3, 2, 7, 3, 6, 3, 2, 4, 5, 3]
optimization.printschedule(s)
```



```
[1, 4, 3, 2, 7, 3, 6, 3, 2, 4, 5, 3]
   Seymour       BOS  8:04-10:11 $ 95 12:08-14:05 $142
    Franny       DAL 12:19-15:25 $342 10:51-14:16 $256
     Zooey       CAK 10:53-13:36 $189  9:58-12:56 $249
      Walt       MIA  9:15-12:29 $225 16:50-19:26 $304
     Buddy       ORD 16:43-19:00 $246 10:33-13:11 $132
       Les       OMA 11:08-13:07 $175 15:07-17:21 $129
```

The cost function

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- **Price**: The total price of all the plane tickets, or possibly a weighted average.
- **Travel time**: The total time that everyone has to spend on a plane.
- **Waiting time**: Time spent at the airport waiting for the other members of the party to arrive.

The cost function

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- **Departure time**: Flights that leave too early in the morning may impose an additional cost by requiring travelers to miss out on sleep.
- **Car rental period**: If the party rents a car, they must return it earlier in the day than when they rented it, or be forced to pay for a whole extra day.

The cost function

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- After choosing some variables that impose costs, you'll need to determine how to combine them into a single number.
- How much money that time on the plane or time waiting in the airport is worth?

The cost function

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- You might decide that:
  - it's worth spending $1 for every minute saved on air travel (this translates into spending an extra $90 for a direct flight that saves an hour and a half).
  - it's worth $0.50 for every minute saved waiting in the airport.
- You could also add the cost of an extra day of car rental if everyone returns to the airport at a later time of the day than when they first rented the car.

Computing the Cost (Part 1)

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```
def schedulecost(sol):
    totalprice = 0
    latestarrival = 0
    earliestdep = 24 * 60
    for d in range(len(sol) / 2):
        # Get the inbound and outbound flights
        origin = people[d][1]
        outbound = flights[(origin, destination)][int(sol[2 * d])]
        returnf = flights[(destination, origin)][int(sol[2 * d + 1])]

        # Total price is the price of all outbound and return flights
        totalprice += outbound[2]
        totalprice += returnf[2]

        # Each minute of flight duration costs $1
        totalprice += getminutes(outbound[1]) - getminutes(outbound[0])
        totalprice += getminutes(returnf[1]) - getminutes(returnf[0])

        # Track the latest arrival and earliest departure
        if latestarrival < getminutes(outbound[1]):
            latestarrival = getminutes(outbound[1])
        if earliestdep > getminutes(returnf[0]):
            earliestdep = getminutes(returnf[0])
```

Computing the Cost (Part 2)

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```
# Every person must wait at the airport until the latest person arrives.
# They also must arrive at the same time and wait for their flights.
totalwait = 0
for d in range(len(sol) / 2):
    origin = people[d][1]
    outbound = flights[(origin, destination)][int(sol[2 * d])]
    returnf = flights[(destination, origin)][int(sol[2 * d + 1])]
    totalwait += latestarrival - getminutes(outbound[1])
    totalwait += getminutes(returnf[0]) - earliestdep

# Does this solution require an extra day of car rental? That'll be $50!
if latestarrival < earliestdep:
    totalprice += 50

return totalprice + totalwait
```

The cost function

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```
>>> reload(optimization)
>>> optimization.schedulecost(s)
```

Educated Optimization

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- **Random Searching**
- Hill Climbing
- Genetic Algorithms
- Simulated Annealing

Random Search

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```
def randomoptimize(domain, costf):
    best = 999999999
    bestr = None
    for i in range(1000):
        # Create a random solution
        r = [random.randint(domain[i][0], domain[i][1])
             for i in range(len(domain))]
        # Get the cost
        cost = costf(r)

        # Compare it to the best one so far
        if cost < best:
            best = cost
            bestr = r

    return bestr
```

Random Searching

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- This function randomly generates 1,000 guesses and computes the schedule cost for each.
- It keeps track of the best guess (the one with the lowest cost) and returns it.

Random Searching

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```
>>> reload(optimization)

>>> domain = [(0,9)]*(len(optimization.people)*2)

>>> s =optimization.randomoptimize(domain,optimization.schedulecost)

>>> optimization.schedulecost(s)

>>> optimization.printschedule(s)
```