Linear_Programing_Randomize

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0.0.1 This file contains Linear programing randomize alg. and relaed test results.

0.0.2 Contents

- I. read from outfile the ramdomly generated test data
- II. Helper functions
- III. Main function
- IV. Test & plots
- V. Greedy cover alg.

```
In [10]: import pandas as pd
         import numpy as np
         import os
         from collections import Counter
         import matplotlib.pyplot as plt
         import pickle
         import time
         from pulp import *
         import random as rd
         import math
         import random as rd
```

0.1 I. read from outfile the ramdomly generated test data (100 tasks, 400 people)

```
In [3]: with open ('outfile', 'rb') as fp:
            itemlist = pickle.load(fp)
        task = itemlist[0]
        people = itemlist[1]
```

0.2 II. Helper functions

- constraints are ramdomly generated, with alpha being the percentage of constraints-involved tasks

In [474]:
```
# cross products
def cross(a,b):
    p = 0
    for (x,y) in zip(a,b):
        p+=(x*y)
    return p

# fomalize outputs
def output(arr):
    new = np.zeros((len(arr),len(arr[0])))
    for i in range(len(new)):
        for j in range(len(new[0])):
            new[i][j] = value(arr[i][j])
    return new

# print constraints
def printCons(prob):
    for a in prob.constraints.values():
        print(a)

# add additional constrain to lp problem:
# person p can be only assigned to team j
def prerequsite(p,j,prob,X):
    prob += X[p][j] == 1
    prob += sum(X[p]) == 1

# create superset of constrants for later use; return[[p1,p2...],task_inc
def generate_constraints(J,P,alpha):
    pairs = []
    chosen_to_be_fixed = []
    for i in np.random.choice(len(J),round(len(J)*alpha),replace=False):
        temp = []
        pre_size = np.random.choice(3) + 2 # decide the size of the alrea
        for j in range(pre_size): # find people fill in
            for k in range(len(P)):
                if (k not in chosen_to_be_fixed) and \
                (sum([(x+y) == 2 for (x,y) in zip(P[k],J[i])])>0): # have
                    chosen_to_be_fixed.append(k)
                    temp.append(k)
                    break
        pairs.append([temp,i])
    return pairs

# seclect a percentage of constraints from the superset; return[p,team_ir
def choose_constraints(J,P,alpha,cons):
    pairs = []
    chosen = []
    for i in range(round(len(J)*alpha)):
```

```
#         print(cons[i])
        task_index = cons[i][1]
        for member in cons[i][0]:
            chosen.append(member)
            pairs.append([member,task_index])
    return pairs
```

0.3 III. Main function

```
In [498]: def LPRD(J,P,R,pairs):
    """
    minimize personal loads with must-link constraints.

    Args:
        J: An array with shape (n_tasks,n_features) containing info about
        P: An array with shape (n_people,n_features) containing info abou
        pairs: A array with shape (n_pairs,2) containing info of the cons
        R: Number of iterations in the randomize part

    Returns:
        A binary matrix X with shape (n_people, n_tasks), indicating the

    Raises:

    """
    X = [[0 for x in range(len(J))] for y in range(len(P))]  # assignment
    ##_____________________________________________-
    # declare your variables
    L = LpVariable("L", 0, 1000)
    namestr = 0
    for i in range(len(X)):
        for j in range(len(X[1])):
            X[i][j] = LpVariable('x'+ str(namestr), 0, 1) # 0=<x<=1
            namestr += 1

    # defines the problem
    prob = LpProblem("problem", LpMinimize)
    # defines the objective function to minimize
    prob += L


    ##_____________________________________________-
    ## additional constraints!!!!

    chosen = [x[0] for x in pairs]
    for pair in pairs:
#         print(pair)
        prerequsite(pair[0],pair[1],prob,X)
```

```
print("# constraints:", len(pairs))

# find able-cover
able_cover = [0]*len(P[0])
for i in range(len(P)):
    able_cover = [x or y for (x,y) in zip(P[i],able_cover)]
print("able to cover:",sum(able_cover))
able_cover = [0]*len(P[0])
for i in range(len(P)):
    if i not in chosen:
        able_cover = [x or y for (x,y) in zip(P[i],able_cover)]
print("able to cover without pre-fixed cover:",sum(able_cover))

# find needed-cover
Jtemp = J[:]
needed_cover = [0]*len(P[0])
for i in range(len(Jtemp)):
    needed_cover = [x or y for (x,y) in zip(Jtemp[i], needed_cover)]
print("need cover:",sum(needed_cover),len(needed_cover))

for pair in pairs:
    Jtemp[pair[1]]  = [max(x-y,0) for (x,y) in zip(Jtemp[pair[1]], P[

needed_cover = [0]*len(P[0])
for i in range(len(Jtemp)):
    needed_cover = [x or y for (x,y) in zip(Jtemp[i], needed_cover)]
print("need cover besides pre-fixed cover:",sum(needed_cover),len(nee

needed_delete = [x>y for (x,y) in zip(needed_cover,able_cover)]
print("cannot cover after constraint:", sum(needed_delete))
needed_delete_mutiplicity = \
        [sum([1 for x in J if x[i]==1]) for i in range(len(needed_del
print("cannot cover(multiplicity) after constraint:", sum(needed_dele

##_____________________________________________
# defines the regular constraints

for i in range(len(X)):  # all people's loads subject to a uppper bou
    prob += sum(X[i])<=L

for i in range(len(J)): # all skills in all tasks must be covered
    for j in range(len(J[0])):
        if needed_delete[j] == 0:
            prob += cross([a[i] for a in X],[a[j] for a in P]) >= J[i
##_____________________________________________
# solve the problem
status = prob.solve(GLPK(msg=0))
```

```
        print(LpStatus[status])

        ##_____________________________________________-
        # print output
        print("L:",value(L))

        ##_____________________________________________-
        #randomize process
        X = output(X)
        for i in range(len(X)):
            for j in range(len(X[0])):
                for k in range(R):
                    if rd.uniform(0,1)<X[i][j]: # if at least one time it's c
                        X[i][j] = 1
                        break
                    if k == R-1:
                        X[i][j] = 0 # if not chosen in any round

        print("L:", max([sum(a) for a in X]))
#       print("X:", X)
        return [value(L),max([sum(a) for a in X]),sum(needed_delete),sum(need
```

0.4 IV. Test

In [477]:
```
# generate a superset of constraint, with 30 tasks as input
all_cons = generate_constraints(task[:30],people,1)
print(len(all_cons))
```

```
100
```

In [ ]:
```
# simple test
t0 = time.time()
constraints = choose_constraints(task[:30],people,0.9,all_cons)
sol = LPRD(task[:30],people,10,constraints)
print(time.time()-t0)
```

In [559]:
```
# generate a superset of constraint
all_cons = generate_constraints(task[:],people,1)
print(len(all_cons))
# save constraints
with open('all_cons', 'wb') as fp:
    pickle.dump(all_cons, fp)
```

In [482]:
```
# test change alpha:
temp = []
for i in range(10):
    t0 = time.time()
    constraints = choose_constraints(task[:],people,i/10,all_cons)
```

```
            sol = LPRD(task[:],people[:],10,constraints)
            print(time.time()-t0)
            temp.append(sol)
```

```
# constraints: 0
able to cover: 225
able to cover without pre-fixed cover: 225
need cover: 109 329
need cover besides pre-fixed cover: 109 329
cannot cover after constraint 0
cannot cover(multiplicity) after constraint 0
Optimal
L: 4.0
L: 4.0
255.85549402236938
# constraints: 27
able to cover: 225
able to cover without pre-fixed cover: 220
need cover: 109 329
need cover besides pre-fixed cover: 109 329
cannot cover after constraint 1
cannot cover(multiplicity) after constraint 1
Optimal
L: 4.0
L: 4.0
253.5968849658966
# constraints: 54
able to cover: 225
able to cover without pre-fixed cover: 215
need cover: 109 329
need cover besides pre-fixed cover: 106 329
cannot cover after constraint 3
cannot cover(multiplicity) after constraint 5
Optimal
L: 4.0
L: 4.0
244.39181399345398
# constraints: 84
able to cover: 225
able to cover without pre-fixed cover: 209
need cover: 109 329
need cover besides pre-fixed cover: 106 329
cannot cover after constraint 4
cannot cover(multiplicity) after constraint 6
Optimal
L: 4.0
L: 4.0
245.1851930618286
```

```
# constraints: 113
able to cover: 225
able to cover without pre-fixed cover: 202
need cover: 109 329
need cover besides pre-fixed cover: 106 329
cannot cover after constraint 6
cannot cover(multiplicity) after constraint 8
Optimal
L: 8.0
L: 8.0
244.6057951450348
# constraints: 146
able to cover: 225
able to cover without pre-fixed cover: 194
need cover: 109 329
need cover besides pre-fixed cover: 104 329
cannot cover after constraint 7
cannot cover(multiplicity) after constraint 9
Optimal
L: 8.0
L: 8.0
250.0923581123352
# constraints: 175
able to cover: 225
able to cover without pre-fixed cover: 186
need cover: 109 329
need cover besides pre-fixed cover: 100 329
cannot cover after constraint 12
cannot cover(multiplicity) after constraint 19
Optimal
L: 8.0
L: 8.0
241.67423510551453
# constraints: 201
able to cover: 225
able to cover without pre-fixed cover: 175
need cover: 109 329
need cover besides pre-fixed cover: 97 329
cannot cover after constraint 16
cannot cover(multiplicity) after constraint 24
Optimal
L: 9.0
L: 9.0
236.63631391525269
# constraints: 231
able to cover: 225
able to cover without pre-fixed cover: 163
need cover: 109 329
```

```
need cover besides pre-fixed cover: 91 329
cannot cover after constraint 21
cannot cover(multiplicity) after constraint 33
Optimal
L: 9.0
L: 9.0
236.0997130870819
# constraints: 262
able to cover: 225
able to cover without pre-fixed cover: 151
need cover: 109 329
need cover besides pre-fixed cover: 91 329
cannot cover after constraint 29
cannot cover(multiplicity) after constraint 63
Optimal
L: 4.0
L: 5.0
226.360533952713
```

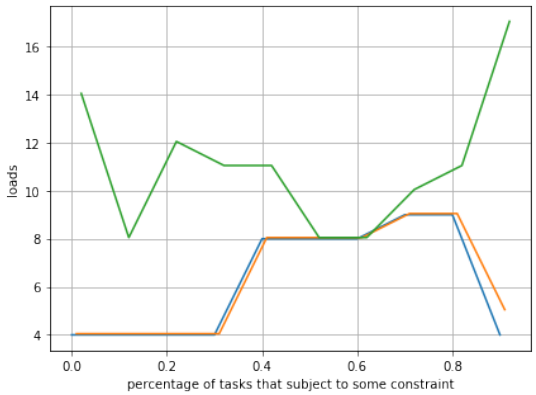
```
In [519]: # save LPRD output
          with open('LRPD', 'wb') as fp:
              pickle.dump(temp, fp)
```

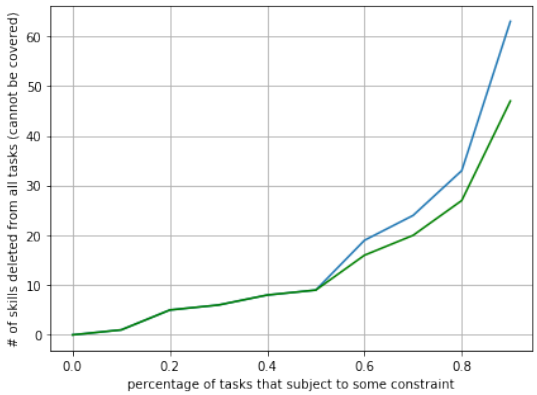
```
In [568]: # plot results
          plt.figure(figsize=(15,5))
          plt.subplot(1,2,1)
          plt.plot([x/10 for x in range(10)], [x[0] for x in temp] )
          plt.plot([x/10+0.01 for x in range(10)], [x[1]+0.05 for x in temp])
          plt.plot([x/10+0.02 for x in range(10)], [x[0]+0.05 for x in greedy_resul

          plt.ylabel('loads')
          plt.xlabel('percentage of tasks that subject to some constraint')
          plt.grid()

          plt.subplot(1,2,2)
          plt.plot([x/10 for x in range(10)], [x[3] for x in temp] )
          # plt.plot([x/10 for x in range(10)], [x[2] for x in temp] )
          plt.plot([x/10 for x in range(10)], [x[1] for x in greedy_results],c='gre

          plt.ylabel('# of skills deleted from all tasks (cannot be covered)')
          plt.xlabel('percentage of tasks that subject to some constraint')
          plt.grid()
          plt.show()
```





0.5 V. Greedy Cover

```
In [555]: # greedy cover for tasks one by one
          def greedy_cover(J,P,pairs):
              tasks, free = initiate(J,P,pairs)
              cover = [0]*len(P)
              cannot_cover = 0
              assignment = []
              for i in range(len(tasks)):
                  task = tasks[i]
                  team = []
                  while sum(task)>0:
                      temp = 0
                      best = 0
                      for k in range(len(P)):
                          if free[k] and k not in team:
                              able_cover = sum([x+y ==2 for (x,y) in zip(P[k],task)
                              if able_cover > temp:
                                  temp = able_cover
                                  best = k
                      if temp == 0:
                          cannot_cover += sum(task)
                          assignment.append(team)
                          break
          #             print(team,temp,best,sum(task))
                      cover[best] += 1
                      team.append(best)
                      task = [max(0,y-x) for (x,y) in zip(P[best],task)]
                  assignment.append(team)
              return max(cover),cannot_cover,assignment
```

```
        # pre-process tasks & people
        def initiate(J,P,pairs):
            tasks = J[:]
            free = [True] * len(P)
            for [x,y] in pairs:
            #         print(x,y)
                    tasks[y] = [max(a-b,0) for (a,b) in zip(tasks[y],P[x])]
                    free[x] = False
            return tasks,free

In [556]: # test
        greedy_results = []
        for i in range(10):
            t0 = time.time()
            constraints = choose_constraints(task[:],people,i/10,all_cons)
            a,b,c = greedy_cover(task[:],people[:],constraints)
            print(time.time()-t0)
            greedy_results.append([a,b,c])

2.9945781230926514
2.750607967376709
2.4696898460388184
2.2583701610565186
2.0872280597686768
1.8298351764678955
1.6376171112060547
1.4072449207305908
1.2246079444885254
0.9304728507995605
```