CLT_METIS_cust_solver

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UNIST

Input 형식

0. 데이터프레임 column 정보

1. 기본 문제 형태 (problem_input)

- xxx.mps 정보를 다음 데이터프레임 형태로 변형하여 사용

Package

```
import argparse
import os
import glob
import time
import math

import numpy as np
import numpy.lib.recfunctions as rfn

import networkx as nx
import metis

import cplex
from mip.model import *
from tqdm import tqdm
import pandas as pd
```

Function

0. cbc_solve : CBC solver

```
def model_solve(model, GAP, TIME):
    model.store_search_progress_log = True
    model.max_mip_gap = GAP
    model.integer_tol = 0.01
    startTime = time.time()
    model.preprocess = True
    status = model.optimize(max_seconds=TIME)
    solve_time = time.time() - startTime
    print('Time: {} (s)'.format(solve_time))
```

```
    print('Status: {}'.format(status))
    print('Objective Value: {}'.format(model.objective_value))
    print('Gap: {}'.format(model.gap))

    return model, solve_time
```

1. Functions for preprocessing

xxx.mps to numpy list for handling

```
def to_element_list(CONSTRAINTS_np):
    # Ignore when constraints have no variable # len(c['expr.ind'] == 0) #Meaningless Constraints
    con_df_dtype = np.dtype([('c.idx', int), ('ind', int), ('val', float),
                             ('sense', object), ('rhs', float)])
    CONSTRAINTS_df = np.concatenate([np.c_[[c['c.idx']]*len(c['expr.ind']),
                                           c['expr.ind'], c['expr.val'],
                                           [c['sense']]*len(c['expr.ind']),
                                           [c['rhs']]*len(c['expr.ind'])] for c in CONSTRAINTS_np])
    CONSTRAINTS_df = np.array([(int(c[0]), int(c[1]), float(c[2]),
                                str(c[3]), float(c[4])) for c in CONSTRAINTS_df], dtype = con_df_dtype)
    return CONSTRAINTS_df
```

Numpy list to mps format

```
def to_mps_format(CONSTRAINTS_df):
    con_np_dtype = np.dtype([('c.idx', int), ('expr.ind', list), ('expr.val', list),
                             ('sense', object), ('rhs', float)])
    con_group = np.split(CONSTRAINTS_df, np.cumsum(np.unique(CONSTRAINTS_df['c.idx'], return_counts=Tru
    CONSTRAINTS_df_np = np.array([(int(c['c.idx'][0]), list(c['ind']), list(c['val']),
                                   str(c['sense'][0]), float(c['rhs'][0]))
                                  for c in con_group], dtype = con_np_dtype)
    return CONSTRAINTS_df_np

def array_to_mps(VARIABLES_np, CONSTRAINTS_np):
    model = Model(solver_name="cbc")

    for v in tqdm(VARIABLES_np):
        model.add_var(name = VARIABLES_idx[int(v['v.idx'])],
                      obj = float(v['v.obj']),
                      ub = float(v['v.ub']),
                      lb = float(v['v.lb']),
                      var_type = str(v['v.var_type']))
    for c in tqdm(CONSTRAINTS_np):
        var_list = [model.var_by_name(VARIABLES_idx[ind]) for ind in c['expr.ind']]
        model.add_constr(LinExpr(variables = list(var_list),
                                 coeffs = list(c['expr.val']),
                                 const = float(c['rhs']),
                                 sense = str(c['sense'])),
                         name = CONSTRAINTS_idx[c['c.idx']],
```

```
                        )

    model.objective = xsum(v.obj * v for v in model.vars)
    print('\n model has {} vars, {} constraints and {} nzs'.format(model.num_cols, model.num_rows, model
    return (model)
```

Solution reflecting at the problem set

```
def update_model(VARIABLES_df_p, CONSTRAINTS_df_p, ANS):
    CONSTRAINTS_df_upd = CONSTRAINTS_df_p
    CONSTRAINTS_df_upd_ANS = np.empty(CONSTRAINTS_df_upd.shape,
                                      dtype = [('c.idx', int), ('ind', int), ('val', float),
                                               ('sense', object), ('rhs', float), ('ANS', float)])
    CONSTRAINTS_df_upd_ANS[['c.idx', 'ind', 'val', 'sense', 'rhs']] =
      CONSTRAINTS_df_upd[['c.idx', 'ind', 'val', 'sense', 'rhs']]

    for c in CONSTRAINTS_df_upd_ANS:
        if ANS[VARIABLES_idx[c['ind']]] != None:
            c['ANS'] = ANS[VARIABLES_idx[c['ind']]] * c['val']
        else:
            c['ANS'] = None

    con_group = np.split(CONSTRAINTS_df_upd_ANS, np.cumsum(np.unique(CONSTRAINTS_df_upd_ANS['c.idx'], r
    con_group_upd = []

    for c in con_group:
        c['rhs'] = c['rhs'][0] + sum(c['ANS'][np.logical_not(np.isnan(c['ANS']))])
        if sum((np.isnan(c['ANS']))) != 0:
            con_group_upd.append(c[np.isnan(c['ANS'])])

    CONSTRAINTS_df_p = np.concatenate(con_group_upd)
    CONSTRAINTS_df_p = CONSTRAINTS_df_p[['c.idx', 'ind', 'val', 'sense', 'rhs']]

    var_ANS = [VARIABLES_name[x] for x in ANS if ANS[x] is not None]
    del_var = np.array([np.where(VARIABLES_df_p['v.idx']==v)[0][0] for v in var_ANS
                        if len(np.where(VARIABLES_df_p['v.idx']==v)[0]) != 0])
    if len(del_var) != 0:
        VARIABLES_df_p = np.delete(VARIABLES_df_p, del_var, axis = 0)
    return (VARIABLES_df_p, CONSTRAINTS_df_p)
```

2. Functions for presolve

fixed_value_solver: 고정변수 solver (Fixed variable solver)

```
def fixed_value_solver(VARIABLES_df_p, ANS):
    fx_var = np.array([int(v['v.idx'])
                       for v in VARIABLES_df_p if v['v.ub'] == v['v.lb'] and v['v.var_type'] == str('I'
    for v in fx_var:
        ANS[VARIABLES_idx[v]] = VARIABLES_df_p[np.where(VARIABLES_df_p['v.idx']==v)]['v.ub'].item()
```

```
    cnt_f = len(fx_var)
    return(VARIABLES_df_p, ANS, cnt_f)
```

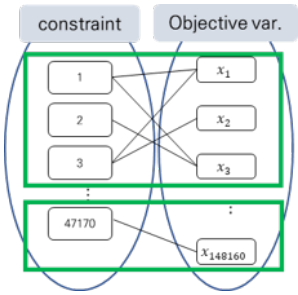
single_constraints_solver: 단순 방정식 solver (Linear Equation in One Variable solver)


```
def single_constraints_solver(VARIABLES_df_p, CONSTRAINTS_df_p, ANS):
    cnt_s = 0
    con_group = np.split(CONSTRAINTS_df_p, np.cumsum(np.unique(
      CONSTRAINTS_df_p['c.idx'],  return_counts=True)[1])[:-1])

    con_group_I = []
    con_group_upd =[]

    for c in con_group:
        if len(c) == 1:
            if c['sense'] ==  '=':
                ANS[VARIABLES_idx[int(c['ind'])]] = - float(c['rhs']) / float(c['val'])
                cnt_s = cnt_s + 1
                con_group_upd.append(c)
            elif VARIABLES_df_p[np.where(
              VARIABLES_df_p['v.idx']==c['ind'])]['v.var_type'].item() == 'I':
                 con_group_I.append(c)
            else:
                con_group_upd.append(c)
        else:
            con_group_upd.append(c)

    CONSTRAINTS_df_p = np.concatenate(con_group_upd)
    CONSTRAINTS_df_p = CONSTRAINTS_df_p[['c.idx', 'ind', 'val', 'sense', 'rhs']]

    for c in con_group_I:
        if c['sense'] == '<':
            ub_upd = max(VARIABLES_df_p['v.lb'][np.where(
              VARIABLES_df_p['v.idx'] == c['ind'])], math.floor(-c['rhs'] / c['val']))
            VARIABLES_df_p['v.ub'][np.where(VARIABLES_df_p['v.idx'] == c['ind'])] =
              min(VARIABLES_df_p['v.ub'][np.where(VARIABLES_df_p['v.idx'] == c['ind'])], ub_upd)
```

```
        elif c['sense'] == '>':
            lb_upd = min(VARIABLES_df_p['v.ub'][np.where(
              VARIABLES_df_p['v.idx'] ==  c['ind'])], math.ceil(-c['rhs'] / c['val']))
            VARIABLES_df_p['v.lb'][np.where(
              VARIABLES_df_p['v.idx'] == c['ind'])] =
              max(VARIABLES_df_p['v.lb'][np.where(
                VARIABLES_df_p['v.idx'] == c['ind'])], -c['rhs'] / c['val'])

    cnt_i = len(con_group_I)
    return(VARIABLES_df_p, CONSTRAINTS_df_p, cnt_s, cnt_i)
```

3. Dicomp_solver : 문제 분할 solver (Dicomposition solver)

- 완전히 독립적인 문제 set으로 분할하는 알고리즘
- 분할 된 Matrix 중 크기가 큰 Matrix는 ind_problem_1, 작은 Matrix는 ind_problem_2




```
def decompose (CONSTRAINTS_df_p,VARIABLES_df_p):
    r = 'int'
    diff = -1
    while diff!=0:
        if r == 'int':
            ind=CONSTRAINTS_df_p['ind'][0]
            Cidx = CONSTRAINTS_df_p[np.isin(CONSTRAINTS_df_p['ind'], ind)]['c.idx']
            ind = CONSTRAINTS_df_p[np.isin(CONSTRAINTS_df_p['c.idx'], Cidx)]['ind']
            diff = len(CONSTRAINTS_df_p[np.isin(CONSTRAINTS_df_p['ind'], ind)])
            r = 'noint'
        else:
            step1 = CONSTRAINTS_df_p[np.isin(CONSTRAINTS_df_p['ind'], ind)]
            Cidx = CONSTRAINTS_df_p[np.isin(CONSTRAINTS_df_p['ind'], ind)]['c.idx']
            ind = CONSTRAINTS_df_p[np.isin(CONSTRAINTS_df_p['c.idx'], Cidx)]['ind']
            step2 = CONSTRAINTS_df_p[np.isin(CONSTRAINTS_df_p['ind'], ind)]
            diff = len(step1)-len(step2)

    ind1 = CONSTRAINTS_df_p[np.isin(CONSTRAINTS_df_p['ind'],ind)==True]
    ind2 = CONSTRAINTS_df_p[np.isin(CONSTRAINTS_df_p['ind'],ind)==False]
    ind1_var = VARIABLES_df_p[np.isin(VARIABLES_df_p['v.idx'],ind1['ind'])]
    ind2_var = VARIABLES_df_p[np.isin(VARIABLES_df_p['v.idx'],ind2['ind'])]

    return(ind1,ind2,ind1_var,ind2_var)
```

4. Metis_2way: METIS solver를 이용한 G(E,V) 이분할

- 목적함수 변수와 제약조건으로 이루어진 matrix를 그래프 G(E,V)로 상정
  - E: 목적함수 변수 set, V: 제약조건 set 인

```
def METIS_2way (CONSTRAINTS_LR):
    const=CONSTRAINTS_LR['c.idx']
    obj=CONSTRAINTS_LR['ind']
    con_LR_index = []
    obj_LR_index = []
    for i in range(len(const)):
        con_LR_index.append("c"+f'{const[i]:08}')
    for i in range(len(obj)) :
        obj_LR_index.append("o"+f'{obj[i]:08}')

    # Graph element setting
    col = obj_LR_index
    row = con_LR_index
    edge = list()
    for i in range(len(col)):
        edge.append((col[i],row[i]))

    # Graph
    B = nx.Graph()
    B.add_nodes_from(col, bipartite=0)
    B.add_nodes_from(row, bipartite=1)
    B.add_edges_from(edge)

    # Partitiong
    part=metis.part_graph(B, nparts=2)
    part0=np.array(B.node)[np.isin(part[1],0)]
    part1=np.array(B.node)[np.isin(part[1],1)]

    part_0_v=[]
    part_1_v=[]
    for i in range(len(part0)):
        if 'o' in part0[i]:
            part_0_v.append(int(part0[i].replace("o","")))
    for i in range(len(part1)):
        if 'o' in part1[i]:
            part_1_v.append(int(part1[i].replace("o","")))

    return(part_0_v,part_1_v)
```

Final code

1. Input

- File number : 싸이버로지텍 예제의 임의 파일 번호 부여
- Time Limit : cbc solver의 time limit (예: 300)
- GAP : cbc solver의 tolerance gap (예: 30)

2. Output

- SOLUTION_fin : 'Input 형식'의 solution 형태로 도출
- 최종 결과물은 싸이버로지텍에서 요구한 형식에 맞춰 xxx.sol로 저장됨
- 만족하지 못한 제약조건 list와 정보를 xxx.csv로 반환

3. 실행 방법

- (1) CMD or Terminal 실행
- (2) 다음의 코드 입력

```
Python CLT_METIS_cust_solver --FILE FileName --TIME Time --GAP GAP --CONVERSION False
```

4. Main Code

```
import argparse
import os
import glob
import time
import math

import numpy as np
import numpy.lib.recfunctions as rfn

import networkx as nx
import metis

import cplex
from mip.model import *

from tqdm import tqdm

def parse_args():
    parser = argparse.ArgumentParser(description='Python module for CLT MIP problems')
    parser.add_argument('--FILE', type=str, required=True, help='mps file to solve')
    parser.add_argument('--CONVERSION', type=str, default='True', help='mps file conversion using CPLEX
    parser.add_argument('--GAP', type=float, default=0.05, help='gap between best solution found and be
    parser.add_argument('--TIME', type=float, default=100, help='maximum runtime in second for solver:

    return parser.parse_args()
def mps_model_read(file):
```

```
    name = os.path.basename(file)
    m = Model(name = name, sense = 'MIN', solver_name = 'cbc')
    m.read(name)
    m.name = name
    m.sense = 'MIN'
    m.solver_name = 'cbc'
    return m

params = parse_args()

filename = str(os.getcwd()+'/'+params.FILE)
print(filename)
name = os.path.basename(filename)
GAP = float(params.GAP)
TIME = float(params.TIME)
TimeLimit = TIME
Tol = GAP
# If file is not callable in cbc, transform the file into CPLEX mps format
if params.CONVERSION == 'True':
    import cplex
    file = cplex.Cplex(filename)
    cplex_file = str(filename[:-4]+'_cplex.mps')
    file.write(cplex_file)
    filename = cplex_file

# Model Copy and Preprocess
# MPS file copy to structured numpy
print('\n###################################################################################################')
print('########################         Model Copy and Preprocess         ########################')
print('###################################################################################################\n')
Preprocess_startTime = time.time()

Total_startTime = time.time()
m = mps_model_read(filename)

print('model has {} vars, {} constraints and {} nzs'.format(m.num_cols, m.num_rows, m.num_nz))

#preprocessing
num_var = m.num_cols
var_index = [v.idx for v in m.vars]
var_names = [v.name for v in m.vars]
var_dtype = np.dtype([('v.idx', int), ('v.obj', float), ('v.ub', float), ('v.lb', float), ('v.var_type'
VARIABLES = [(int(v.idx), float(v.obj), float(v.ub), float(v.lb), str(v.var_type)) for v in m.vars]

VARIABLES_np = np.array(VARIABLES, dtype=var_dtype)
VARIABLES_df = VARIABLES_np.copy()
VARIABLES_idx = dict(zip(var_index, var_names))
VARIABLES_name = dict(zip(var_names, var_index))

num_con = m.num_rows
con_index = [c.idx for c in m.constrs]
con_names = [c.name for c in m.constrs]
con_np_dtype = np.dtype([('c.idx', int), ('expr.ind', list), ('expr.val', list),
```

```
                        ('sense', object), ('rhs', float)])
CONSTRAINTS = [(int(c.idx),
               list([np.int(VARIABLES_name[ind.name]) for ind in c.expr.expr.keys()]),
               list([np.float(val) for val in c.expr.expr.values()]),
               str(c.expr.sense), float(c.expr.const)) for c in m.constrs]

CONSTRAINTS_np = np.array(CONSTRAINTS, dtype = con_np_dtype)
CONSTRAINTS_idx = dict(zip(con_index, con_names))
CONSTRAINTS_name = dict(zip(con_names, con_index))

ANS = dict.fromkeys(var_names, None)
OBJ = dict.fromkeys(var_names, None)

for v in m.vars:
    OBJ[v.name] = v.obj

# Define function for constraints table in mps format and element list
CONSTRAINTS_df = to_element_list(CONSTRAINTS_np)
CONSTRAINTS_df_np = to_mps_format(CONSTRAINTS_df)



###
Presolve_startTime = time.time()
#model_p = model_solve(m, GAP, TIME)
ANS = dict.fromkeys(var_names, None)
VARIABLES_df_p = VARIABLES_df.copy()
CONSTRAINTS_df_p = CONSTRAINTS_df.copy()



cnt_MC = 0
cnt_MOV = 0

# Remove Meaningless Constraint

cnt_MC = CONSTRAINTS_np.shape[0] - to_mps_format(CONSTRAINTS_df_p).shape[0]
print('Remove {} MCs'.format(cnt_MC))

# Remove Meaningless Objective Variables
s = set(np.unique(CONSTRAINTS_df_p['ind']))
v_not = np.array([int(v) for v in VARIABLES_df_p['v.idx'] if int(v) not in s])
for v in v_not:
    ANS[VARIABLES_idx[v]] = 0
cnt_MOV = len(v_not)
if len(v_not) != 0:
    VARIABLES_df_p = np.delete(VARIABLES_df_p, v_not, axis = 0)
print('Remove {} MOVs'.format(cnt_MOV))


cnt_f = -1
VARIABLES_df_p, ANS, cnt_f = fixed_value_solver(VARIABLES_df_p, ANS)
VARIABLES_df_p, CONSTRAINTS_df_p = update_model(VARIABLES_df_p, CONSTRAINTS_df_p, ANS)
```

```
print('Model has {} fixed value variables'.format(cnt_f))




cnt_s = -1
cnt_i = -1
while cnt_s != 0:
    VARIABLES_df_p, CONSTRAINTS_df_p, cnt_s, cnt_i = single_constraints_solver(VARIABLES_df_p, CONSTRAI
    VARIABLES_df_p, CONSTRAINTS_df_p = update_model(VARIABLES_df_p, CONSTRAINTS_df_p, ANS)
    print('Model has {} simple equations'.format(cnt_s))
    print('Model has {} integer bound-fixing variables'.format(cnt_i))


print(VARIABLES_df.shape, VARIABLES_df_p.shape)
print(CONSTRAINTS_df.shape, CONSTRAINTS_df_p.shape)



pre = []
for v in var_names:
    if ANS[v] != None:
        pre.append(ANS[v] * float(VARIABLES_df[np.where(VARIABLES_df['v.idx']==VARIABLES_name[v])]['v.ob
print(sum(pre))
CONSTRAINTS_df_p_np = to_mps_format(CONSTRAINTS_df_p)

print(filename)
Presolve_endTime = time.time() - Presolve_startTime
print('Presolve_Time: {} (s)'.format(Presolve_endTime))

Total_endTime = time.time() - Total_startTime
print('Total_Time: {} (s)'.format(Total_endTime))



CONSTRAINTS_df_p_cp = CONSTRAINTS_df_p.copy()
VARIABLES_df_p_cp = VARIABLES_df_p.copy()

CONSTRAINTS_df_p_decomp1,CONSTRAINTS_df_p_decomp2,VARIABLES_df_p_decomp1,VARIABLES_df_p_decomp2 = decomp
CONSTRAINTS_df_p_np_decomp1=to_mps_format(CONSTRAINTS_df_p_decomp1)
CONSTRAINTS_df_p_np_decomp2=to_mps_format(CONSTRAINTS_df_p_decomp2)

model_p1 = array_to_mps(VARIABLES_df_p_decomp1, CONSTRAINTS_df_p_np_decomp1)
model_p1.name = name
model_p1.sense = 'MIN'
model_p1.solver_name = 'cbc'

model_p1.write(str(filename[:-4]+'_presolve.mps'))
model_p1 = Model(name=name, sense='MIN', solver_name='cbc')
model_p1.read(str(filename[:-4]+'_presolve.mps.mps'))

model_p1.max_mip_gap = GAP
model_p1.solver.set_mip_gap = GAP
```

```
model_p1_solve_time = 0
result1,solve_time=model_solve(model_p1, GAP, TIME)

model_p2 = array_to_mps(VARIABLES_df_p_decomp2, CONSTRAINTS_df_p_np_decomp2)
model_p2.name = name
model_p2.sense = 'MIN'
model_p2.solver_name = 'cbc'

        ## mps file save is required due to segmentation fault
model_p2.write(str(filename[:-4]+'_presolve.mps'))
model_p2 = Model(name=name, sense='MIN', solver_name='cbc')
model_p2.read(str(filename[:-4]+'_presolve.mps.mps'))

model_p2.max_mip_gap = GAP
model_p2.solver.set_mip_gap = GAP

model_p2_solve_time = 0
result2, solve_time=model_solve(model_p2,  GAP, TIME)


print('Presolve objective value : {} '.format(sum(pre)))
print('1st decomposition objective value : {}'.format(result1.objective_value))
print('2nd decomposition objective value : {}'.format(result2.objective_value))


num_feasible = []
num_optimal = []
num_infeasible = []
totalvalue = []
for a in (result1, result2):
    print(a.status.name)
    if a.status.name!='NO_SOLUTION_FOUND' :
        num_feasible.append(a.num_cols)
        if a. status.name == "OPTIMAL" :
            num_optimal.append(a.num_cols)
        totalvalue.append(a.objective_value)
    else :
        num_infeasible.append(a.num_cols)
        savepath_write =str(filename[:-4]+'_sym.mps')
        print(savepath_write)
        a.write(str(filename[:-4]+'_sym.mps'))
        a = Model(name = name, sense = 'MIN', solver_name = "cbc")
        a.read(savepath_write+'.mps')
        metis_file= savepath_write
        name = os.path.basename(metis_file)


        # CBC solver to translate readable file
        ## Solve the mps file with cbc solver
        m = Model(name = name, sense = 'MIN', solver_name = "cbc")
        m.read(metis_file+'.mps')
        print('model has {} vars, {} constraints and {} nzs'.format(m.num_cols, m.num_rows, m.num_nz))
```

```
        #preprocessing
        num_var = m.num_cols
        var_index = [v.idx for v in m.vars]
        var_names = [v.name for v in m.vars]
        var_dtype = np.dtype([('v.idx', int), ('v.obj', float), ('v.ub', float), ('v.lb', float), ('v.va
        VARIABLES = [(int(v.idx), float(v.obj), float(v.ub), float(v.lb), str(v.var_type)) for v in m.va

        VARIABLES_np = np.array(VARIABLES, dtype=var_dtype)
        VARIABLES_df = VARIABLES_np.copy()
        VARIABLES_idx = dict(zip(var_index, var_names))
        VARIABLES_name = dict(zip(var_names, var_index))

        num_con = m.num_rows
        con_index = [c.idx for c in m.constrs]
        con_names = [c.name for c in m.constrs]
        con_np_dtype = np.dtype([('c.idx', int), ('expr.ind', list), ('expr.val', list),
                                 ('sense', object), ('rhs', float)])
        CONSTRAINTS = [(int(c.idx),
                        list([np.int(VARIABLES_name[ind.name]) for ind in c.expr.expr.keys()]),
                        list([np.float(val) for val in c.expr.expr.values()]),
                        str(c.expr.sense), float(c.expr.const)) for c in m.constrs]

        CONSTRAINTS_np = np.array(CONSTRAINTS, dtype = con_np_dtype)
        CONSTRAINTS_idx = dict(zip(con_index, con_names))
        CONSTRAINTS_name = dict(zip(con_names, con_index))

        ANS = dict.fromkeys(var_names, None)
        OBJ = dict.fromkeys(var_names, None)

        for v in m.vars:
            OBJ[v.name] = v.obj

        # Define function for constraints table in mps format and element list
        CONSTRAINTS_df = to_element_list(CONSTRAINTS_np)
        CONSTRAINTS_df_np = to_mps_format(CONSTRAINTS_df)

        Presolve_startTime = time.time()
        ANS = dict.fromkeys(var_names, None)
        VARIABLES_df_p = VARIABLES_df.copy()
        CONSTRAINTS_df_p = CONSTRAINTS_df.copy()

        part_0_v, part_1_v=METIS_2way(CONSTRAINTS_df)

        VARIABLES_LR=VARIABLES_df
        VARIABLES_METIS_0=VARIABLES_LR[np.isin(VARIABLES_LR['v.idx'],part_0_v)]
        VARIABLES_METIS_1=VARIABLES_LR[np.isin(VARIABLES_LR['v.idx'],part_1_v)]

        CONSTRAINTS_LR=CONSTRAINTS_df
        CONSTRAINTS_METIS_0=CONSTRAINTS_LR[np.isin(CONSTRAINTS_LR['ind'],part_0_v)]
        CONSTRAINTS_METIS_1=CONSTRAINTS_LR[np.isin(CONSTRAINTS_LR['ind'],part_1_v)]

        linking_const=list(set(CONSTRAINTS_METIS_0[np.isin(CONSTRAINTS_METIS_0['c.idx'],CONSTRAINTS_METI
```

```
print(len(linking_const))
print(len(VARIABLES_METIS_0))
print(len(VARIABLES_METIS_1))
print(len(CONSTRAINTS_METIS_0))
print(len(CONSTRAINTS_METIS_1))

CONSTRAINTS_METIS_0=CONSTRAINTS_METIS_0[np.isin(CONSTRAINTS_METIS_0['c.idx'],linking_const)==Fal
CONSTRAINTS_METIS_1=CONSTRAINTS_METIS_1[np.isin(CONSTRAINTS_METIS_1['c.idx'],linking_const)==Fal
print(len(CONSTRAINTS_METIS_0))
print(len(CONSTRAINTS_METIS_1))
CONSTRAINTS_metis_0=to_mps_format(CONSTRAINTS_METIS_0)
CONSTRAINTS_metis_1=to_mps_format(CONSTRAINTS_METIS_1)

model_p1 = array_to_mps(VARIABLES_METIS_0, CONSTRAINTS_metis_0)
model_p1.name = name
model_p1.sense = 'MIN'
model_p1.solver_name = 'cbc'

model_p1.write(str(filename[:-4]+'_presolve.mps'))
model_p1 = Model(name=name, sense='MIN', solver_name='cbc')
model_p1.read(str(filename[:-4]+'_presolve.mps.mps'))

model_p1.max_mip_gap = GAP
model_p1.solver.set_mip_gap = GAP

model_p1_solve_time = 0
result3,solve_time=model_solve(model_p1, GAP, TIME)

model_p2 = array_to_mps(VARIABLES_METIS_1, CONSTRAINTS_metis_1)
model_p2.name = name
model_p2.sense = 'MIN'
model_p2.solver_name = 'cbc'

model_p2.write(str(filename[:-4]+'_presolve.mps'))
model_p2 = Model(name=name, sense='MIN', solver_name='cbc')
model_p2.read(str(filename[:-4]+'_presolve.mps.mps'))

model_p2.max_mip_gap = GAP
model_p2.solver.set_mip_gap = GAP

model_p2_solve_time = 0
result4,solve_time=model_solve(model_p2, GAP, TIME)



VARIABLES_idx2 = dict(zip(var_names,var_index))
sol_names = []
for v in result3.vars:
    sol_names.append(v.name)
for v in result4.vars:
    sol_names.append(v.name)

sol_index = []
```

```
    for v in sol_names:
        sol_index.append(VARIABLES_idx2[v])

    org_var_index = []
    for v in var_names:
        org_var_index.append(VARIABLES_idx2[v])
    org_var_index

    no_solution=np.array(org_var_index)[np.isin(org_var_index, sol_index)==False]
    no_solution_names=[]
    for v in no_solution:
        no_solution_names.append(VARIABLES_idx[v])
    no_solution_names
    sol_names = []
    for v in result3.vars:
        sol_names.append(v.name)
    for v in result4.vars:
        sol_names.append(v.name)
    for v in no_solution_names:
        sol_names.append(v)
    sol_names

    sol_val = []
    for v in result3.vars:
        sol_val.append(v.x)
    for v in result4.vars:
        sol_val.append(v.x)
    for v in no_solution_names:
        sol_val.append(VARIABLES_df[np.isin(VARIABLES_df['v.idx'],VARIABLES_idx2[v])]['v.lb'][0])
    SOLUTION = dict(zip(sol_names, sol_val))

    const_stat = []
    const_name = []
    lhs = []

    for lc in linking_const:
        linking_const_set=CONSTRAINTS_df[np.isin(CONSTRAINTS_df['c.idx'], lc)]
        linking_var=VARIABLES_df[np.isin(VARIABLES_df['v.idx'],linking_const_set['ind'])]['v.idx']

        const_name.append([CONSTRAINTS_idx[lc],linking_const_set['sense'][0], linking_const_set['rhs

        linking_const_lhs = []
        for c in linking_var:

            linking_const_lhs.append(SOLUTION[VARIABLES_idx[c]]*linking_const_set[np.isin(linking_c

        if linking_const_set['sense'][0] == '<':
            const_stat.append((sum(linking_const_lhs)+np.array(linking_const_set['rhs'][0], dtype =
            lhs.append(sum(linking_const_lhs))
        if linking_const_set['sense'][0] == '>':
            const_stat.append((sum(linking_const_lhs)+np.array(linking_const_set['rhs'][0], dtype =
            lhs.append(sum(linking_const_lhs))
        if linking_const_set['sense'][0] == '=':
```

```
                const_stat.append(abs(sum(linking_const_lhs)+np.array(linking_const_set['rhs'][0], dtyp
                lhs.append(sum(linking_const_lhs))

            const_satis_ratio=sum(const_stat)/len(linking_const)*100
            num_const_unsatis = len(linking_const)-sum(const_stat)

    linking_result = []
    for c in range(len(const_name)):
        linking_result.append((CONSTRAINTS_idx2[const_name[c][0]],const_name[c][0],lhs[c],const_name[c]

    linking_result_dtype = np.dtype([('c.idx',int),('c.name', object), ('lhs', object), ('sense', objec
    linking_result=np.array([(c[0], c[1], c[2], c[3], c[4],c[5]) for c in linking_result], dtype = link
    linking_result_F=linking_result[np.isin(linking_result['TF'],False)]

    print('The number of unsatisfied constraint:{}'.format(len(const_stat)-sum(const_stat)))
    return(linking_result_F)

def total_obj_calculator(SOLUTION):
    obj_value=[]
    for v in VARIABLES_df:
        obj_value.append(SOLUTION[VARIABLES_idx[v['v.idx']]]*v['v.obj'])
    return(np.nansum(obj_value))

def check_const(check_con_idx):
    var_set=CONSTRAINTS_df[np.isin(CONSTRAINTS_df['c.idx'],check_con_idx)]
    print(check_con_idx,var_set['sense'][0],var_set['rhs'][0])
    print('sol|var|sol*var|v.idx|v.obj|ub|lb|type|variable name')
    for v in var_set:
        print(SOLUTION[VARIABLES_idx[v['ind']]], v['val'],SOLUTION[VARIABLES_idx[v['ind']]]*v['val'], VA
             VARIABLES_idx[VARIABLES_df[np.isin(VARIABLES_df['v.idx'],v['ind'])]['v.idx'][0]])
def sol_to_change(sol_to_):
    sol_to_change = []
    for v in sol_to_:
        print('{} is to {} '.format(VARIABLES_idx[v[0]],v[1]))
        SOLUTION.update(zip([v[0]],[v[1]]))

CONST_satisfy_list_pre=linking_result_F

print('Do you want customizing the solution? ([y] or [n])')
key = input()
if key == 'y':
    end = 'y'
    while end =='y':
        print(CONST_satisfy_list_pre)
        print('Which constraint do you want to check? Enter the constraint index (only one)')
        const_idx_select = input()
        if const_idx_select!='n':
            print(check_const(int(const_idx_select)))
            print('Enter the variable index and solution which do you want. (multiple is avable, e.g. >
            var_idx_select=input()
            if var_idx_select != 'n':
                var_idx_select=var_idx_select.split(',')
                var_to=[]
```

```
                for v in var_idx_select:
                    var_to.append(int(v))
                print(VARIABLES_df[np.isin(VARIABLES_df['v.idx'],var_to)])
                print('Enter the solution')
                sol_select= input()
                sol_select=sol_select.split(',')
                sol=[]
                for v in sol_select:
                    sol.append(int(v))
                var_to_sol=[]
                for v in range(len(var_to)):
                    var_to_sol.append((var_to[v],sol[v]))
                sol_to_change(var_to_sol)
                CONST_satisfy_list=CONST_satisfy_function(SOLUTION)

                print('Do you want to customizint the solution more? ([y] or [n])')
                CONST_satisfy_list_pre=CONST_satisfy_list
                end = input()
            else: end = 'n'
        else: end = 'n'
    print('==============================')
    print('     End the process')
    print('==============================')

    SOLUTION_1st=[]
    for v in var_names:
        SOLUTION_1st.append((v,SOLUTION[v]))

else:
    SOLUTION_1st=[]
    for v in var_names:
        SOLUTION_1st.append((v,SOLUTION[v]))



print('The total objective value is {}'.format(total_obj_calculator(SOLUTION)))

SOLUTION_1st_dtype = np.dtype([('v.name', object), ('sol', int)])
SOLUTION_1st_list = np.array([(c[0], c[1]) for c in SOLUTION_1st], dtype = SOLUTION_1st_dtype)

FINAL=pd.DataFrame(SOLUTION_1st_list)

savepath_copy = currentpath +'processing/Copy/'
savename_copy = savepath_copy + os.path.basename('model_p2')
savename_copy = savename_copy[:-4]+'_copy.mps'
resultname=filename.replace('data','processing/result_LP_sol')+'.csv'
FINAL.to_csv(resultname,header=True, index=False)



Total_endTime = time.time() - Total_startTime
solved_ratio=(sum(num_feasible)+len(pre))/(sum(num_feasible)+len(pre)+sum(num_infeasible))*100
optimal_ratio=(sum(num_optimal)+len(pre))/(sum(num_feasible)+len(pre)+sum(num_infeasible))*100
```

```
infeasible_ratio = 100-solved_ratio




import pandas as pd
if result1.status.name != "INFEASIBLE":
    total_value= sum(pre)+result1.objective_value+result2.objective_value
    FINAL = [[sum(pre),result1.objective_value, result2.objective_value, 0,0,
              total_value,
              result1.status.name,result2.status.name,'nan','nan',
              len(pre),result1.num_cols, result2.num_cols,0,0,
              solved_ratio, optimal_ratio,  infeasible_ratio,Total_endTime           ]]
    print('====================================================================')
    print('The summary of {}'.format(filename))
    print('Ratio of solved variables (%) is :{}'.format(solved_ratio))
    print('Ratio of optimal solved variables (%) is :{}'.format(solved_ratio))
    print('The toal value is :{}'.format((total_value)))
    print('Presolve objective value : {} '.format(sum(pre)))
    print('1st decomposition objective value : {}'.format(result1.objective_value))
    print('2nd decomposition objective value : {}'.format(result2.objective_value))
    print('Total_Time: {} (s)'.format(Total_endTime))
    print('====================================================================')

else:
    total_value= sum(pre)+result2.objective_value + result3.objective_value + result4.objective_value

    FINAL = [[sum(pre),result1.objective_value, result2.objective_value, result3.objective_value, resul
              total_value,
              result1.status.name,result2.status.name,result3.status.name,result4.status.name,
              len(pre),result1.num_cols, result2.num_cols,result3.num_cols,result4.num_cols,
              solved_ratio, optimal_ratio,  infeasible_ratio,
              Total_endTime,
              len(linking_const), num_const_unsatis, const_satis_ratio,(m.num_rows-num_const_unsatis)/m
    print('====================================================================')
    print('The summary of {}'.format(filename))
    print('Ratio of optimal solved variables (%) is :{}'.format(solved_ratio))
    print('The toal value is :{}'.format((total_value)))
    print('Presolve objective value : {} '.format(sum(pre)))
    print('1st decomposition objective value : {}'.format(result1.objective_value))
    print('2nd decomposition objective value : {}'.format(result2.objective_value))
    print('1st part of METIS objective value : {}'.format(result3.objective_value))
    print('2nd part of METIS objective value : {}'.format(result4.objective_value))
    print('{} of {} linking constraints violate the constraints ({}% satisfaction at the linking constra
    print('{}% satisfaction at the total constraints'.format((m.num_rows-num_const_unsatis)/m.num_rows*
    print('Total_Time: {} (s)'.format(Total_endTime))
    print('====================================================================')


FINAL=pd.DataFrame(FINAL)
resultname=filename.replace('data','processing/result')+'.csv'
FINAL.to_csv(resultname,header=True, index=False)
```

```
FINAL=pd.DataFrame(linking_result_F)
resultname=filename.replace('data','processing/unsatis_const')+'.csv'
FINAL.to_csv(resultname,header=True, index=False)
```