mmCEsim Example Configuration

I. Configuration File

```
# Example_Configuration.sim
# mmCEsim Simulation Example
# Author: Wuqiong Zhao
# Date: 2022-09-20

version: 0.1.0 # the targeted mmCEsim version
meta: # document meta data
  title: mmCEsim Simulation Example
  description:
    This is a basic millimeter wave channel estimation simulation example with mmCEsim.
    The involved algorithms are `OMP' and `Oracle LS'.
    There are 4 jobs in total, with SNR and pilot overhead as variables and NMSE as metric.
    The PFD report is auto generated via `simreport.cls'
    and a corresponding plain text report is also available.
  author: Wuqiong Zhao
  email: contact@mmcesim.org
  website: https://mmcesim.org
  license: MIT
  date: "2022-09-18"
  comments: This is an uplink channel.
physics:
  frequency: narrow # assume narrow band
  off_grid: false # do not consider off-grid problem
nodes:
  - id: BS # this should be unique
    role: receiver
    num: 1 # this is the default value
    size: [16, 1] # UPA with size 8x4
    beam: [4, 1]
    grid: same # the same as physics size
    beamforming:
      variable: "W"
      scheme: random
  - id: UE # user
    role: transmitter
    num: 1 # a single-user model
    size: 8 # ULA with size 8
    beam: 2
    grid: 8
    beamforming:
      variable: "F"
      scheme: random
channels:
  - id: H
    from: BS
    to: UE # 'from -> to' specifies the channel direction
    sparsity: 6
    gains:
      mode: normal
      mean: 0
      variance: 1
sounding:
  variables:
    received: "y" # received signal vector
    noise: "noise" # received noise vector
    channel: "H_cascaded" # the cascaded channel (actually the same as 'H' for simple MIMO)
preamble: |
  COMMENT Here starts the preamble.
estimation: |
  VNt::m = NEW `DICTIONARY.T`
  VNr::m = NEW `DICTIONARY.R`
  lambda_hat = INIT `GRID.*`
  Q = INIT `MEASUREMENT` `GRID.*`
  i::u0 = LOOP 0 `PILOT`/`BEAM.T`
    F_t::m = NEW F_{:,:,i}
    W_t::m = NEW W_{:,:,i}
    Q_{i*`BEAM.*`:(i+1)*`BEAM.*`-1,:} = \kron(F_t^T, W_t^H) @ \kron(VNt^*, VNr) # the sensing
matrix
  END
  none_zero::u1 = NEW \find(\abs(VNr^H@H_cascaded@VNt)>0.1)
  # PRINT \size(none_zero,0) '\n' # make sure the number of non-zero elements
  BRANCH
  lambda_hat = ESTIMATE Q y none_zero
  RECOVER VNr @ \reshape(lambda_hat, `GRID.R`, `GRID.T`) @ VNt^H
  MERGE
conclusion: |
  PRINT "">>\t"" `JOB_CNT` '\n'
simulation:
  backend: cpp # cpp (default) | matlab | octave | py
  metric: [NMSE] # used for compare
  jobs:
    - name: "NMSE v.s. SNR (Pilot: 32)"
      test_num: 100
      SNR: [-10:2:20]
      SNR_mode: dB # dB (default) | linear
      pilot: 32
      # pilot_mode: percent # num (default) | percent
      algorithms: # compare different languages
        - alg: OMP
          max_iter: 6
          label: OMP # used in report
          estimated_channel: H_hat_OMP # variable name for the estimated channel
        - alg: Oracle_LS
          label: Oracle LS
    - name: NMSE v.s. Pilot (-10 dB)
      test_num: 200
      SNR: -10
      pilot: [8:8:128]
      algorithms: # compare different languages
        - alg: OMP
          max_iter: 6
          label: "OMP (Iter: 6)"
        - alg: OMP
          max_iter: 9
          label: "OMP (Iter: 9)"
        - alg: OMP
          max_iter: 12
          label: "OMP (Iter: 12)"
        - alg: Oracle_LS
          label: Oracle LS # used in report
    - name: NMSE v.s. Pilot (0 dB)
      test_num: 200
      SNR: 0
      pilot: [8:8:128]
      algorithms: # compare different languages
        - alg: OMP
          max_iter: 6
          label: "OMP (Iter: 6)"
        - alg: OMP
          max_iter: 9
          label: "OMP (Iter: 9)"
        - alg: OMP
          max_iter: 12
          label: "OMP (Iter: 12)"
        - alg: Oracle_LS
          label: Oracle LS # used in report
    - name: NMSE v.s. Pilot (10 dB)
      test_num: 200
      SNR: 10
      pilot: [8:8:128]
      algorithms: # compare different languages
        - alg: OMP
          max_iter: 6
          label: "OMP (Iter: 6)"
        - alg: OMP
          max_iter: 9
          label: "OMP (Iter: 9)"
        - alg: OMP
          max_iter: 12
          label: "OMP (Iter: 12)"
        - alg: Oracle_LS
          label: Oracle LS # used in report
  report:
    name: mmCEsim_Example_Report
    format: [pdf, latex] # both compiled PDF and tex files
    plot: true # plot data
    table: false # do not print table
    latex:
      command: xelatex # command to compile the report
      UTF8: false # no need for UTF8 support with this setting
```

II. Algorithms

1) OMP

```
h::v = FUNCTION OMP Q::m y::v L::u0
  COMMENT Start of OMP algorithm!
  h = \zeros(\size(Q, 1)) # initialize as zeros
  Q_H::m = NEW Q^H # the conjugate transpose of Q
  r = NEW y # residual
  r_last::v = NEW r * 2 # the residual in last iteration
  support = INIT \length(y) dtype=u # over-length support array
  term = INIT $\size(Q_H, 0)$ dtype=f # float number array
  j::u0 = NEW 0
  a::v = INIT
  FOR "" $j != \length(y)$ $j = j + 1$
    term = \abs(Q_H @ r)
    index::u0 = NEW \index_max(term)
    IF \ismember(index, support)
      BREAK # end of the LOOP
    END
    support_{j} = index
    columns::m = NEW Q_{:, support_{0:j}}
    a = \pinv(columns) @ y
    r = y - columns @ a
    IF \sum(\abs(r - r_last)) / \sum(\abs(r_last)) < 0.0001 || j >= L
      j = j + 1
      BREAK # accurate enough to end iteration
    ELSE
      r_last = r
    END
  END
  # prepare for the final return
  h_{support_{0:j-1}} = a
END
```

2) Oracle LS

```
h::v = FUNCTION Oracle_LS Q::m y::v indices::u1
  h = \zeros(\size(Q,1))
  h_{indices} = \pinv(Q_{:, indices}) @ y
END
```

III. Plain Text Report

```
#------------------------------------------------------------------------------
# Title      : mmCEsim Simulation Example
# Description: This is a basic millimeter wave channel estimation simulation example with
mmCEsim. The involved algorithms are `OMP' and `Oracle LS'. There are 4 jobs in total, with SNR
and pilot overhead as variables and NMSE as metric. The PFD report is auto generated via
`simreport.cls' and a corresponding plain text report is also available.
# Author     : Wuqiong Zhao
# Time       : 2022-09-20 17:26:59 (UTC +0800)
#
# Report generated by mmCEsim 0.1.0.
# GitHub organization at https://github.com/mmcesim.
# Web app is available at https://app.mmcesim.org.
# Visit https://mmcesim.org for more information.
#------------------------------------------------------------------------------

# System Settings

  Transmitter: 8x1, Grid: 8x1, Beam: 2x1
  Receiver: 16x1, Grid: 16x1, Beam: 4x1
  Channel Sparsity: 6
  Off Grid: false
  Bandwidth: Narrowband

# Job 1: NMSE v.s. SNR (Pilot: 32)

    SNR [dB]  |     OMP      |  Oracle LS
  ------------+--------------+--------------
      -10     |   4.37272    |   -2.09213
       -8     |   2.02612    |   -4.57477
       -6     |  -0.141382   |   -5.82391
       -4     |   -2.20674   |   -8.56238
       -2     |   -4.45431   |   -10.3981
       0      |   -7.81253   |   -12.262
       2      |   -9.77837   |   -14.3932
       4      |   -13.0801   |   -16.6153
       6      |   -14.6947   |   -17.9794
       8      |   -17.7463   |   -20.9488
       10     |   -19.3891   |   -21.8804
       12     |   -21.627    |   -24.4251
       14     |   -23.8749   |   -26.3628
       16     |   -25.6213   |   -28.1834
       18     |   -27.7443   |   -30.267
       20     |   -30.3653   |   -32.6013

  (Simulated with 100 Monte Carlo tests.)

# Job 2: NMSE v.s. Pilot (-10 dB)

     Pilot    |OMP (Iter: 6) |OMP (Iter: 9) |OMP (Iter: 12)|  Oracle LS
  ------------+--------------+--------------+--------------+--------------
       8      |   9.43562    |   10.9644    |   12.1366    |   4.54507
       16     |   6.83408    |   8.12045    |    9.1951    |   1.40745
       24     |   5.31838    |   6.57979    |   7.52597    |   -1.07162
       32     |   3.79419    |   5.06062    |   6.06315    |   -2.83111
       40     |    2.9794    |   4.23719    |   5.18707    |   -3.44415
       48     |   2.11401    |   3.35817    |   4.31526    |   -4.45314
       56     |   1.29435    |   2.55505    |    3.4288    |   -4.73415
       64     |   0.898796   |    2.0144    |   2.81049    |   -5.28493
       72     |  -0.0644258  |   1.12447    |   2.06325    |   -5.87547
       80     |  -0.282325   |   0.876599   |   1.79616    |   -6.29767
       88     |  -0.821232   |   0.336695   |   1.19017    |   -6.76116
       96     |   -1.27881   |  -0.0578278  |   0.801581   |   -7.50009
      104     |   -1.63714   |  -0.267611   |   0.693091   |   -7.45052
      112     |   -2.24395   |  -0.948726   |  0.0564768   |   -8.03804
      120     |   -2.9736    |   -1.73462   |  -0.847883   |   -8.5239
      128     |   -3.00642   |   -1.63139   |  -0.642469   |   -8.54792

  (Simulated with 200 Monte Carlo tests.)

# Job 3: NMSE v.s. Pilot (0 dB)

     Pilot    |OMP (Iter: 6) |OMP (Iter: 9) |OMP (Iter: 12)|  Oracle LS
  ------------+--------------+--------------+--------------+-------------
       8      |   1.11523    |   2.15941    |   3.02545    |   -5.4531
       16     |   -3.00515   |   -1.83224   |  -0.712897   |   -9.34415
       24     |   -6.03076   |   -4.53612   |   -3.36582   |   -11.4422
       32     |   -7.55521   |   -5.82254   |   -4.60541   |   -12.3771
       40     |   -8.81007   |   -7.04291   |   -5.84614   |   -13.0268
       48     |   -10.4826   |   -8.50466   |   -7.19055   |   -14.3701
       56     |   -10.9924   |   -8.82936   |   -7.56498   |   -14.4853
       64     |   -11.4763   |   -9.29036   |   -8.02801   |   -15.2996
       72     |   -12.5736   |   -10.2873   |   -8.82094   |   -16.235
       80     |   -12.8527   |   -10.4871   |   -9.07245   |   -16.2999
       88     |   -13.4492   |   -11.1876   |   -9.87788   |   -17.0232
       96     |   -13.8076   |   -11.4993   |   -10.1895   |   -17.2846
      104     |    -14.33    |   -11.9624   |   -10.5537   |   -17.898
      112     |   -14.6855   |   -12.3814   |   -11.141    |   -18.2309
      120     |   -14.9338   |   -12.5006   |   -11.1606   |   -18.4375
      128     |   -15.6921   |   -13.1381   |   -11.7075   |   -18.9248

  (Simulated with 200 Monte Carlo tests.)

# Job 4: NMSE v.s. Pilot (10 dB)

     Pilot    |OMP (Iter: 6) |OMP (Iter: 9) |OMP (Iter: 12)|  Oracle LS
  ------------+--------------+--------------+--------------+-------------
       8      |   -5.60356   |   -5.16937   |   -4.48161   |   -15.709
       16     |   -16.0018   |   -13.8204   |   -12.4833   |   -19.2826
       24     |    -17.85    |   -15.3629   |   -13.7404   |   -21.045
       32     |   -19.0555   |   -16.7039   |   -15.3025   |   -21.7845
       40     |   -19.9551   |   -17.0695   |   -15.5148   |   -22.9763
       48     |   -21.2469   |   -18.433    |   -16.9781   |   -24.0644
       56     |   -22.194    |   -19.5846   |   -18.0337   |   -24.7222
       64     |   -23.0673   |   -19.9871   |   -18.3673   |   -25.9508
       72     |   -23.6024   |   -20.7672   |   -19.3183   |   -26.281
       80     |   -23.6333   |   -20.7876   |   -19.3059   |   -26.6468
       88     |   -24.1485   |   -21.3595   |   -19.9062   |   -26.8524
       96     |   -24.7868   |   -22.3319   |   -21.0762   |   -27.3651
      104     |   -25.0294   |   -22.0495   |   -20.5769   |   -28.0073
      112     |   -24.868    |   -21.9972   |   -20.5392   |   -27.7029
      120     |   -25.3675   |   -22.5448   |   -21.0681   |   -28.1576
```

```
    128     |   −25.4865   |   −22.6952   |   −21.2605   |   −28.2129
```

(Simulated with 200 Monte Carlo tests.)