MIMO Oracle LS Configuration

I. Configuration File

```yaml
# MIMO_Oracle_LS.sim
# Basic MIMO Oracle LS Test
# Author: Wuqiong Zhao
# Date: 2022-09-18

version: 0.1.0 # the targeted mmCEsim version
meta: # document meta data
  title: MIMO mmWave Oracle LS Test
  description:
    Oracle LS performance is tested in relation to the number of measurements.
    Here in the MIMO system it is about the pilot overhead.
  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: 20
      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
    - name: NMSE v.s. Pilot (-10dB)
      test_num: 100
      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 (0dB)
    test_num: 100
    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 (10dB)
    test_num: 100
    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: MIMO_Oracle_LS
  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      : MIMO mmWave Oracle LS Test
# Description: Oracle LS performance is tested in relation to the number of measurements. Here in
the MIMO system it is about the pilot overhead.
# Author     : Wuqiong Zhao
# Time       : 2022-09-18 23:50:36 (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.
#-------------------------------------------------------------------------

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

    SNR [dB]   |     OMP
  -------------+--------------
      -10      |   3.81085
       -8      |   2.76497
       -6      |  -0.108602
       -4      |   -2.78565
       -2      |   -4.49888
        0      |   -7.06448
        2      |   -9.96098
        4      |   -12.4437
        6      |    -14.89
        8      |   -17.1794
       10      |   -20.066
       12      |   -21.3236
       14      |   -23.3729
       16      |   -25.3477
       18      |   -27.5364
       20      |   -29.8061

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

     Pilot     |OMP (Iter: 6) |OMP (Iter: 9) |OMP (Iter: 12)|  Oracle LS
  -------------+--------------+--------------+--------------+--------------
        8      |   9.29147    |   11.1003    |    12.442    |   4.61661
       16      |   7.06669    |   8.39594    |   9.43706    |   0.67903
       24      |   5.22735    |   6.53095    |   7.53088    |  -0.905885
       32      |   4.01495    |   5.23436    |   6.09897    |   -2.29101
       40      |    2.8341    |   4.16595    |   5.08355    |   -3.49978
       48      |   2.07976    |   3.38491    |   4.27345    |   -4.30095
       56      |   1.17769    |   2.26523    |   3.10669    |   -4.69988
       64      |   0.708705   |   1.91326    |   2.81092    |   -6.03628
       72      |   0.627685   |   1.72649    |   2.54455    |   -6.15611
       80      |  -0.495722   |   0.783126   |   1.76376    |   -6.53475
       88      |   -1.12431   |  0.0944202   |   1.02376    |   -6.94699
       96      |   -1.78634   |  -0.709536   |  0.0547727   |   -7.01059
      104      |   -1.6923    |  -0.482098   |   0.479924   |   -7.57271
      112      |   -2.19586   |   -0.7909    |   0.139849   |   -8.41195
      120      |   -2.85093   |   -1.56401   |   -0.65627   |   -8.4773
      128      |   -2.88086   |   -1.55443   |  -0.582589   |   -8.34687

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

     Pilot     |OMP (Iter: 6) |OMP (Iter: 9) |OMP (Iter: 12)|  Oracle LS
  -------------+--------------+--------------+--------------+--------------
        8      |   1.24927    |    2.3114    |   3.26089    |   -4.16754
       16      |   -2.60043   |   -1.45311   |   -0.34267   |   -8.89127
       24      |   -4.82847   |   -3.36367   |   -2.2532    |   -10.5206
       32      |   -7.60735   |   -6.08404   |   -4.89255   |   -12.7766
       40      |   -8.68186   |   -7.12114   |   -5.94706   |   -13.3402
       48      |   -9.61706   |   -7.86804   |   -6.60229   |   -13.7675
```

56	-11.2967	-9.37743	-8.22066	-15.3957
64	-11.1199	-9.09962	-7.88106	-15.0207
72	-12.2335	-10.179	-8.80498	-16.1753
80	-12.4081	-10.3687	-9.07331	-16.1488
88	-13.123	-10.6738	-9.40079	-17.0334
96	-13.5101	-11.3258	-10.0716	-16.8357
104	-14.275	-11.875	-10.5275	-17.595
112	-14.7718	-12.1967	-10.7295	-18.5515
120	-14.6316	-12.1726	-10.8159	-18.4154
128	-15.082	-12.4944	-11.1075	-18.8066

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

Pilot	OMP (Iter: 6)	OMP (Iter: 9)	OMP (Iter: 12)	Oracle LS
8	-2.4839	-2.27776	-1.7673	-14.6491
16	-15.1133	-12.907	-11.522	-18.9323
24	-17.8415	-15.6355	-14.1765	-20.9991
32	-19.9081	-17.2209	-15.6865	-22.8901
40	-20.9334	-17.8381	-16.1223	-23.942
48	-21.4787	-18.69	-17.0548	-24.3977
56	-22.0357	-19.1439	-17.6341	-25.2308
64	-22.6179	-19.9313	-18.4736	-25.4502
72	-23.2901	-20.4693	-19.0734	-26.0957
80	-23.5597	-20.9976	-19.5402	-26.0201
88	-23.9612	-21.2653	-19.8898	-26.7341
96	-24.9116	-21.9873	-20.4588	-27.5813
104	-24.6044	-21.8746	-20.3737	-27.2753
112	-25.2839	-22.4067	-20.9804	-28.0445
120	-25.3087	-22.6475	-21.2299	-28.4159
128	-25.4355	-22.583	-21.131	-28.3711