# 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: |
  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) \cdot \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
  lambda_hat = ESTIMATE Q y none_zero
  RECOVER VNr @ \reshape(lambda_hat, `GRID.R`, `GRID.T`) @ VNt^H
  MERGE

conclusion: |
  PRINT ">>" `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
- 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
II. Algorithms

1) OMP

\[ h::v = FUNCTION OMP Q::m y::v L::u0 \]

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

2) Oracle LS

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

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

(Simulated with 100 Monte Carlo tests.)

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

<table>
<thead>
<tr>
<th>Pilot</th>
<th>OMP (Iter: 6)</th>
<th>OMP (Iter: 9)</th>
<th>OMP (Iter: 12)</th>
<th>Oracle LS</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>9.43562</td>
<td>10.9644</td>
<td>12.1366</td>
<td>4.54507</td>
</tr>
<tr>
<td>16</td>
<td>6.83408</td>
<td>8.12045</td>
<td>9.1951</td>
<td>1.40745</td>
</tr>
<tr>
<td>24</td>
<td>5.31838</td>
<td>6.57979</td>
<td>7.52597</td>
<td>-1.07162</td>
</tr>
<tr>
<td>32</td>
<td>3.79419</td>
<td>5.06062</td>
<td>6.06315</td>
<td>-2.83111</td>
</tr>
</tbody>
</table>
## Job 4: NMSE v.s. Pilot (10 dB)

<table>
<thead>
<tr>
<th>Pilot</th>
<th>OMP (Iter: 6)</th>
<th>OMP (Iter: 9)</th>
<th>OMP (Iter: 12)</th>
<th>Oracle LS</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>2.9794</td>
<td>4.23719</td>
<td>5.18707</td>
<td>-3.44415</td>
</tr>
<tr>
<td>48</td>
<td>2.11401</td>
<td>3.35817</td>
<td>4.31526</td>
<td>-4.45314</td>
</tr>
<tr>
<td>56</td>
<td>1.29435</td>
<td>2.55505</td>
<td>3.4288</td>
<td>-4.73415</td>
</tr>
<tr>
<td>64</td>
<td>0.898796</td>
<td>2.0144</td>
<td>2.81049</td>
<td>-5.28493</td>
</tr>
<tr>
<td>72</td>
<td>-0.0644258</td>
<td>1.12447</td>
<td>2.06325</td>
<td>-5.87547</td>
</tr>
<tr>
<td>80</td>
<td>-0.282325</td>
<td>0.876599</td>
<td>1.79616</td>
<td>-6.30767</td>
</tr>
<tr>
<td>88</td>
<td>-0.821232</td>
<td>0.336695</td>
<td>1.19017</td>
<td>-6.76116</td>
</tr>
<tr>
<td>96</td>
<td>-1.27881</td>
<td>-0.0578278</td>
<td>0.801581</td>
<td>-7.50009</td>
</tr>
</tbody>
</table>

(Simulated with 200 Monte Carlo tests.)

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

<table>
<thead>
<tr>
<th>Pilot</th>
<th>OMP (Iter: 6)</th>
<th>OMP (Iter: 9)</th>
<th>OMP (Iter: 12)</th>
<th>Oracle LS</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>1.11523</td>
<td>2.15941</td>
<td>3.02545</td>
<td>-5.4531</td>
</tr>
<tr>
<td>48</td>
<td>-3.00515</td>
<td>-1.83224</td>
<td>-0.712897</td>
<td>-9.34415</td>
</tr>
<tr>
<td>56</td>
<td>-6.03076</td>
<td>-4.53612</td>
<td>-3.36582</td>
<td>-11.4422</td>
</tr>
<tr>
<td>64</td>
<td>-7.55521</td>
<td>-5.82254</td>
<td>-4.60541</td>
<td>-12.3771</td>
</tr>
<tr>
<td>72</td>
<td>-8.81007</td>
<td>-7.04291</td>
<td>-5.84614</td>
<td>-13.0268</td>
</tr>
<tr>
<td>80</td>
<td>-10.4826</td>
<td>-8.50466</td>
<td>-7.19055</td>
<td>-14.3781</td>
</tr>
<tr>
<td>88</td>
<td>-10.9924</td>
<td>-8.82936</td>
<td>-7.56498</td>
<td>-14.4853</td>
</tr>
<tr>
<td>104</td>
<td>-12.5736</td>
<td>-10.2873</td>
<td>-8.82094</td>
<td>-16.235</td>
</tr>
<tr>
<td>112</td>
<td>-12.8527</td>
<td>-10.4871</td>
<td>-9.07245</td>
<td>-16.2999</td>
</tr>
<tr>
<td>120</td>
<td>-13.4492</td>
<td>-11.1876</td>
<td>-9.87788</td>
<td>-17.0232</td>
</tr>
<tr>
<td>128</td>
<td>-13.8076</td>
<td>-11.4993</td>
<td>-10.1895</td>
<td>-17.2846</td>
</tr>
<tr>
<td>136</td>
<td>-14.33</td>
<td>-11.9624</td>
<td>-10.5537</td>
<td>-17.898</td>
</tr>
<tr>
<td>144</td>
<td>-14.6855</td>
<td>-12.3814</td>
<td>-11.141</td>
<td>-18.2309</td>
</tr>
</tbody>
</table>

(Simulated with 200 Monte Carlo tests.)

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

<table>
<thead>
<tr>
<th>Pilot</th>
<th>OMP (Iter: 6)</th>
<th>OMP (Iter: 9)</th>
<th>OMP (Iter: 12)</th>
<th>Oracle LS</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>-5.66356</td>
<td>-5.16937</td>
<td>-4.48161</td>
<td>-15.709</td>
</tr>
<tr>
<td>64</td>
<td>-23.0673</td>
<td>-19.9871</td>
<td>-18.3673</td>
<td>-25.9508</td>
</tr>
</tbody>
</table>

(Simulated with 200 Monte Carlo tests.)