```
from __future__ import division
import numpy as np
import pylab
from matplotlib.lines import Line2D
import pprint
import random
from collections import defaultdict


# for debugging
import ipdb
import sys
import traceback

import dcd


def compare_solvers(num_runs):
    """
    call different solvers, compare objectives
    """

    #solver = "finite_diff_primal"
    solver = "cvxopt_dual_solver"
    #solver = "finite_diff_dual"
    #solver = "dcd"

    solvers = ["cvxopt_dual_solver", "dcd"]

    obj = defaultdict(list)

    for i in xrange(num_runs):

        # pick random values
        off_diag = random.uniform(0.0, 1.0)
        num_data = random.randint(10,500)
        shift = random.uniform(0.0, 2.0)

        # define task similarity matrix
        task_sim = np.array([[1.0, off_diag],[off_diag, 1.0]])

        # generate toy data
        xt_1, lt_1 = dcd.generate_training_data(num_data, 1.5, shift)
        xt_2, lt_2 = dcd.generate_training_data(num_data, 1.5, shift)
        data = {"task_1": {"xt": xt_1, "lt": lt_1},
                "task_2": {"xt": xt_2, "lt": lt_2}}

        for solver in solvers:

            # new implementation
            W, p_obj, d_obj = dcd.train_mtl_svm(data, task_sim, solver)

            if solver == "dcd":
                current_obj = d_obj[-1]
            else:
                current_obj = -d_obj

            print solver, current_obj

```

```
60              # record objectives
61              obj[solver].append(current_obj)
62
63
64
65
66      # scatter plot of objectives
67      x = obj[solvers[0]]
68      y = obj[solvers[1]]
69
70      m = np.zeros((len(x),2))
71      m[:,0] = x
72      m[:,1] = y
73
74      pprint.pprint(m)
75
76      pylab.figure()
77      pylab.plot(x, y, "o")
78      pylab.plot([0.0, 1.0], [0.0, 1.0], "-r")
79      pylab.show()
80
81
82  def main():
83      """
84      runs experiment in different settings
85      """
86
87      compare_solvers(20)
88
89
90  if __name__ == '__main__':
91
92      # enable post-mortem debugging
93      try:
94          main()
95      except:
96          type, value, tb = sys.exc_info()
97          traceback.print_exc()
98          ipdb.post_mortem(tb)
99
100 if __name__ == "pyreport.main":
101     main()
```

```
task similarity matrix:
array([[ 1.        ,  0.02395166],
       [ 0.02395166,  1.        ]])

matrix M:
array([[ 0.97714326,  0.02285674],
       [ 0.02285674,  0.97714326]])
solver cvxopt_dual_solver
-----------------------------------------------------
solver: cvxopt_qp   problem: unnamed
istop:  1000 (optimal)
Solver:   Time Elapsed = 2.22       CPU Time Elapsed = 2.21
objFunValue: -0.53107256 (feasible, max constraint =  0)
resulting weight matrix W:
array([[-0.41329226, -0.18443929],
       [-0.38850495, -0.24054106]])
cvxopt_dual_solver 0.531072562827
```

```
task similarity matrix:
array([[ 1.        ,  0.02395166],
       [ 0.02395166,  1.        ]])

matrix M:
array([[ 0.97714326,  0.02285674],
       [ 0.02285674,  0.97714326]])
solver dcd
resulting weight matrix W:
array([[-0.41329715, -0.18442002],
       [-0.38855878, -0.24059351]])
dcd 0.531072744982
task similarity matrix:
array([[ 1.       ,  0.8121275],
       [ 0.8121275,  1.       ]])

matrix M:
array([[ 0.69053027,  0.30946973],
       [ 0.30946973,  0.69053027]])
solver cvxopt_dual_solver
-----------------------------------------------------
solver: cvxopt_qp   problem: unnamed
istop:  1000 (optimal)
Solver:   Time Elapsed = 8.8        CPU Time Elapsed = 8.79
objFunValue: -0.31440141 (feasible, max constraint =  0)
resulting weight matrix W:
array([[-0.24570256, -0.3220841 ],
       [-0.2414341 , -0.32632011]])
cvxopt_dual_solver 0.314401405879
task similarity matrix:
array([[ 1.       ,  0.8121275],
       [ 0.8121275,  1.       ]])

matrix M:
array([[ 0.69053027,  0.30946973],
       [ 0.30946973,  0.69053027]])
solver dcd
resulting weight matrix W:
array([[-0.24570479, -0.32208705],
       [-0.2414353 , -0.32632161]])
dcd 0.314401415014
task similarity matrix:
array([[ 1.       ,  0.1189885],
       [ 0.1189885,  1.       ]])

matrix M:
array([[ 0.90388473,  0.09611527],
       [ 0.09611527,  0.90388473]])
solver cvxopt_dual_solver
-----------------------------------------------------
solver: cvxopt_qp   problem: unnamed
istop:  1000 (optimal)
Solver:   Time Elapsed = 0.31       CPU Time Elapsed = 0.31
objFunValue: -0.53548055 (feasible, max constraint =  0)
resulting weight matrix W:
array([[-0.38790735, -0.18576988],
       [-0.39132622, -0.18964302]])
cvxopt_dual_solver 0.535480545756
task similarity matrix:
array([[ 1.       ,  0.1189885],
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       [ 0.1189885,  1.       ]])

matrix M:
array([[ 0.90388473,  0.09611527],
       [ 0.09611527,  0.90388473]])
solver dcd
resulting weight matrix W:
array([[-0.38789548, -0.18573109],
       [-0.39132689, -0.18964192]])
dcd 0.535480752166
task similarity matrix:
array([[ 1.        ,  0.33525827],
       [ 0.33525827,  1.        ]])

matrix M:
array([[ 0.79930862,  0.20069138],
       [ 0.20069138,  0.79930862]])
solver cvxopt_dual_solver
-----------------------------------------------------
solver: cvxopt_qp   problem: unnamed
istop:  1000 (optimal)
Solver:   Time Elapsed = 0.18       CPU Time Elapsed = 0.17
objFunValue: -0.59596049 (feasible, max constraint =  0)
resulting weight matrix W:
array([[-0.44697593,  0.00256822],
       [-0.44506346, -0.01267998]])
cvxopt_dual_solver 0.595960491373
task similarity matrix:
array([[ 1.        ,  0.33525827],
       [ 0.33525827,  1.        ]])

matrix M:
array([[ 0.79930862,  0.20069138],
       [ 0.20069138,  0.79930862]])
solver dcd
resulting weight matrix W:
array([[-0.4469757 ,  0.00256753],
       [-0.44506349, -0.01268014]])
dcd 0.595960495106
task similarity matrix:
array([[ 1.        ,  0.66789221],
       [ 0.66789221,  1.        ]])

matrix M:
array([[ 0.71406085,  0.28593915],
       [ 0.28593915,  0.71406085]])
solver cvxopt_dual_solver
-----------------------------------------------------
solver: cvxopt_qp   problem: unnamed
istop:  1000 (optimal)
Solver:   Time Elapsed = 11.11      CPU Time Elapsed = 11.1
objFunValue: -0.33019337 (feasible, max constraint =  0)
resulting weight matrix W:
array([[-0.25627298, -0.32044764],
       [-0.24947317, -0.32694904]])
cvxopt_dual_solver 0.330193369206
task similarity matrix:
array([[ 1.        ,  0.66789221],
       [ 0.66789221,  1.        ]])
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matrix M:
array([[ 0.71406085,  0.28593915],
       [ 0.28593915,  0.71406085]])
solver dcd
resulting weight matrix W:
array([[-0.25627358, -0.32045047],
       [-0.24947468, -0.32695613]])
dcd 0.330193373036
task similarity matrix:
array([[ 1.        ,  0.73671582],
       [ 0.73671582,  1.        ]])

matrix M:
array([[ 0.7021483,  0.2978517],
       [ 0.2978517,  0.7021483]])
solver cvxopt_dual_solver
-----------------------------------------------------
solver: cvxopt_qp   problem: unnamed
istop:  1000 (optimal)
Solver:   Time Elapsed = 9.73       CPU Time Elapsed = 9.73
objFunValue: -0.33257923 (feasible, max constraint =  0)
resulting weight matrix W:
array([[-0.2557565 , -0.32348933],
       [-0.25960636, -0.32925617]])
cvxopt_dual_solver 0.332579229313
task similarity matrix:
array([[ 1.        ,  0.73671582],
       [ 0.73671582,  1.        ]])

matrix M:
array([[ 0.7021483,  0.2978517],
       [ 0.2978517,  0.7021483]])
solver dcd
resulting weight matrix W:
array([[-0.25575651, -0.32348933],
       [-0.25960636, -0.32925622]])
dcd 0.332579235656
task similarity matrix:
array([[ 1.        ,  0.50330991],
       [ 0.50330991,  1.        ]])

matrix M:
array([[ 0.74917525,  0.25082475],
       [ 0.25082475,  0.74917525]])
solver cvxopt_dual_solver
-----------------------------------------------------
solver: cvxopt_qp   problem: unnamed
istop:  1000 (optimal)
Solver:   Time Elapsed = 0.25       CPU Time Elapsed = 0.24
objFunValue: -0.4496897 (feasible, max constraint =  0)
resulting weight matrix W:
array([[-0.3707179 , -0.24213402],
       [-0.34747834, -0.26020624]])
cvxopt_dual_solver 0.449689697712
task similarity matrix:
array([[ 1.        ,  0.50330991],
       [ 0.50330991,  1.        ]])

matrix M:
array([[ 0.74917525,  0.25082475],
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       [ 0.25082475,  0.74917525]])
solver dcd
resulting weight matrix W:
array([[-0.37070866, -0.24212554],
       [-0.34747876, -0.26020567]])
dcd 0.449689717145
task similarity matrix:
array([[ 1.        ,  0.13896373],
       [ 0.13896373,  1.        ]])

matrix M:
array([[ 0.89125851,  0.10874149],
       [ 0.10874149,  0.89125851]])
solver cvxopt_dual_solver
-----------------------------------------------------
solver: cvxopt_qp   problem: unnamed
istop:  1000 (optimal)
Solver:   Time Elapsed = 6.35       CPU Time Elapsed = 6.35
objFunValue: -0.36022818 (feasible, max constraint =  0)
resulting weight matrix W:
array([[-0.27711768, -0.31757531],
       [-0.26354338, -0.32707921]])
cvxopt_dual_solver 0.36022817819
task similarity matrix:
array([[ 1.        ,  0.13896373],
       [ 0.13896373,  1.        ]])

matrix M:
array([[ 0.89125851,  0.10874149],
       [ 0.10874149,  0.89125851]])
solver dcd
resulting weight matrix W:
array([[-0.27711768, -0.31757531],
       [-0.26354339, -0.32707921]])
dcd 0.360228180744
task similarity matrix:
array([[ 1.        ,  0.29890694],
       [ 0.29890694,  1.        ]])

matrix M:
array([[ 0.81292756,  0.18707244],
       [ 0.18707244,  0.81292756]])
solver cvxopt_dual_solver
-----------------------------------------------------
solver: cvxopt_qp   problem: unnamed
istop:  1000 (optimal)
Solver:   Time Elapsed = 0.03       CPU Time Elapsed = 0.02
objFunValue: -0.58039369 (feasible, max constraint =  0)
resulting weight matrix W:
array([[-0.45082479, -0.04403235],
       [-0.44362071, -0.04758978]])
cvxopt_dual_solver 0.580393692064
task similarity matrix:
array([[ 1.        ,  0.29890694],
       [ 0.29890694,  1.        ]])

matrix M:
array([[ 0.81292756,  0.18707244],
       [ 0.18707244,  0.81292756]])
solver dcd
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resulting weight matrix W:
array([[-0.45083864, -0.04406358],
       [-0.44362065, -0.04759128]])
dcd 0.580393707323
task similarity matrix:
array([[ 1.        ,  0.63473096],
       [ 0.63473096,  1.        ]])

matrix M:
array([[ 0.72031654,  0.27968346],
       [ 0.27968346,  0.72031654]])
solver cvxopt_dual_solver
-----------------------------------------------------
solver: cvxopt_qp   problem: unnamed
istop:  1000 (optimal)
Solver:   Time Elapsed = 1.59       CPU Time Elapsed = 1.58
objFunValue: -0.60144021 (feasible, max constraint =  0)
resulting weight matrix W:
array([[-0.43413972, -0.06261731],
       [-0.43384045, -0.06268818]])
cvxopt_dual_solver 0.601440210676
task similarity matrix:
array([[ 1.        ,  0.63473096],
       [ 0.63473096,  1.        ]])

matrix M:
array([[ 0.72031654,  0.27968346],
       [ 0.27968346,  0.72031654]])
solver dcd
resulting weight matrix W:
array([[-0.4341397 , -0.06261729],
       [-0.43384044, -0.06268817]])
dcd 0.601440224863
task similarity matrix:
array([[ 1.        ,  0.93136194],
       [ 0.93136194,  1.        ]])

matrix M:
array([[ 0.67465883,  0.32534117],
       [ 0.32534117,  0.67465883]])
solver cvxopt_dual_solver
-----------------------------------------------------
solver: cvxopt_qp   problem: unnamed
istop:  1000 (optimal)
Solver:   Time Elapsed = 0.4        CPU Time Elapsed = 0.4
objFunValue: -0.39289922 (feasible, max constraint =  0)
resulting weight matrix W:
array([[-0.3166541 , -0.28516048],
       [-0.31523082, -0.29117092]])
cvxopt_dual_solver 0.392899221664
task similarity matrix:
array([[ 1.        ,  0.93136194],
       [ 0.93136194,  1.        ]])

matrix M:
array([[ 0.67465883,  0.32534117],
       [ 0.32534117,  0.67465883]])
solver dcd
resulting weight matrix W:
array([[-0.31665355, -0.28516075],
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       [-0.31523151, -0.29117191]])
dcd 0.392899334903
task similarity matrix:
array([[ 1.        ,  0.58741131],
       [ 0.58741131,  1.        ]])

matrix M:
array([[ 0.72990381,  0.27009619],
       [ 0.27009619,  0.72990381]])
solver cvxopt_dual_solver
-----------------------------------------------------
solver: cvxopt_qp   problem: unnamed
istop:  1000 (optimal)
Solver:   Time Elapsed = 0.02       CPU Time Elapsed = 0.02
objFunValue: -0.36482124 (feasible, max constraint =  0)
resulting weight matrix W:
array([[-0.28694331, -0.30847612],
       [-0.2930584 , -0.32223151]])
cvxopt_dual_solver 0.364821241615
task similarity matrix:
array([[ 1.        ,  0.58741131],
       [ 0.58741131,  1.        ]])

matrix M:
array([[ 0.72990381,  0.27009619],
       [ 0.27009619,  0.72990381]])
solver dcd
resulting weight matrix W:
array([[-0.28694331, -0.30847612],
       [-0.29305841, -0.32223154]])
dcd 0.364821246372
task similarity matrix:
array([[ 1.        ,  0.26689852],
       [ 0.26689852,  1.        ]])

matrix M:
array([[ 0.82598837,  0.17401163],
       [ 0.17401163,  0.82598837]])
solver cvxopt_dual_solver
-----------------------------------------------------
solver: cvxopt_qp   problem: unnamed
istop:  1000 (optimal)
Solver:   Time Elapsed = 0.01       CPU Time Elapsed = 0.00999999999999
objFunValue: -0.47181268 (feasible, max constraint =  0)
resulting weight matrix W:
array([[-0.35010381, -0.251767  ],
       [-0.41551142, -0.10349031]])
cvxopt_dual_solver 0.471812682282
task similarity matrix:
array([[ 1.        ,  0.26689852],
       [ 0.26689852,  1.        ]])

matrix M:
array([[ 0.82598837,  0.17401163],
       [ 0.17401163,  0.82598837]])
solver dcd
resulting weight matrix W:
array([[-0.35010369, -0.25176696],
       [-0.41551137, -0.10349024]])
dcd 0.471812691015
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task similarity matrix:
array([[ 1.        ,  0.49660783],
       [ 0.49660783,  1.        ]])

matrix M:
array([[ 0.75085093,  0.24914907],
       [ 0.24914907,  0.75085093]])
solver cvxopt_dual_solver
-----------------------------------------------------
solver: cvxopt_qp   problem: unnamed
istop:  1000 (optimal)
Solver:   Time Elapsed = 3.44       CPU Time Elapsed = 3.44
objFunValue: -0.57036418 (feasible, max constraint =  0)
resulting weight matrix W:
array([[-0.42529063, -0.11273875],
       [-0.43529072, -0.09690991]])
cvxopt_dual_solver 0.570364182014
task similarity matrix:
array([[ 1.        ,  0.49660783],
       [ 0.49660783,  1.        ]])

matrix M:
array([[ 0.75085093,  0.24914907],
       [ 0.24914907,  0.75085093]])
solver dcd
resulting weight matrix W:
array([[-0.4252906 , -0.11273874],
       [-0.43529073, -0.09690989]])
dcd 0.570364195531
task similarity matrix:
array([[ 1.        ,  0.26899309],
       [ 0.26899309,  1.        ]])

matrix M:
array([[ 0.82510045,  0.17489955],
       [ 0.17489955,  0.82510045]])
solver cvxopt_dual_solver
-----------------------------------------------------
solver: cvxopt_qp   problem: unnamed
istop:  1000 (optimal)
Solver:   Time Elapsed = 1.43       CPU Time Elapsed = 1.43
objFunValue: -0.42968549 (feasible, max constraint =  0)
resulting weight matrix W:
array([[-0.33395158, -0.26217177],
       [-0.3205299 , -0.28037328]])
cvxopt_dual_solver 0.429685494502
task similarity matrix:
array([[ 1.        ,  0.26899309],
       [ 0.26899309,  1.        ]])

matrix M:
array([[ 0.82510045,  0.17489955],
       [ 0.17489955,  0.82510045]])
solver dcd
resulting weight matrix W:
array([[-0.33395306, -0.26217464],
       [-0.32053679, -0.28038667]])
dcd 0.429685567145
task similarity matrix:
array([[ 1.        ,  0.07257009],
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       [ 0.07257009,  1.        ]])

matrix M:
array([[ 0.93662777,  0.06337223],
       [ 0.06337223,  0.93662777]])
solver cvxopt_dual_solver
-----------------------------------------------------
solver: cvxopt_qp   problem: unnamed
istop:  1000 (optimal)
Solver:   Time Elapsed = 3.54       CPU Time Elapsed = 3.53
objFunValue: -0.55706741 (feasible, max constraint =  0)
resulting weight matrix W:
array([[-0.4292848 , -0.12087387],
       [-0.42004795, -0.1177544 ]])
cvxopt_dual_solver 0.557067408331
task similarity matrix:
array([[ 1.        ,  0.07257009],
       [ 0.07257009,  1.        ]])

matrix M:
array([[ 0.93662777,  0.06337223],
       [ 0.06337223,  0.93662777]])
solver dcd
resulting weight matrix W:
array([[-0.4292843 , -0.12087431],
       [-0.42004795, -0.11775379]])
dcd 0.557067490467
task similarity matrix:
array([[ 1.        ,  0.16142192],
       [ 0.16142192,  1.        ]])

matrix M:
array([[ 0.87797356,  0.12202644],
       [ 0.12202644,  0.87797356]])
solver cvxopt_dual_solver
-----------------------------------------------------
solver: cvxopt_qp   problem: unnamed
istop:  1000 (optimal)
Solver:   Time Elapsed = 10.13      CPU Time Elapsed = 10.13
objFunValue: -0.48592011 (feasible, max constraint =  0)
resulting weight matrix W:
array([[-0.35506356, -0.2504866 ],
       [-0.35018651, -0.25459519]])
cvxopt_dual_solver 0.485920111055
task similarity matrix:
array([[ 1.        ,  0.16142192],
       [ 0.16142192,  1.        ]])

matrix M:
array([[ 0.87797356,  0.12202644],
       [ 0.12202644,  0.87797356]])
solver dcd
resulting weight matrix W:
array([[-0.35506363, -0.25048662],
       [-0.35018653, -0.25459519]])
dcd 0.485920115673
task similarity matrix:
array([[ 1.        ,  0.18020094],
       [ 0.18020094,  1.        ]])
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matrix M:
array([[ 0.86753845,  0.13246155],
       [ 0.13246155,  0.86753845]])
solver cvxopt_dual_solver
-----------------------------------------------------
solver: cvxopt_qp   problem: unnamed
istop:  1000 (optimal)
Solver:   Time Elapsed = 1.52       CPU Time Elapsed = 1.51
objFunValue: -0.37765349 (feasible, max constraint =  0)
resulting weight matrix W:
array([[-0.27996116, -0.31236519],
       [-0.27742546, -0.31796438]])
cvxopt_dual_solver 0.377653488798
task similarity matrix:
array([[ 1.        ,  0.18020094],
       [ 0.18020094,  1.        ]])

matrix M:
array([[ 0.86753845,  0.13246155],
       [ 0.13246155,  0.86753845]])
solver dcd
resulting weight matrix W:
array([[-0.27995019, -0.31239367],
       [-0.27742526, -0.3179645 ]])
dcd 0.377653645943
task similarity matrix:
array([[ 1.        ,  0.47812644],
       [ 0.47812644,  1.        ]])

matrix M:
array([[ 0.75559068,  0.24440932],
       [ 0.24440932,  0.75559068]])
solver cvxopt_dual_solver
-----------------------------------------------------
solver: cvxopt_qp   problem: unnamed
istop:  1000 (optimal)
Solver:   Time Elapsed = 0.66       CPU Time Elapsed = 0.66
objFunValue: -0.57203319 (feasible, max constraint =  0)
resulting weight matrix W:
array([[-0.41769657, -0.1074792 ],
       [-0.42750345, -0.11292979]])
cvxopt_dual_solver 0.57203319382
task similarity matrix:
array([[ 1.        ,  0.47812644],
       [ 0.47812644,  1.        ]])

matrix M:
array([[ 0.75559068,  0.24440932],
       [ 0.24440932,  0.75559068]])
solver dcd
resulting weight matrix W:
array([[-0.41769555, -0.10747613],
       [-0.4275055 , -0.11293179]])
dcd 0.572033428309
task similarity matrix:
array([[ 1.        ,  0.30469956],
       [ 0.30469956,  1.        ]])

matrix M:
array([[ 0.81067495,  0.18932505],
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       [ 0.18932505,  0.81067495]])
solver cvxopt_dual_solver
-----------------------------------------------------
solver: cvxopt_qp   problem: unnamed
istop:  1000 (optimal)
Solver:   Time Elapsed = 0.02       CPU Time Elapsed = 0.02
objFunValue: -0.63928962 (feasible, max constraint =  0)
resulting weight matrix W:
array([[-0.39410342, -0.11640884],
       [-0.39235187, -0.07877715]])
cvxopt_dual_solver 0.639289619102
task similarity matrix:
array([[ 1.        ,  0.30469956],
       [ 0.30469956,  1.        ]])

matrix M:
array([[ 0.81067495,  0.18932505],
       [ 0.18932505,  0.81067495]])
solver dcd
resulting weight matrix W:
array([[-0.3941032 , -0.1164087 ],
       [-0.39235104, -0.07877725]])
dcd 0.639289751631
array([[ 0.53107256,  0.53107274],
       [ 0.31440141,  0.31440142],
       [ 0.53548055,  0.53548075],
       [ 0.59596049,  0.5959605 ],
       [ 0.33019337,  0.33019337],
       [ 0.33257923,  0.33257924],
       [ 0.4496897 ,  0.44968972],
       [ 0.36022818,  0.36022818],
       [ 0.58039369,  0.58039371],
       [ 0.60144021,  0.60144022],
       [ 0.39289922,  0.39289933],
       [ 0.36482124,  0.36482125],
       [ 0.47181268,  0.47181269],
       [ 0.57036418,  0.5703642 ],
       [ 0.42968549,  0.42968557],
       [ 0.55706741,  0.55706749],
       [ 0.48592011,  0.48592012],
       [ 0.37765349,  0.37765365],
       [ 0.57203319,  0.57203343],
       [ 0.63928962,  0.63928975]])
```

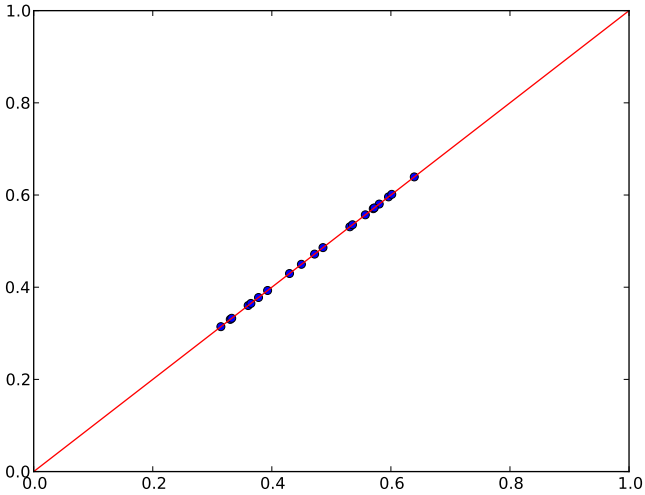
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0