CoSyNE

for Mathematica

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Implemented according to the paper :

- Faustino Gomez, Juergen Schmidhuber and Risto Miikkulainen (2008). Accelerated Neural Evolution through Cooperatively Coevolved Synapses. *Journal of Machine Learning Research* 9 (May), pp 937-965.

The current implementation uses only mutations (no crossover).The typical usage involves nesting coSyNeStep or coSyNeStepParallel function, see the examples.

CoSyNE Functions

```
prependFitness[g_, fitFn_] := {fitFn[g], g}
```

```
newRandomPop[size_, n_, dist_, fitFn_] :=
 prependFitness[#, fitFn] & /@ Table[RandomReal[dist], {size}, {n}]
```

```
newRandomPopParallel[size_, n_, dist_, fitFn_] :=
 ParallelMap[prependFitness[#, fitFn] &, Table[RandomReal[dist], {size}, {n}]]
```

```
conditionalPermutation[data_, pick_] := ReplacePart[data,
   MapThread[Rule, {Flatten@Position[pick, True], RandomSample[Pick[data, pick]]}]];
```

```
sel[s_, g_] := MapThread[{#2, #3}⟦#1⟧ &, Prepend[g, s]]
```

```
uniformXover[g_] := Module[{k, i},
  i = NestList[3 - # &, Table[RandomInteger[{1, 2}], {Length[g⟦1⟧]}], 1];
  Map[sel[#, g] &, i]
 ]
```

```
cauchyPerturbation[x_] := x + RandomReal[CauchyDistribution[0, 0.3]]
```

```
cauchyMutate[g_, mprob_] :=
 MapAt[cauchyPerturbation, g, Position[Sign[RandomReal[{0, 1}, {Length[g]}] - mprob], -1]]
```

```
xoverIndividuals[indiv_, fitnessFn_, mprob_] := Module[{g = indiv⟦All, 2⟧, res},
  prependFitness[#, fitnessFn] & /@ (cauchyMutate[#, mprob] & /@ uniformXover[g])
 ]
```

```
evolutionStep[pop_, fitFn_, OptionsPattern[
    {mutate → 0.5, minimize → False, permuteAll → False, verbose → False, elite → 0}]] :=
 Module[{fp = Sort[pop], p2, fmin, fmax, g2, t, r, res, perm, n = Length[Last@First@pop],
    fit, tbl, mprob = OptionValue[mutate], el, newIndiv2, newFit2},
   (*Reverse if maximizing*)
   If[¬ OptionValue[minimize], fp = Reverse@fp];
   (*store elite*)
   el = fp⟦1 ;; OptionValue[elite]⟧;
   (*take the top quarter and mutate it twice to get one half size of new individuals*)
   p2 = mapFn[prependFitness[#, fitFn] &, (cauchyMutate[#, mprob] & /@
       Join[fp⟦1 ;; Length[fp] / 4⟧, fp⟦1 ;; Length[fp] / 4⟧]⟦All, 2⟧)];
   (*take the original genomes and their fitness separately*)
   g2 = fp⟦All, 2⟧; fit = First /@ fp;
   (*compute the poermutations probabilities*)
   t = ParallelTable[
     Power[Rescale[fit⟦i⟧, # @@ (First /@ fp) & /@ {Min, Max}], 1 / n], {i, Length[pop]}];
   (*for maximizing, 1 - probabilities, such that bests are les permuted*)
   If[¬ OptionValue[minimize], t = 1 - t];
   (*generate random binary numbers*)
   r = RandomReal[{0, 1}, {Length[pop]}];
   (*generate permutation pattern, for elitism, use 0 in the beg.*)
   If[OptionValue[permuteAll], perm = ParallelTable[True, {Length[pop]}],
    perm = Sign[t - r] /. {-1 → False, 1 → True}];
   (*permutate the old ones, join the new ones, sort*)
   newIndiv2 = Transpose[ParallelMap[conditionalPermutation[#1, perm] &, g2ᵀ]];
   res = Sort@Join[el, mapFn[prependFitness[#, fitFn] &, newIndiv2], p2];
   (*reverse if maximizing*)
   If[¬ OptionValue[minimize], res = Reverse@res];
   (*cut off the worst*)
   If[OptionValue[verbose], PrintTemporary[Round[#, 0.001] & /@ res⟦1 ;; Length[pop], 1⟧]];
   res⟦1 ;; Length[pop]⟧
 ]
```

Serial evaluation wrapper:

```
coSyNEstep[pop_, fitFn_, opts : OptionsPattern[
     {mutate → 0.5, minimize → False, permuteAll → False, verbose → False, elite → 0}]] :=
 Block[{mapFn = Map}, evolutionStep[pop, fitFn, opts]]
```

Parallel evaluation wrapper :

```
coSyNEstepParallel[pop_, fitFn_, opts : OptionsPattern[
     {mutate → 0.5, minimize → False, permuteAll → False, verbose → False, elite → 0}]] :=
 Block[{mapFn = ParallelMap}, evolutionStep[pop, fitFn, opts]]
```

Prioritized parallel evaluationwrapper (bigger instances get evaluated first) :

```
prioritizedParallelMap[fn_, x_] :=
 With[{ord = Reverse[Ordering[rankFn /@ x]]}, ParallelMap[fn, x⟦ord⟧]⟦ord⟧]
```

```
coSyNEstepPrioritizedParallel[pop_, fitFn_, rankingFn_, opts : OptionsPattern[
     {mutate → 0.5, minimize → False, permuteAll → False, verbose → False, elite → 0}]] :=
 Block[{mapFn = prioritizedParallelMap, rankFn = rankingFn},
  evolutionStep[pop, fitFn, opts]]
```

Examples

Simple experiment that compares cosyne with standard direct encoding evolution. Fitness function is the sum of absolute gene values (L1-norm), which is minimized (search for the zero vector).

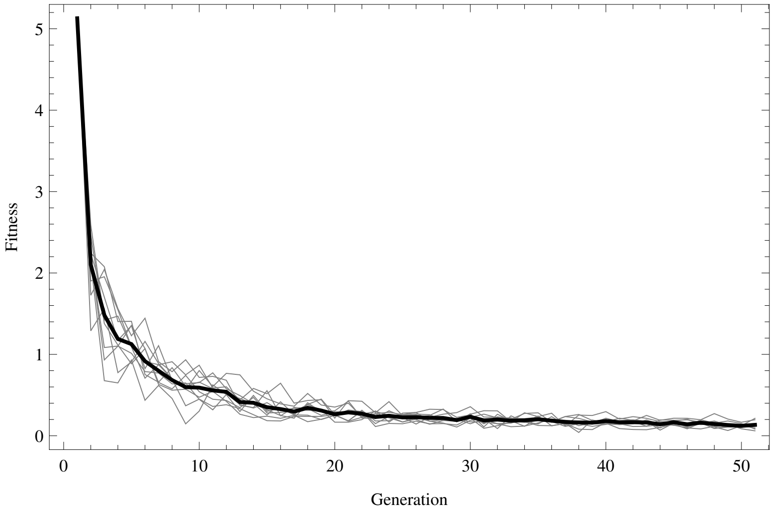
```
fitFn[g_] := Norm[g, 1]
```

Populatin with 16 individuals, each has 5 genes.

```
pop = newRandomPop[16, 5, NormalDistribution[0, 1], fitFn];
```

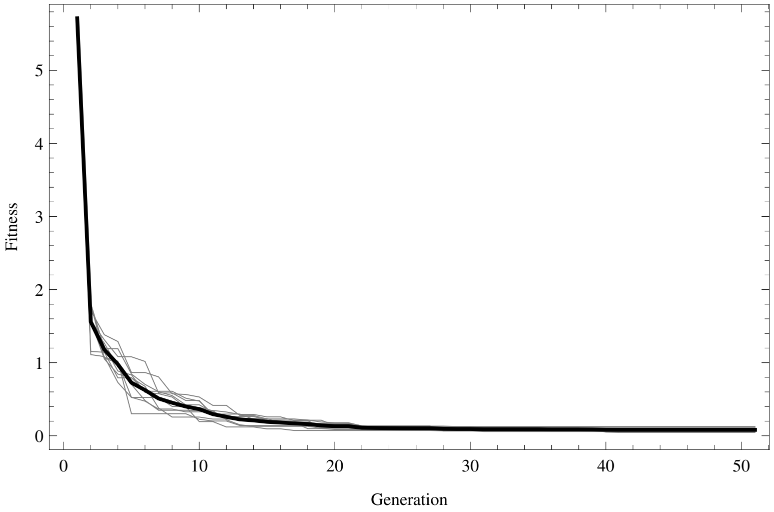
50 evolution steps repeated 20 times for cosyne and non - cosyne.

```
c = Table[First /@ First /@
     NestList[coSyNEstep[#, fitFn, minimize → True,
        mutate → 0.8, permuteAll → True, verbose → False, elite → 0] &, pop,
      50], {10}];

Show[{ListLinePlot[c, PlotStyle → Gray, PlotRange → All, ImageSize → 400,
   FrameLabel → {"Generation", "Fitness"}, AxesOrigin → {0, 0}, Frame → True],
  ListLinePlot[Mean[c], PlotRange → All, PlotStyle → {Thick, Black}]}]
```



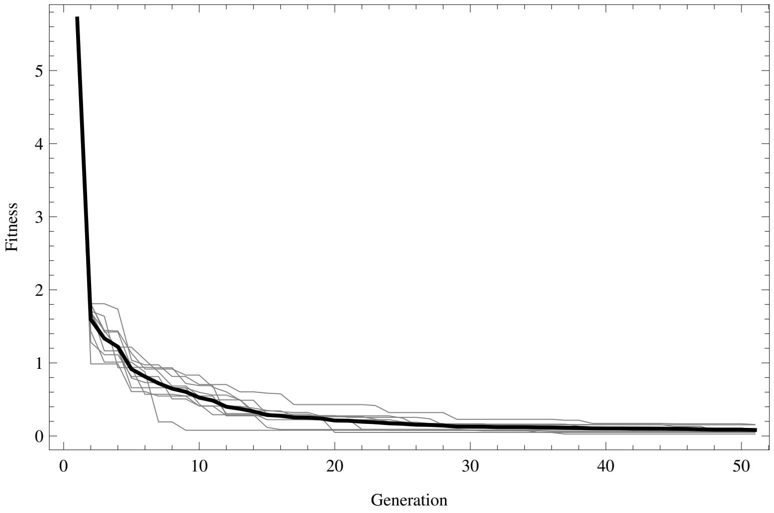
The same example using 1 elite individual

```
c = Table[First /@ First /@
     NestList[coSyNEstep[#, fitFn, minimize → True,
        mutate → 0.8, permuteAll → True, verbose → False, elite → 1] &, pop,
      50], {10}];

Show[{ListLinePlot[c, PlotStyle → Gray, PlotRange → All, ImageSize → 400,
    FrameLabel → {"Generation", "Fitness"}, AxesOrigin → {0, 0}, Frame → True],
  ListLinePlot[Mean[c], PlotRange → All, PlotStyle → {Thick, Black}]}]
```



Probabilistic permutation (individuals with best rank have low probability of being permuted -- the elity is not needed):

```
c = Table[First /@ First /@
     NestList[coSyNEstep[#, fitFn, minimize → True,
        mutate → 0.8, permuteAll → False, verbose → False, elite → 0] &, pop,
      50], {10}];

Show[{ListLinePlot[c, PlotStyle → Gray, PlotRange → All, ImageSize → 400,
    FrameLabel → {"Generation", "Fitness"}, AxesOrigin → {0, 0}, Frame → True],
  ListLinePlot[Mean[c], PlotRange → All, PlotStyle → {Thick, Black}]}]
```


Fitness
Generation