sim

Simulate neural network

Syntax

```
[Y,Xf,Af] = sim(net,X,Xi,Ai,T)
[Y,Xf,Af] = sim(net,{Q TS},Xi,Ai)
[Y,...] = sim(net,...,'useParallel',...)
[Y,...] = sim(net,...,'useGPU',...)
[Y,...] = sim(net,...,'showResources',...)
[Ycomposite,...] = sim(net,Xcomposite,...)
[Ygpu,...] = sim(net,Xgpu,...)
```

To Get Help

Type `help network/sim`.

Description

`sim` simulates neural networks.

`[Y,Xf,Af] = sim(net,X,Xi,Ai,T)` takes

`net`	Network
`X`	Network inputs
`Xi`	Initial input delay conditions (default = zeros)
`Ai`	Initial layer delay conditions (default = zeros)
`T`	Network targets (default = zeros)

and returns

`Y`	Network outputs
`Xf`	Final input delay conditions
`Af`	Final layer delay conditions

`sim` is usually called implicitly by calling the neural network as a function. For instance, these two expressions return the same result:

```
y = sim(net,x,xi,ai)
y = net(x,xi,ai)
```

Note that arguments `Xi`, `Ai`, `Xf`, and `Af` are optional and need only be used for networks that have input or layer delays.

The signal arguments can have two formats: cell array or matrix.

The cell array format is easiest to describe. It is most convenient for networks with multiple inputs and outputs, and allows sequences of inputs to be presented:

X	Ni-by-TS cell array	Each element X{i,ts} is an Ri-by-Q matrix.
Xi	Ni-by-ID cell array	Each element Xi{i,k} is an Ri-by-Q matrix.
Ai	Nl-by-LD cell array	Each element Ai{i,k} is an Si-by-Q matrix.
T	No-by-TS cell array	Each element X{i,ts} is a Ui-by-Q matrix.
Y	No-by-TS cell array	Each element Y{i,ts} is a Ui-by-Q matrix.
Xf	Ni-by-ID cell array	Each element Xf{i,k} is an Ri-by-Q matrix.
Af	Nl-by-LD cell array	Each element Af{i,k} is an Si-by-Q matrix.

where

Ni	=	net.numInputs
Nl	=	net.numLayers
No	=	net.numOutputs
ID	=	net.numInputDelays
LD	=	net.numLayerDelays
TS	=	Number of time steps
Q	=	Batch size
Ri	=	net.inputs{i}.size
Si	=	net.layers{i}.size
Ui	=	net.outputs{i}.size

The columns of Xi, Ai, Xf, and Af are ordered from oldest delay condition to most recent:

Xi{i,k}	=	Input i at time ts = k - ID
Xf{i,k}	=	Input i at time ts = TS + k - ID
Ai{i,k}	=	Layer output i at time ts = k - LD
Af{i,k}	=	Layer output i at time ts = TS + k - LD

The matrix format can be used if only one time step is to be simulated (TS = 1). It is convenient for networks with only one input and output, but can also be used with networks that have more.

Each matrix argument is found by storing the elements of the corresponding cell array argument in a single matrix:

X	(sum of Ri)-by-Q matrix
Xi	(sum of Ri)-by-(ID*Q) matrix
Ai	(sum of Si)-by-(LD*Q) matrix
T	(sum of Ui)-by-Q matrix
Y	(sum of Ui)-by-Q matrix
Xf	(sum of Ri)-by-(ID*Q) matrix
Af	(sum of Si)-by-(LD*Q) matrix

[Y,Xf,Af] = sim(net,{Q TS},Xi,Ai) is used for networks that do not have an input, such as Hopfield networks, when cell array notation is used.

`[Y,...] = sim(net,...,'useParallel',...)`, `[Y,...] = sim(net,...,'useGPU',...)`, or `[Y,...] = sim(net,...,'showResources',...)` (or the network called as a function) accepts optional name/value pair arguments to control how calculations are performed. Two of these options allow training to happen faster or on larger datasets using parallel workers or GPU devices if Parallel Computing Toolbox is available. These are the optional name/value pairs:

`'useParallel','no'`	Calculations occur on normal MATLAB thread. This is the default `'useParallel'` setting.
`'useParallel','yes'`	Calculations occur on parallel workers if a parallel pool is open. Otherwise calculations occur on the normal MATLAB thread.
`'useGPU','no'`	Calculations occur on the CPU. This is the default 'useGPU' setting.
`'useGPU','yes'`	Calculations occur on the current gpuDevice if it is a supported GPU (See Parallel Computing Toolbox for GPU requirements.) If the current gpuDevice is not supported, calculations remain on the CPU. If `'useParallel'` is also `'yes'` and a parallel pool is open, then each worker with a unique GPU uses that GPU, other workers run calculations on their respective CPU cores.
`'useGPU','only'`	If no parallel pool is open, then this setting is the same as `'yes'`. If a parallel pool is open, then only workers with unique GPUs are used. However, if a parallel pool is open, but no supported GPUs are available, then calculations revert to performing on all worker CPUs.
`'showResources','no'`	Do not display computing resources used at the command line. This is the default setting.
`'showResources','yes'`	Show at the command line a summary of the computing resources actually used. The actual resources may differ from the requested resources, if parallel or GPU computing is requested but a parallel pool is not open or a supported GPU is not available. When parallel workers are used, each worker's computation mode is described, including workers in the pool that are not used.

`[Ycomposite,...] = sim(net,Xcomposite,...)` takes Composite data and returns Composite results. If Composite data is used, then `'useParallel'` is automatically set to `'yes'`.

`[Ygpu,...] = sim(net,Xgpu,...)` takes gpuArray data and returns gpuArray results. If gpuArray data is used, then `'useGPU'` is automatically set to `'yes'`.

Examples

In the following examples, the `sim` function is called implicitly by calling the neural network object (`net`) as a function.

Simulate Feedforward Networks

This example loads a dataset that maps neighborhood characteristics, `x`, to median house prices, `t`. A feedforward network with 10 neurons is created and trained on that data, then simulated.

```
[x,t] =  house_dataset;
net = feedforwardnet(10);
net = train(net,x,t);
y = net(x);
```

Simulate NARX Time Series Networks

This example trains an open-loop nonlinear-autoregressive network with external input, to model a levitated magnet system defined by a control current `x` and the magnet's vertical position response `t`, then simulates the network. The function `preparets` prepares the data before training and simulation. It creates the open-loop network's combined inputs `xo`, which contains both the external input `x` and previous values of position `t`. It also prepares the delay states `xi`.

```
[x,t] = maglev_dataset;
net = narxnet(10);
[xo,xi,~,to] = preparets(net,x,{},t);
net = train(net,xo,to,xi);
y = net(xo,xi)
```

This same system can also be simulated in closed-loop form.

```
netc = closeloop(net);
view(netc)
[xc,xi,ai,tc] = preparets(netc,x,{},t);
yc = netc(xc,xi,ai);
```

Simulate in Parallel on a Parallel Pool

Parallel Computing Toolbox allows Neural Network Toolbox to simulate and train networks faster and on larger datasets than can fit on one PC. Here training and simulation happens across parallel MATLAB workers.

```
parpool
[X,T] = vinyl_dataset;
net = feedforwardnet(10);
net = train(net,X,T,'useParallel','yes','showResources','yes');
Y = net(X,'useParallel','yes');
```

Simulate on GPUs

Use Composite values to distribute the data manually, and get back the results as a Composite value. If the data is loaded as it is distributed, then while each piece of the dataset must fit in RAM, the entire dataset is limited only by the total RAM of all the workers.

```
Xc = Composite;
for i=1:numel(Xc)
    Xc{i} = X+rand(size(X))*0.1;  % Use real data instead of random
end
Yc = net(Xc,'showResources','yes');
```

Networks can be simulated using the current GPU device, if it is supported by Parallel Computing Toolbox.

```
gpuDevice % Check if there is a supported GPU
Y = net(X,'useGPU','yes','showResources','yes');
```

To put the data on a GPU manually, and get the results on the GPU:

```
Xgpu = gpuArray(X);
Ygpu = net(Xgpu,'showResources','yes');
Y = gather(Ygpu);
```

To run in parallel, with workers associated with unique GPUs taking advantage of that hardware, while the rest of the workers use CPUs:

```
Y = net(X,'useParallel','yes','useGPU','yes','showResources','yes');
```

Using only workers with unique GPUs might result in higher speeds, as CPU workers might not keep up.

```
Y = net(X,'useParallel','yes','useGPU','only','showResources','yes');
```

More About

collapse all

Algorithms

`sim` uses these properties to simulate a network `net`.

```
net.numInputs, net.numLayers
net.outputConnect, net.biasConnect
net.inputConnect, net.layerConnect
```

These properties determine the network's weight and bias values and the number of delays associated with each weight:

```
net.IW{i,j}
net.LW{i,j}
net.b{i}
net.inputWeights{i,j}.delays
net.layerWeights{i,j}.delays
```

These function properties indicate how `sim` applies weight and bias values to inputs to get each layer's output:

```
net.inputWeights{i,j}.weightFcn
net.layerWeights{i,j}.weightFcn
net.layers{i}.netInputFcn
net.layers{i}.transferFcn
```

See Also

`adapt` | `init` | `revert` | `train`

Introduced before R2006a