Make

```
$ make benchmark
nvc -Wall -tp=native -c17 -mp -Minfo=all -g -acc -ta=tesla -pg -c
benchmark.c
run_classification:
    156, Generating enter data create(input[:n])
    163, Generating enter data create(input[i][:1],input->->weights[:we])
    167, Generating update device(input->->depth,input->->height,input->-
>width)
    169, Generating update device(input->->weights[:we])
    177, Generating enter data create(likelihoods[:n][:10])
    199, Generating exit data delete(input[:1][:1])
    213, Generating exit data delete(likelihoods[i])
    216, Generating exit data delete(likelihoods[:1][:1])
do_layers_test:
    272, Generating update device(batch->->->weights[:we])
         Generating update self(batch->->->weights[:we])
nvc -Wall -tp=native -c17 -mp -Minfo=all -g -acc -ta=tesla -pg -c network.c
make_network:
     23, Generating enter data create(net[:1])
free_network:
     73, Generating exit data delete(net->l0->filters[:1][:1])
     80, Generating exit data delete(net->l3->filters[:1][:1])
     87, Generating exit data delete(net->l6->filters[:1][:1])
     95, Generating exit data delete(net->l9->filters[:1][:1])
    100, Generating exit data delete(net->l10->likelihoods[:1])
    103, Generating exit data delete(net->l0[:1],net->l8[:1],net-
>l7[:1],net->l6[:1],net->l5[:1],net->l4[:1],net->l3[:1],net->l2[:1],net-
>l1[:1],net->l10[:1],net->l9[:1])
    115, Generating exit data delete(net[:1])
make_batch:
    119, Generating enter data create(out[:12])
    122, Generating enter data create(out[i][:size])
free_batch:
    138, Generating exit data delete(b[i])
    141, Generating exit data delete(b[:1][:1][:1])
net_classify:
    205, Generating update device(likelihoods[:n][:10])
nvc -Wall -tp=native -c17 -mp -Minfo=all -g -acc -ta=tesla -pg -c layers.c
make_conv_layer:
     25, Generating enter data create(l[:1])
     42, Generating update device(l->output_depth,l->output_height,l-
>output_width,l->pad,l->stride,l->input_depth,l->input_height,l-
>filter_width,l->filter_height,l->input_width)
         Generating enter data create(l->filters[:num_filters])
     51, Generating update device(l->bias)
conv_load:
    161, Generating update device(l->filters->->weights[:we])
    165, Generating update device(l->biases->weights[:l->output_depth])
make_relu_layer:
    171, Generating enter data create(l[:1])
```

```
    180, Generating update device(l->input_width,l->output_depth,l-
>output_width,l->output_height,l->input_depth,l->input_height)
relu_forward:
    191, Generating update device(inputs->->weights[:we])
         Generating NVIDIA GPU code
        194, #pragma acc loop gang /* blockIdx.x */
        196, #pragma acc loop vector(128) collapse(3) /* threadIdx.x */
        197,   /* threadIdx.x collapsed */
        198,   /* threadIdx.x collapsed */
    191, Generating default present(inputs[start:end-start+1]
[:],outputs[start:end-start+1],outputs[start:end-start+1]
[:],l,inputs[start:end-start+1])
    196, Loop is parallelizable
    197, Loop is parallelizable
    198, Loop is parallelizable
    213, Generating update self(outputs->->weights[:we])
make_pool_layer:
    220, Generating enter data create(l[:1])
    236, Generating update device(l->pad,l->input_depth,l->input_height,l-
>pool_height,l->output_depth,l->output_height,l->input_width,l-
>output_width,l->stride,l->pool_width)
make_fc_layer:
    288, Generating enter data create(l[:1])
    297, Generating update device(l[:1])
         Generating enter data create(l->filters[:num_neurons])
    305, Generating update device(l->bias)
fc_load:
    350, Generating update device(l->filters->->weights[:l->num_inputs])
    352, Generating update device(l->biases->weights[:l->output_depth])
make_softmax_layer:
    358, Generating enter data create(l[:1])
    367, Generating update device(l[:1])
    370, Generating enter data create(l->likelihoods[:l->output_depth])
change_relu_layer:
    467, Generating present(l[:])
         Generating NVIDIA GPU code
        470, #pragma acc loop gang /* blockIdx.x */
change_pool_layer:
    482, Generating present(l[:])
         Generating NVIDIA GPU code
        485, #pragma acc loop gang /* blockIdx.x */
change_softmax_layer:
    502, Generating present(l[:])
         Generating NVIDIA GPU code
        505, #pragma acc loop gang, vector(128) /* blockIdx.x threadIdx.x
*/
nvc -Wall -tp=native -c17 -mp -Minfo=all -g -acc -ta=tesla -pg -c volume.c
volume_get:
     20, Generating acc routine seq
         Generating NVIDIA GPU code
volume_set:
     25, Generating acc routine seq
         Generating NVIDIA GPU code
make_volume:
     32, Generating enter data create(new_vol[:1])
```

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     34, Generating enter data create(new_vol->weights[:depth*
(height*width)])
     46, Generating update device(new_vol->height,new_vol->depth,new_vol-
>width,new_vol->weights[:depth*(height*width)])
copy_volume:
     53, Generating NVIDIA GPU code
         56, #pragma acc loop gang, vector(128) collapse(3) /* blockIdx.x
threadIdx.x */
         57,   /* blockIdx.x threadIdx.x collapsed */
         58,   /* blockIdx.x threadIdx.x collapsed */
     53, Generating default present(dest,src)
     78, Generating update self(dest->weights[:dest->depth*(dest-
>width*dest->height)])
free_volume:
     99, Generating exit data delete(v[:1],v->weights[:v->depth*(v-
>width*v->height)])
change_volume_acc:
    144, Generating present(new_vol[:])
         Generating NVIDIA GPU code
        146, #pragma acc loop gang, vector(128) collapse(3) /* blockIdx.x
threadIdx.x */
        147,   /* blockIdx.x threadIdx.x collapsed */
        148,   /* blockIdx.x threadIdx.x collapsed */
nvc -Wall -tp=native -c17 -mp -Minfo=all -g -acc -ta=tesla -pg -o benchmark
benchmark.o network.o layers.o volume.o -lm
```

```
$ ./benchmark benchmark
RUNNING BENCHMARK ON 1200 PICTURES...
Making network...
libcupti.so not found
Loading batches...
Loading input batch 0...
Running classification...
    for batch size 1000
    n mod b_size 200
end conv 1
end relu 1
end conv 1
end relu 1
end:Forward Pass
78.250000% accuracy
120643746 microseconds

Accelerator Kernel Timing data
/home/olia/Olia/Diplomatiki/cs61c/benchmark.c
  run_classification  NVIDIA  devicenum=0
    time(us): 19,900
    156: data region reached 1 time
    163: data region reached 1200 times
        163: data copyin transfers: 1200
             device time(us): total=2,961 max=15 min=2 avg=2
    167: update directive reached 1200 times
```

```
        167: data copyin transfers: 3600
             device time(us): total=10,856 max=10 min=3 avg=3
    169: update directive reached 1200 times
        169: data copyin transfers: 1200
             device time(us): total=6,079 max=15 min=5 avg=5
    177: data region reached 1 time
        42: kernel launched 1200 times
            grid: [1]  block: [128]
            elapsed time(us): total=15,588 max=29 min=11 avg=12
    199: data region reached 1 time
        199: data copyin transfers: 1
             device time(us): total=4 max=4 min=4 avg=4
    213: data region reached 1200 times
    216: data region reached 1 time
/home/olia/Olia/Diplomatiki/cs61c/layers.c
  make_conv_layer  NVIDIA  devicenum=0
    time(us): 107
    25: data region reached 3 times
    42: update directive reached 3 times
        42: data copyin transfers: 30
             device time(us): total=90 max=3 min=3 avg=3
    42: data region reached 3 times
        42: data copyin transfers: 3
             device time(us): total=8 max=4 min=2 avg=2
    51: update directive reached 3 times
        51: data copyin transfers: 3
             device time(us): total=9 max=3 min=3 avg=3
/home/olia/Olia/Diplomatiki/cs61c/layers.c
  conv_load  NVIDIA  devicenum=0
    time(us): 177
    161: update directive reached 56 times
        161: data copyin transfers: 56
             device time(us): total=169 max=4 min=3 avg=3
    165: update directive reached 3 times
        165: data copyin transfers: 3
             device time(us): total=8 max=3 min=2 avg=2
/home/olia/Olia/Diplomatiki/cs61c/layers.c
  make_relu_layer  NVIDIA  devicenum=0
    time(us): 54
    171: data region reached 3 times
    180: update directive reached 3 times
        180: data copyin transfers: 18
             device time(us): total=54 max=3 min=3 avg=3
/home/olia/Olia/Diplomatiki/cs61c/layers.c
  relu_forward  NVIDIA  devicenum=0
    time(us): 103,287
    191: compute region reached 6 times
        191: kernel launched 6 times
            grid: [200-1000]  block: [128]
            elapsed time(us): total=43,121 max=23,296 min=618 avg=7,186
    191: data region reached 12 times
        191: data copyin transfers: 7200
             device time(us): total=16,894 max=12 min=2 avg=2
        207: data copyin transfers: 7200
             device time(us): total=16,818 max=16 min=2 avg=2
```

```
    191: update directive reached 3600 times
        191: data copyin transfers: 3600
             device time(us): total=32,243 max=42 min=3 avg=8
    213: update directive reached 3600 times
        213: data copyout transfers: 3600
             device time(us): total=37,332 max=47 min=5 avg=10
/home/olia/Olia/Diplomatiki/cs61c/layers.c
  make_pool_layer  NVIDIA  devicenum=0
    time(us): 90
    220: data region reached 3 times
    236: update directive reached 6 times
        236: data copyin transfers: 30
             device time(us): total=90 max=3 min=3 avg=3
/home/olia/Olia/Diplomatiki/cs61c/layers.c
  make_fc_layer  NVIDIA  devicenum=0
    time(us): 9
    288: data region reached 1 time
    297: update directive reached 1 time
        297: data copyin transfers: 1
             device time(us): total=3 max=3 min=3 avg=3
    297: data region reached 1 time
        297: data copyin transfers: 1
             device time(us): total=3 max=3 min=3 avg=3
    305: update directive reached 1 time
        305: data copyin transfers: 1
             device time(us): total=3 max=3 min=3 avg=3
/home/olia/Olia/Diplomatiki/cs61c/layers.c
  fc_load  NVIDIA  devicenum=0
    time(us): 32
    350: update directive reached 10 times
        350: data copyin transfers: 10
             device time(us): total=30 max=3 min=3 avg=3
    352: update directive reached 1 time
        352: data copyin transfers: 1
             device time(us): total=2 max=2 min=2 avg=2
/home/olia/Olia/Diplomatiki/cs61c/layers.c
  make_softmax_layer  NVIDIA  devicenum=0
    time(us): 6
    358: data region reached 1 time
    367: update directive reached 1 time
        367: data copyin transfers: 1
             device time(us): total=3 max=3 min=3 avg=3
    370: data region reached 1 time
        370: data copyin transfers: 1
             device time(us): total=3 max=3 min=3 avg=3
/home/olia/Olia/Diplomatiki/cs61c/network.c
  make_network  NVIDIA  devicenum=0
    time(us): 0
    23: data region reached 1 time
/home/olia/Olia/Diplomatiki/cs61c/network.c
  free_network  NVIDIA  devicenum=0
    time(us): 3
    73: data region reached 1 time
    80: data region reached 1 time
    87: data region reached 1 time
```

```
    95: data region reached 1 time
    100: data region reached 1 time
        100: data copyin transfers: 1
             device time(us): total=3 max=3 min=3 avg=3
    103: data region reached 1 time
    115: data region reached 1 time
/home/olia/Olia/Diplomatiki/cs61c/network.c
  make_batch  NVIDIA  devicenum=0
    time(us): 0
    119: data region reached 1 time
    122: data region reached 12 times
        42: kernel launched 12 times
            grid: [1]  block: [128]
            elapsed time(us): total=313 max=32 min=18 avg=26
/home/olia/Olia/Diplomatiki/cs61c/network.c
  free_batch  NVIDIA  devicenum=0
    time(us): 3
    138: data region reached 12 times
    141: data region reached 1 time
        141: data copyin transfers: 1
             device time(us): total=3 max=3 min=3 avg=3
/home/olia/Olia/Diplomatiki/cs61c/network.c
  net_classify  NVIDIA  devicenum=0
    time(us): 3,235
    205: update directive reached 1 time
        205: data copyin transfers: 1200
             device time(us): total=3,235 max=12 min=2 avg=2
/home/olia/Olia/Diplomatiki/cs61c/volume.c
  make_volume  NVIDIA  devicenum=0
    time(us): 387,859
    32: data region reached 22082 times
    34: data region reached 22082 times
        34: data copyin transfers: 22082
             device time(us): total=61,611 max=15 min=2 avg=2
    46: update directive reached 22082 times
        46: data copyin transfers: 88328
             device time(us): total=326,248 max=34 min=2 avg=3
/home/olia/Olia/Diplomatiki/cs61c/volume.c
  copy_volume  NVIDIA  devicenum=0
    time(us): 9,713
    53: compute region reached 1200 times
        53: kernel launched 1200 times
            grid: [1024]  block: [128]
            elapsed time(us): total=269,755 max=244 min=222 avg=224
    53: data region reached 2400 times
    78: update directive reached 1200 times
        78: data copyout transfers: 1200
             device time(us): total=9,713 max=18 min=6 avg=8
/home/olia/Olia/Diplomatiki/cs61c/volume.c
  free_volume  NVIDIA  devicenum=0
    time(us): 53,708
    99: data region reached 44164 times
        99: data copyin transfers: 20882
             device time(us): total=53,708 max=21 min=2 avg=2
```

GProf Results

```
Flat profile:

Each sample counts as 0.01 seconds.
  %   cumulative   self              self     total
 time   seconds   seconds    calls   s/call   s/call  name
 60.81     16.92    16.92 8074752000     0.00     0.00  volume_get
 30.62     25.45     8.52        6     1.42     4.25  conv_forward
  6.00     27.12     1.67        1     1.67     1.67  change_softmax_layer
  1.69     27.59     0.47 150068078     0.00     0.00  volume_set
  0.40     27.70     0.11    22082     0.00     0.00  make_volume
  0.29     27.78     0.08        6     0.01     0.03  pool_forward
  0.14     27.82     0.04        1     0.04     0.31  load_batch
  0.07     27.84     0.02        2     0.01     0.01  fc_forward
  0.00     27.84     0.00    22082     0.00     0.00  free_volume
  0.00     27.84     0.00     1200     0.00     0.00  copy_volume
  0.00     27.84     0.00        6     0.00     0.00  relu_forward
  0.00     27.84     0.00        3     0.00     0.00  conv_load
  0.00     27.84     0.00        3     0.00     0.00  make_conv_layer
  0.00     27.84     0.00        3     0.00     0.00  make_pool_layer
  0.00     27.84     0.00        3     0.00     0.00  make_relu_layer
  0.00     27.84     0.00        2     0.00    12.83  net_forward
  0.00     27.84     0.00        2     0.00     0.00  softmax_forward
  0.00     27.84     0.00        1     0.00     0.00  change_volume_acc
  0.00     27.84     0.00        1     0.00    26.17  do_benchmark
  0.00     27.84     0.00        1     0.00     0.00  fc_load
  0.00     27.84     0.00        1     0.00     0.00  free_batch
  0.00     27.84     0.00        1     0.00     0.00  free_network
  0.00     27.84     0.00        1     0.00     0.00  get_accuracy
  0.00     27.84     0.00        1     0.00     0.00  load_cnn_snapshot
  0.00     27.84     0.00        1     0.00     0.20  make_batch
  0.00     27.84     0.00        1     0.00     0.00  make_fc_layer
  0.00     27.84     0.00        1     0.00     0.00  make_network
  0.00     27.84     0.00        1     0.00     0.00  make_softmax_layer
  0.00     27.84     0.00        1     0.00    25.86  net_classify
  0.00     27.84     0.00        1     0.00    26.17  run_classification


                     Call graph


granularity: each sample hit covers 2 byte(s) for 0.04% of 27.84 seconds

index % time    self  children    called     name
                0.00   26.17       1/1           main [3]
[1]     94.0    0.00   26.17       1         do_benchmark [1]
                0.00   26.17       1/1           run_classification [2]
-----------------------------------------------
                0.00   26.17       1/1           do_benchmark [1]
[2]     94.0    0.00   26.17       1         run_classification [2]
                0.00   25.86       1/1           net_classify [4]
                0.04    0.27       1/1           load_batch [12]
```

```
                0.00    0.00       1/1           load_cnn_snapshot [16]
                0.00    0.00   10000/22082       free_volume [21]
                0.00    0.00       1/1           get_accuracy [31]
                0.00    0.00       1/1           free_network [30]
-----------------------------------------------
                                                  <spontaneous>
[3]     94.0    0.00   26.17                 main [3]
                0.00   26.17       1/1           do_benchmark [1]
-----------------------------------------------
                0.00   25.86       1/1           run_classification [2]
[4]     92.9    0.00   25.86       1         net_classify [4]
                0.00   25.65       2/2           net_forward [5]
                0.00    0.20       1/1           make_batch [13]
                0.00    0.00    1200/1200        copy_volume [22]
                0.00    0.00       1/1           free_batch [29]
-----------------------------------------------
                0.00   25.65       2/2           net_classify [4]
[5]     92.2    0.00   25.65       2         net_forward [5]
                8.52   16.95       6/6           conv_forward [6]
                0.08    0.08       6/6           pool_forward [14]
                0.02    0.00       2/2           fc_forward [15]
                0.00    0.00       6/6           relu_forward [23]
                0.00    0.00       2/2           softmax_forward [26]
-----------------------------------------------
                8.52   16.95       6/6           net_forward [5]
[6]     91.5    8.52   16.95       6         conv_forward [6]
               16.87    0.00 8047411200/8074752000     volume_get [7]
                0.09    0.00 27340800/150068078     volume_set [10]
-----------------------------------------------
                0.06    0.00 27340800/8074752000     pool_forward [14]
               16.87    0.00 8047411200/8074752000     conv_forward [6]
[7]     60.8   16.92    0.00 8074752000         volume_get [7]
-----------------------------------------------
                1.67    0.00       1/1           __libc_csu_init [9]
[8]      6.0    1.67    0.00       1         change_softmax_layer [8]
-----------------------------------------------
                                                  <spontaneous>
[9]      6.0    0.00    1.67                 __libc_csu_init [9]
                1.67    0.00       1/1           change_softmax_layer [8]
                0.00    0.00       1/1           change_volume_acc [27]
-----------------------------------------------
                0.00    0.00   19256/150068078     conv_load [20]
                0.02    0.00 6835200/150068078     pool_forward [14]
                0.09    0.00 27340800/150068078     conv_forward [6]
                0.10    0.00 30720000/150068078     load_batch [12]
                0.27    0.00 85152822/150068078     make_volume [11]
[10]     1.7    0.47    0.00 150068078         volume_set [10]
-----------------------------------------------
                0.00    0.00      11/22082       make_fc_layer [19]
                0.00    0.00      12/22082       make_network [17]
                0.00    0.00      59/22082       make_conv_layer [18]
                0.05    0.12   10000/22082       load_batch [12]
                0.06    0.14   12000/22082       make_batch [13]
[11]     1.4    0.11    0.27   22082         make_volume [11]
                0.27    0.00 85152822/150068078     volume_set [10]
```

```
-----------------------------------------------
                0.04    0.27       1/1           run_classification [2]
[12]     1.1    0.04    0.27       1         load_batch [12]
                0.05    0.12   10000/22082       make_volume [11]
                0.10    0.00 30720000/150068078     volume_set [10]
-----------------------------------------------
                0.00    0.20       1/1           net_classify [4]
[13]     0.7    0.00    0.20       1         make_batch [13]
                0.06    0.14   12000/22082       make_volume [11]
-----------------------------------------------
                0.08    0.08       6/6           net_forward [5]
[14]     0.6    0.08    0.08       6         pool_forward [14]
                0.06    0.00 27340800/8074752000     volume_get [7]
                0.02    0.00 6835200/150068078     volume_set [10]
-----------------------------------------------
                0.02    0.00       2/2           net_forward [5]
[15]     0.1    0.02    0.00       2         fc_forward [15]
-----------------------------------------------
                0.00    0.00       1/1           run_classification [2]
[16]     0.0    0.00    0.00       1         load_cnn_snapshot [16]
                0.00    0.00       1/1           make_network [17]
                0.00    0.00       3/3           conv_load [20]
                0.00    0.00       1/1           fc_load [28]
-----------------------------------------------
                0.00    0.00       1/1           load_cnn_snapshot [16]
[17]     0.0    0.00    0.00       1         make_network [17]
                0.00    0.00       3/3           make_conv_layer [18]
                0.00    0.00      12/22082       make_volume [11]
                0.00    0.00       1/1           make_fc_layer [19]
                0.00    0.00       3/3           make_relu_layer [25]
                0.00    0.00       3/3           make_pool_layer [24]
                0.00    0.00       1/1           make_softmax_layer [32]
-----------------------------------------------
                0.00    0.00       3/3           make_network [17]
[18]     0.0    0.00    0.00       3         make_conv_layer [18]
                0.00    0.00      59/22082       make_volume [11]
-----------------------------------------------
                0.00    0.00       1/1           make_network [17]
[19]     0.0    0.00    0.00       1         make_fc_layer [19]
                0.00    0.00      11/22082       make_volume [11]
-----------------------------------------------
                0.00    0.00       3/3           load_cnn_snapshot [16]
[20]     0.0    0.00    0.00       3         conv_load [20]
                0.00    0.00   19256/150068078     volume_set [10]
-----------------------------------------------
                0.00    0.00      82/22082       free_network [30]
                0.00    0.00   10000/22082       run_classification [2]
                0.00    0.00   12000/22082       free_batch [29]
[21]     0.0    0.00    0.00   22082         free_volume [21]
-----------------------------------------------
                0.00    0.00    1200/1200        net_classify [4]
[22]     0.0    0.00    0.00    1200         copy_volume [22]
-----------------------------------------------
                0.00    0.00       6/6           net_forward [5]
[23]     0.0    0.00    0.00       6         relu_forward [23]
```

```
-----------------------------------------------
                0.00    0.00       3/3           make_network [17]
[24]     0.0    0.00    0.00       3         make_pool_layer [24]
-----------------------------------------------
                0.00    0.00       3/3           make_network [17]
[25]     0.0    0.00    0.00       3         make_relu_layer [25]
-----------------------------------------------
                0.00    0.00       2/2           net_forward [5]
[26]     0.0    0.00    0.00       2         softmax_forward [26]
-----------------------------------------------
                0.00    0.00       1/1           __libc_csu_init [9]
[27]     0.0    0.00    0.00       1         change_volume_acc [27]
-----------------------------------------------
                0.00    0.00       1/1           load_cnn_snapshot [16]
[28]     0.0    0.00    0.00       1         fc_load [28]
-----------------------------------------------
                0.00    0.00       1/1           net_classify [4]
[29]     0.0    0.00    0.00       1         free_batch [29]
                0.00    0.00   12000/22082       free_volume [21]
-----------------------------------------------
                0.00    0.00       1/1           run_classification [2]
[30]     0.0    0.00    0.00       1         free_network [30]
                0.00    0.00      82/22082       free_volume [21]
-----------------------------------------------
                0.00    0.00       1/1           run_classification [2]
[31]     0.0    0.00    0.00       1         get_accuracy [31]
-----------------------------------------------
                0.00    0.00       1/1           make_network [17]
[32]     0.0    0.00    0.00       1         make_softmax_layer [32]
-----------------------------------------------


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   [8] change_softmax_layer   [21] free_volume            [32]
make_softmax_layer
  [27] change_volume_acc      [31] get_accuracy           [11] make_volume
   [6] conv_forward           [12] load_batch              [4] net_classify
  [20] conv_load              [16] load_cnn_snapshot       [5] net_forward
  [22] copy_volume            [13] make_batch             [14] pool_forward
   [1] do_benchmark           [18] make_conv_layer        [23] relu_forward
  [15] fc_forward             [19] make_fc_layer           [2]
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  [28] fc_load                [17] make_network           [26]
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  [29] free_batch             [24] make_pool_layer         [7] volume_get
  [30] free_network           [25] make_relu_layer        [10] volume_set
```