

# Deep Learning with torch:: CHEAT SHEET

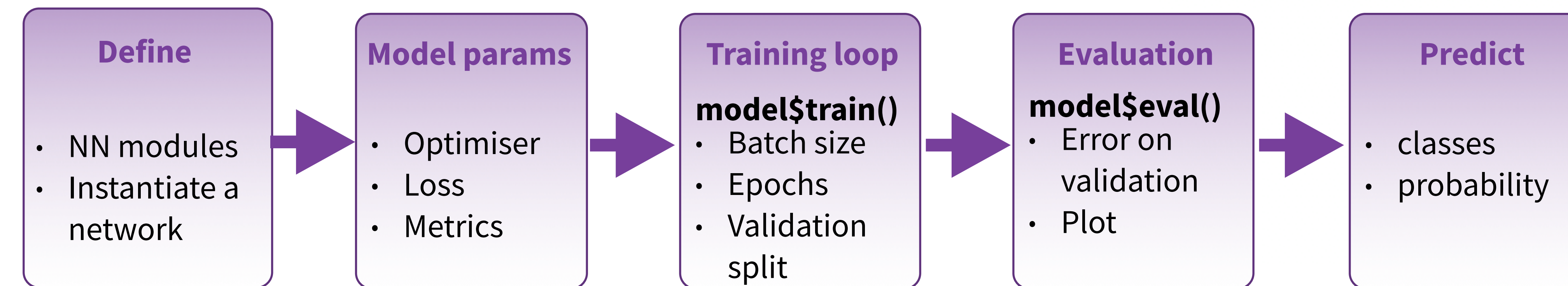


## Intro

`torch` is based on Pytorch, a framework popular among deep learning researchers.

`torch`'s GPU acceleration allows to implement fast machine learning algorithms using its convenient interface, as well as a vast range of use cases, not only for deep learning, according to its flexibility and its low level API.

It is part of an ecosystem of packages to interface with specific dataset like `torchaudio` for timeseries-like and `torchvision` for image-like data.



<https://torch.mlverse.org/>

<https://mlverse.shinyapps.io/torch-tour/>

## INSTALLATION

The `torch` R package uses the C++ `libtorch` library. You can install the prerequisites directly from R.

<https://torch.mlverse.org/docs/articles/installation.html>

```
install.packages("torch")
library(torch)
install_torch()
```

See ?install\_torch for GPU instructions

## Working with torch models

### DEFINE A NN MODULE

```
dense <- nn_module(
  "no_biais_dense_layer",
  initialize = function(in_f, out_f) {
    self$w <- nn_parameter(torch_randn(in_f, out_f))
  },
  forward = function(x) {
    torch_mm(x, self$w)
  }
)
```

Create a nn module names `no_biais_dense_layer`

### ASSEMBLE MODULES INTO NETWORK

```
model <- dense(4, 3)
```

Instantiate a network from a single module

```
model <- nn_sequential(
  dense(4,3), nn_relu(), nn_dropout(0.4),
  dense(3,1), nn_sigmoid())
```

Instantiate a sequential network with multiple layers

### MODEL FIT

```
model$train()
# Turns on gradient update
```

```
with_enable_grad({
  y_pred <- model(trainset)
  loss <- (y_pred - y)$pow(2)$mean()
  loss$backward()
})
```

Detailed training loop step (alternative)

### EVALUATE A MODEL

```
model$eval()
# or
with_no_grad({
  model(validationset)
})
```

Perform forward operation with no gradient update

### OPTIMIZATION

```
optim_sgd()
# Stochastic gradient descent optimiser
```

```
optim_adam()
# ADAM optimiser
```

### CLASSIFICATION LOSS FUNCTION

```
nn_cross_entropy_loss()
nn_bce_loss()
nn_bce_with_logits_loss()
# (Binary) cross-entropy losses
nn_nll_loss()
# Negative log-likelihood loss
nn_margin_ranking_loss()
nn_hinge_embedding_loss()
nn_multi_margin_loss()
nn_multilabel_margin_loss()
# (Multiclass) (multi label) hinge losses
```

### REGRESSION LOSS FUNCTION

```
nn_l1_loss()
# L1 loss
nn_mse_loss()
# MSE loss
nn_ctc_loss()
# Connectionist Temporal Classification loss
nn_cosine_embedding_loss()
# Cosine embedding loss
nn_kl_div_loss()
# Kullback-Leibler divergence loss
nn_poisson_nll_loss()
# Poisson NLL loss
```

### OTHER MODEL OPERATIONS

```
summary()
# Print a summary of a torch model
```

```
torch_save(); torch_load()
# Save/Load models to files
```

```
load_state_dict()
# Load a model saved in python
```

## Neural-network layers

### CORE LAYERS

**nn\_linear()**  
Add a linear transformation NN layer to an input

**nn\_bilinear()** to two inputs

**nn\_sigmoid(), nn\_relu()**  
Apply an activation function to an output

**nn\_dropout(), nn\_dropout2d(), nn\_dropout3d()**  
Applies Dropout to the input

**nn\_batch\_norm1d(), nn\_batch\_norm2d(), nn\_batch\_norm3d()**  
Applies batch normalisation to the weights

### CONVOLUTIONAL LAYERS

**nn\_conv1d()** 1D, e.g. temporal convolution

**nn\_conv\_transpose2d()**  
Transposed 2D (deconvolution)

**nn\_conv2d()** 2D, e.g. spatial convolution over images

**nn\_conv\_transpose3d()**  
Transposed 3D (deconvolution)

**nn\_conv3d()** 3D, e.g. spatial convolution over volumes

**nnf\_pad()**  
Zero-padding layer

### ACTIVATION LAYERS

**nn\_leaky\_relu()**  
Leaky version of a rectified linear unit

**nn\_relu6()**  
rectified linear unit clamped by 6

**nn\_rrelu()**  
Randomized leaky rectified linear unit

**nn\_elu(), nn\_selu()**  
Exponential linear unit, Scaled Exp lineal unit

### POOLING LAYERS

**nn\_max\_pool1d(), nn\_max\_pool2d(), nn\_max\_pool3d()**  
Maximum pooling for 1D to 3D

**nn\_avg\_pool1d(), nn\_avg\_pool2d(), nn\_avg\_pool3d()**  
Average pooling for 1D to 3D

**nn\_adaptive\_max\_pool1d(), nn\_adaptive\_max\_pool2d(), nn\_adaptive\_max\_pool3d()**  
Adaptive maximum pooling

**nn\_adaptive\_avg\_pool1d(), nn\_adaptive\_avg\_pool2d(), nn\_adaptive\_avg\_pool3d()**  
Adaptive average pooling

### RECURRENT LAYERS

**nn\_rnn()**  
Fully-connected RNN where the output is to be fed back to input

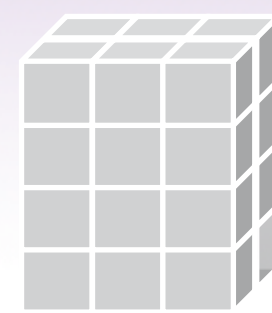
**nn\_gru()**  
Gated recurrent unit - Cho et al

**nn\_lstm()**  
Long-Short Term Memory unit - Hochreiter 1997



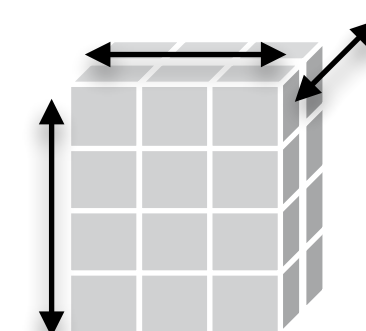
# Tensor manipulation

## TENSOR CREATION



**tt** ← **torch\_rand(4,3,2)** uniform distrib.  
**tt** ← **torch\_randn(4,3,2)** unit normal distrib.  
**tt** ← **torch\_randint(1,7,c(4,3,2))** uniform integers within [1,7)  
 Create a random values tensor with shape

**tt** ← **torch\_ones(4,3,2)**  
**torch\_ones\_like(a)**  
 Create a tensor full of 1 with given shape, or with the same shape as 'a'. Also **torch\_zeros**, **torch\_full**, **torch\_arange**,...



**tt\$shape** [1] 4 3 2 **tt\$ndim** [1] 3 **tt\$dtype** torch\_Float  
**tt\$requires\_grad** [1] FALSE **torch\_device(type='cpu')**  
 Get 't' tensor shape and attributes

**tt\$stride()** jump needed to go from one element to the next in each dimension  
 [1] 6 2 1

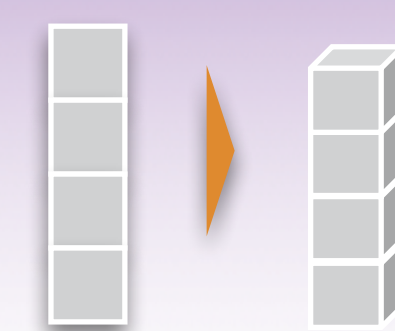


**tt** ← **torch\_tensor(a, dtype=torch\_float(), device="cuda")**  
 Copy the R array 'a' into a tensor of float on the GPU

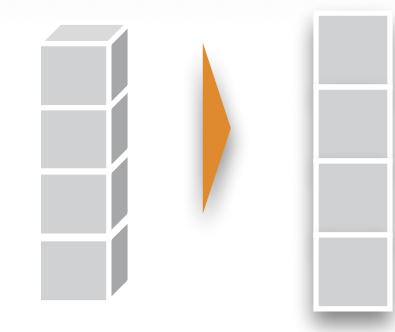


**a** ← **as.matrix(tt\$to(device="cpu"))**

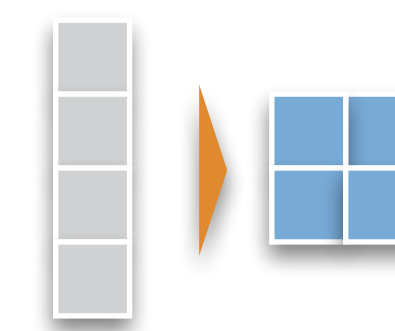
## TENSOR SHAPE OPERATIONS



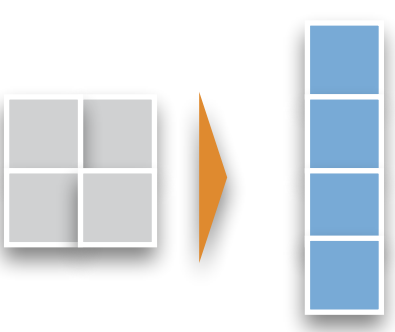
**tt\$unsqueeze(1)**  
**torch\_unsqueeze(t,1)**  
 Add a unitary dimension to tensor "tt" as first dimension



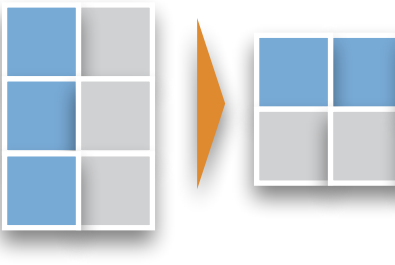
**tt\$squeeze(1)**  
**torch\_squeeze(t,1)**  
 Remove first unitary dimension to tensor "tt"



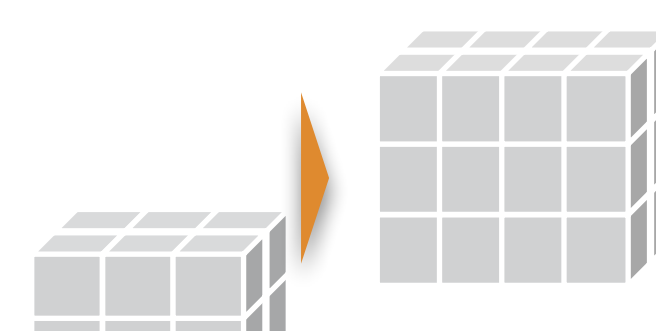
**torch\_reshape()** **\$view()**  
 Change the tensor shape, with copy or (tentatively) without



**torch\_flatten()**  
 Flattens an input



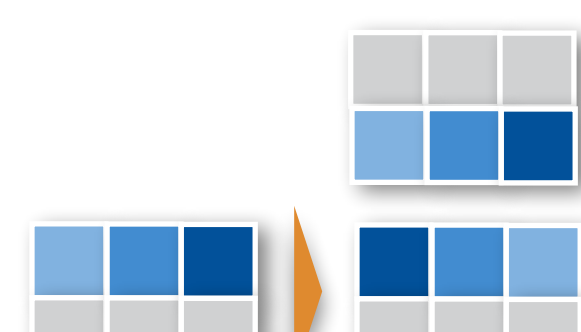
**torch\_transpose()**



**torch\_movedim(c(1,2))**  
 switch dimension 1 with 2



**torch\_movedim(c(1,2,3), c(3,1,2))**  
 move dim 1 to dim 3, dim 2 to 1, dim 3 to 2  
**torch\_permute(c(3,1,2))**  
 Only provide the target dimension order



**torch\_flip(1)** flip values along dim 1



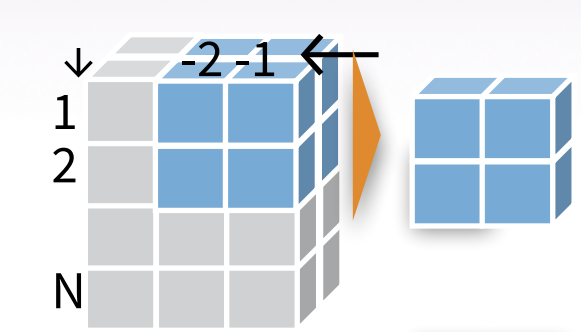
**torch\_flip(2)** 2

**torch\_flip(c(1,2))** both dims

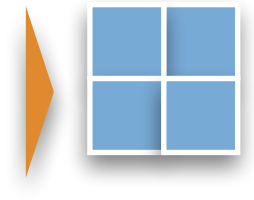
## TENSOR SLICING



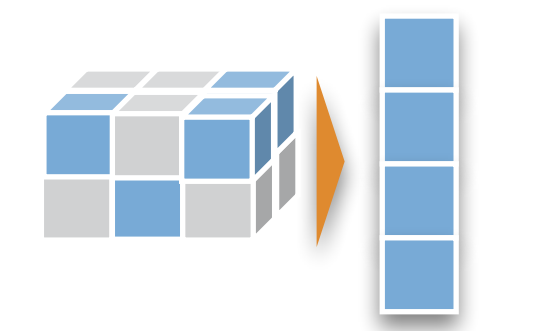
**tt[1:2, -2:-1, ]**  
 Slice a 3D tensor  
**tt[5:N, -2:-1, ..]**  
 Slice a 3D or more tensor, N for last



**tt[1:2, -2:-1, 1:1]**  
**tt[1:2, -2:-1, 1, keep=TRUE]**  
 Slice a 3D and keep the unitary dim.



**tt[1:2, -2:-1, 1]**  
 Slice by default remove unitary dim.

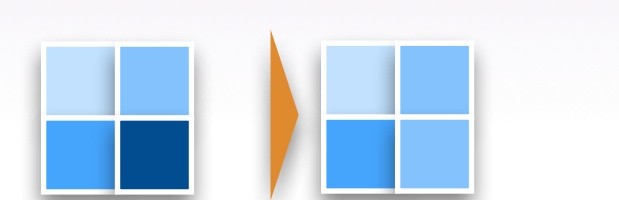


**tt[ tt > 3.1]**  
 Boolean filtering (flattened result)

## TENSOR VALUES OPERATIONS



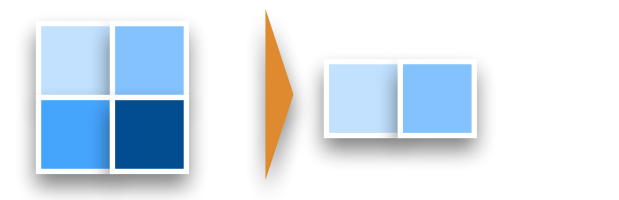
**+, -, \***  
 Operations with two tensors



**\$pow(2), \$log(), \$exp(), \$abs(), \$floor(), \$round(), \$cos(), \$fmod(3), \$fmax(1), \$fmin(3)**  
 Element-wise operations on a tensor

**\$eq(), \$ge(), \$le()**  
 Element-wise comparison

**\$to(dtype = torch\_long())**  
 Mutate values type



**\$sum(dim=1), \$mean(), \$max()**  
 Aggregation functions on a single tensor  
**\$amax()**

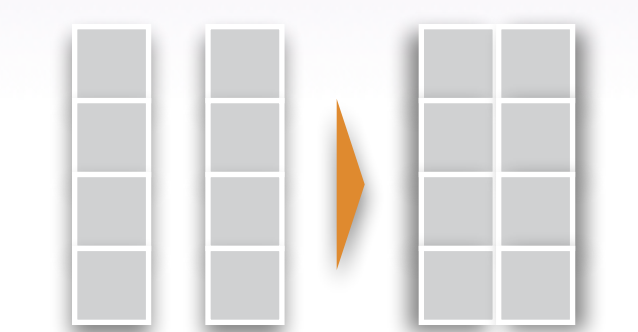


**torch\_repeat\_interleave()**  
 Repeats the input n times

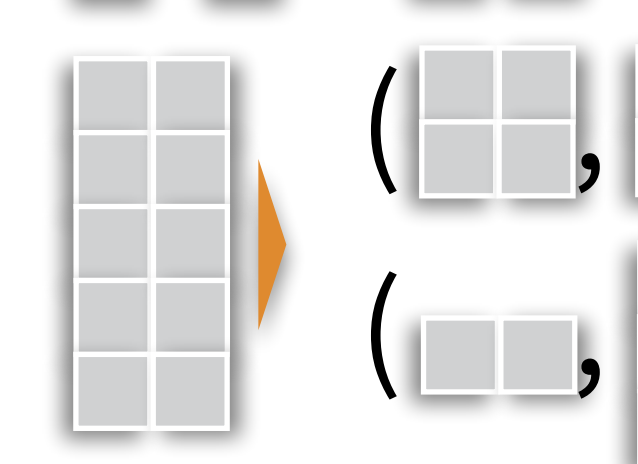
## TENSOR CONCATENATION



**torch\_stack()**  
 Stack of tensors



**torch\_cat()**  
 Assemble tensors



**torch\_split(2)**  
 split tensor in sections of size 2

**torch\_split(c(1,3,1))**  
 split tensor into explicit sizes

## TRAINING AN IMAGE RECOGNIZER ON MNIST DATA

5041

The "Hello, World!" of deep learning

## Pre-trained models

Torch applications are deep learning models that are made available alongside pre-trained weights. These models can be used for prediction, feature extraction, and fine-tuning.

### NATIVE R MODELS

**library(torchvision)**  
**resnet34** ← **model\_resnet34(pretrained=TRUE)**  
 Resnet image classification model  
  
**resnet34\_headless** ← **nn\_prune\_head(resnet34, 1)**  
 Remove top layer of a model

### IMPORTING FROM PYTORCH

{torchvisionlib} allows you to import a pytorch model without recoding its nn modules in R. This is done in two steps

1- instantiate the model in Python, script it, and save it:

```
import torch
import torchvision
```

```
model = torchvision.models.segmentation.\
    fcn_resnet50(pretrained = True)
model.eval()
```

```
scripted_model = torch.jit.script(model)
torch.jit.save(scripted_model, "fcn_resnet50.pt")
```

2- load and use the model in R:

```
library(torchvisionlib)
model ← torch::jit_load("fcn_resnet50.pt")
```

## Troubleshooting

### HELPERS

**with\_detect\_anomaly()**  
 Provides insight of a nn\_module() behaviour

## Callbacks

A callback is a set of functions to be applied at given stages of the training procedure. You can use callbacks to get a view on internal states and statistics of the model during training.

```
# input layer: use MNIST images
library(torchvision)
train_ds ← mnist_dataset( root = "~/cache",
  download = TRUE,
  transform = torchvision::transform_to_tensor
)
test_ds ← mnist_dataset( root = "~/cache",
  train = FALSE,
  transform = torchvision::transform_to_tensor
)
train_dl ← dataloader(train_ds, batch_size = 32,
  shuffle = TRUE)
test_dl ← dataloader(test_ds, batch_size = 32)

# defining the model and layers
net ← nn_module(
  "Net",
  initialize = function() {
    self$fc1 ← nn_linear(784, 128)
    self$fc2 ← nn_linear(128, 10)
  },
  forward = function(x) {
    x %>% torch_flatten(start_dim = 2) %>%
      self$fc1() %>% nnf_relu() %>%
      self$fc2() %>% nnf_log_softmax(dim = 1)
  }
)
model ← net()
# define loss and optimizer
optimizer ← optim_sgd(model$parameters, lr = 0.01)
# train (fit)
for (epoch in 1:10) {
  train_losses ← c()
  test_losses ← c()
  for (b in enumerate(train_dl)) {
    optimizer$zero_grad()
    output ← model(b[[1]]$to(device = device))
    loss ← nnf_nll_loss(output, b[[2]]$to(device = device))
    loss$backward()
    optimizer$step()
    train_losses ← c(train_losses, loss$item())
  }
  for (b in enumerate(test_dl)) {
    model$eval()
    output ← model(b[[1]]$to(device = device))
    loss ← nnf_nll_loss(output, b[[2]]$to(device = device))
    test_losses ← c(test_losses, loss$item())
    model$train()
  }
}
```