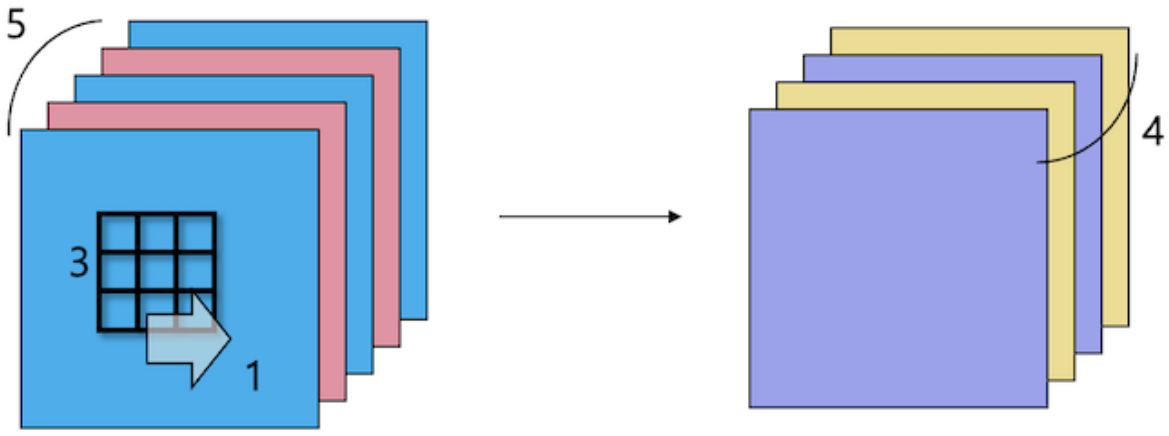
In [1]:

```
# import packages
import time
import torch
import numpy as np
import torch.nn as nn
import torch.nn.functional as F
import torch.optim as optim
import matplotlib.pyplot as plt
from torchsummary import summary as summary_
from torchvision import utils
import torchvision.datasets as dataset
import torchvision.transforms as transforms
```

In [2]:

```
layer = torch.nn.Conv2d(5, 4, 3, 1, 0) #in_channels, out_channels, kernel_size, stride, padding)
print(layer)
```

```
Conv2d(5, 4, kernel_size=(3, 3), stride=(1, 1))
```



In [3]:

```
'''
If an image of size (1,5,11,11) #batch (Number of data), channel, width, height
go through above CNN layer, the output size will be (1, 4, 9, 9)

*Max pooling calculation
torch.nn.MaxPool2d(kernel_size=3, stride=3)
(1, 4, 9, 9) -> (1, 4, 3, 3)

'''
```

Out[3]:

```
'₩nIf an image of size (1,5,11,11) #batch (Number of data), channel, width, height
₩ngo through above CNN layer, the output size will be (1, 4, 9, 9)₩n₩n*Max pooling
calculation₩ntorch.nn.MaxPool2d(kernel_size=3, stride=3)₩n(1, 4, 9, 9) -> (1, 4,
3, 3)₩n₩n'
```

Today's Topic: Modeling the Convolutional Neural Network

How to implement convlutional neural network using pytorch?

1. MNIST data load

The MNIST dataset is the handwriting image data from 1 to 9.

In [4]:

```
#Torchvision provides a variety of data sets, such as MNIST and CIFAR-10.
#It also provides famous models such as resnet and transfroms for preprocessing.


mnist_train = dataset.MNIST(root='MNIST/',
                            train=True,
                            transform=transforms.ToTensor(),
                            download=True)

mnist_test = dataset.MNIST(root='MNIST/',
                            train=False,
                            transform=transforms.ToTensor(),
                            download=True)
```

```
Downloading http://yann.lecun.com/exdb/mnist/train-images-idx3-ubyte.gz
Downloading http://yann.lecun.com/exdb/mnist/train-images-idx3-ubyte.gz to MNIST/M
NIST/raw/train-images-idx3-ubyte.gz


Extracting MNIST/MNIST/raw/train-images-idx3-ubyte.gz to MNIST/MNIST/raw

Downloading http://yann.lecun.com/exdb/mnist/train-labels-idx1-ubyte.gz
Downloading http://yann.lecun.com/exdb/mnist/train-labels-idx1-ubyte.gz to MNIST/M
NIST/raw/train-labels-idx1-ubyte.gz


Extracting MNIST/MNIST/raw/train-labels-idx1-ubyte.gz to MNIST/MNIST/raw

Downloading http://yann.lecun.com/exdb/mnist/t10k-images-idx3-ubyte.gz
Downloading http://yann.lecun.com/exdb/mnist/t10k-images-idx3-ubyte.gz to MNIST/MN
IST/raw/t10k-images-idx3-ubyte.gz


Extracting MNIST/MNIST/raw/t10k-images-idx3-ubyte.gz to MNIST/MNIST/raw

Downloading http://yann.lecun.com/exdb/mnist/t10k-labels-idx1-ubyte.gz
Downloading http://yann.lecun.com/exdb/mnist/t10k-labels-idx1-ubyte.gz to MNIST/MN
IST/raw/t10k-labels-idx1-ubyte.gz


Extracting MNIST/MNIST/raw/t10k-labels-idx1-ubyte.gz to MNIST/MNIST/raw
```

In [5]:

```
#The data type in torchvision.dataset is the same as the data set in torch.utils.data used in th
e previous lecture.
mnist_train
```

Out[5]:

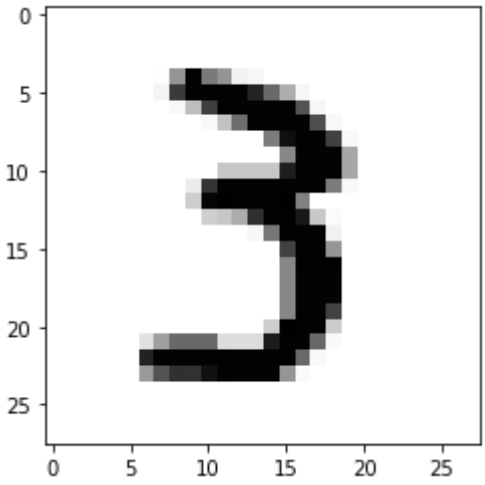
```
Dataset MNIST
    Number of datapoints: 60000
    Root location: MNIST/
    Split: Train
    StandardTransform
Transform: ToTensor()
```

In [6]:

```
#Observe the MNIST data set
plt.imshow(mnist_train.train_data[5820, :, :], cmap='Greys')
print(f'WnNumber of train data: {len(mnist_train)} Number of test data: {len(mnist_test)}')
print(f'Shape of train data: {mnist_train.train_data.shape}Wn')
```

```
/usr/local/lib/python3.7/dist-packages/torchvision/datasets/mnist.py:75: UserWarni
ng: train_data has been renamed data
  warnings.warn("train_data has been renamed data")

Number of train data: 60000 Number of test data: 10000
Shape of train data: torch.Size([60000, 28, 28])
```



In [7]:

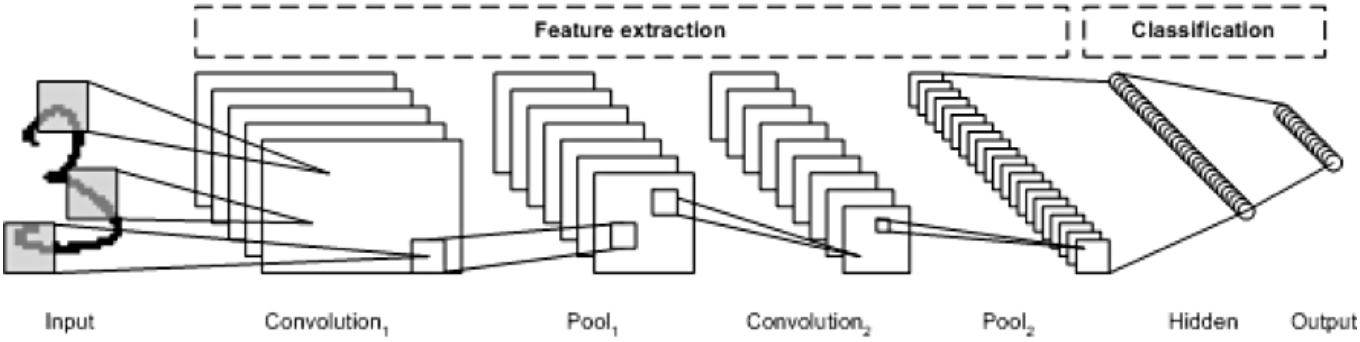
```
#Make data loader of train data
batch_size = 128
train_loader = torch.utils.data.DataLoader(dataset=mnist_train,
                                           batch_size=batch_size,
                                           shuffle=True,
                                           drop_last=True)
```

In [8]:

```
#We don't use data loader for test data this time.
x_test = mnist_test.test_data.view(len(mnist_test), 1, 28, 28).float()
y_test = mnist_test.test_labels
```

```
/usr/local/lib/python3.7/dist-packages/torchvision/datasets/mnist.py:80: UserWarni
ng: test_data has been renamed data
  warnings.warn("test_data has been renamed data")
/usr/local/lib/python3.7/dist-packages/torchvision/datasets/mnist.py:70: UserWarni
ng: test_labels has been renamed targets
  warnings.warn("test_labels has been renamed targets")
```

2. Let's build convolutional layers



In [9]:

```
#torch.nn.Conv2d(in_channel, out_channel, kernel, stride, padding)
#torch.nn.MaxPool2d(kernel_size, stride)

# If you have a model with lots of layers, you can create a sequential layer like below.

#sefl.layer1 = torch.nn.Sequential(torch.nn.Conv2d(), torch.ReLU(), torch.nn.MaxPool2d())
```

Problem 1(10pt)

Fill in the blanks of the code, considering the output shape of the previous layer. Calculate output dimensions for each layers (three layers) and *Describe it in detail*.

- The input data is image with **one channel of 28x28 size**.

(H, W) = (input height, input width) \ (FH, FW) = (filter height, filter width) \ (OH, OW) = (output height, output width) \ P: padding, S: stride \

$$OH = \frac{H + 2P - FH}{S} + 1$$

$$OW = \frac{W + 2P - FW}{S} + 1$$

In [10]:

```
class CNN(torch.nn.Module):
  def __init__(self):
    super(CNN, self).__init__()
    self.layer1 = torch.nn.Sequential(
        torch.nn.Conv2d(1, 32, kernel_size=5, stride=1, padding=0),
        torch.nn.ReLU(),
        torch.nn.MaxPool2d(kernel_size=2, stride=2))

    self.layer2 = torch.nn.Sequential(
          torch.nn.Conv2d(32, 16, kernel_size=5, stride=1, padding=0),
          torch.nn.ReLU(),
          torch.nn.MaxPool2d(kernel_size=2, stride=2))

    self.layer3 = torch.nn.Sequential(
            torch.nn.Linear(256, 32, bias=True),
            torch.nn.ReLU())

    self.fc = torch.nn.Linear(32, 10, bias=True)

  def forward(self, x):
    # print(f'input dimension is {np.shape(x)}')
    print("shape is : ",x.shape)
    y = self.layer1(x)
    print("shape is : ",y.shape)
    y = self.layer2(y)
    print("shape is : ",y.shape)
    y = y.view(y.size(0), -1)  # Flatten them for FC
    print("shape is : ",y.shape)
    y = self.layer3(y)
    print("shape is : ",y.shape)
    y = self.fc(y)
    print("shape is : ",y.shape)

    return y
```

In [11]:

```
#model before training
model = CNN()

data = mnist_train.train_data[5820, :, :].view(1, 1, 28, 28).float()
label = mnist_train.train_labels[5820]

y = model(data)
y = torch.argmax(y, 1)
print(f"Wncorrect answer : {label}, what model says : {y[0]}")
```

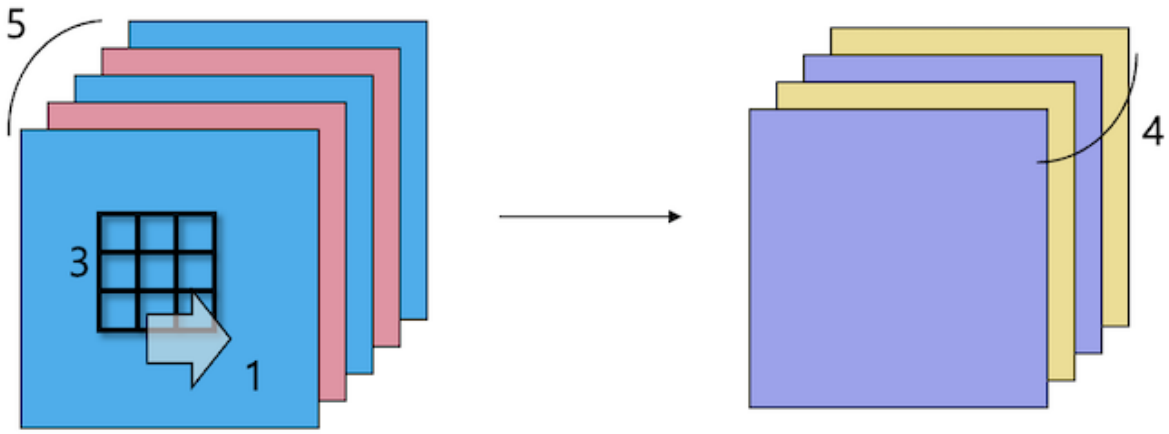
```
/usr/local/lib/python3.7/dist-packages/torchvision/datasets/mnist.py:65: UserWarni
ng: train_labels has been renamed targets
  warnings.warn("train_labels has been renamed targets")

shape is :  torch.Size([1, 1, 28, 28])
shape is :  torch.Size([1, 32, 12, 12])
shape is :  torch.Size([1, 16, 4, 4])
shape is :  torch.Size([1, 256])
shape is :  torch.Size([1, 32])
shape is :  torch.Size([1, 10])

correct answer : 3, what model says : 6
```

In [12]:

```
#흑백사진을 넣어서 처음 채널이 1입니다.
#그 후 print를 찍어보았을때 다음 채널은 32가 필요합니다.
#linear 과정이 layer3에서 32로 가기때문에 32로 채워넣었습니다.
```



How to calculate the number of learnable parameter?

if it is a MLP layer, the output dimension will be 28x28x5x4. \ if it is with CNN kernel, 3x3x5x4 + 4(bias) \

Convolutional Neural Networks (CNN) have characteristics that enable invariance to the transformations of images \ because of the parameter sharing and pooling strategy

Problem 2(10pt)

How many parameters to be trained in convolution layers in the above model? \ (Hint1: you should consider the *bias* of convolution layer)

1. number of parameter in the first CNN layer
2. number of parameter in the second CNN layer
3. number of parameter in the third FC layer

In [13]:

```
"""
1. (5*5*1 + 1)*32 = 832
2. (5*5*32+1)*16 = 12816
3. (256 + 1)*32 = 8224
"""
model.parameters
```

Out[13]:

```
<bound method Module.parameters of CNN(
  (layer1): Sequential(
    (0): Conv2d(1, 32, kernel_size=(5, 5), stride=(1, 1))
    (1): ReLU()
    (2): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1, ceil_mode=Fals
e)
  )
  (layer2): Sequential(
    (0): Conv2d(32, 16, kernel_size=(5, 5), stride=(1, 1))
    (1): ReLU()
    (2): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1, ceil_mode=Fals
e)
  )
  (layer3): Sequential(
    (0): Linear(in_features=256, out_features=32, bias=True)
    (1): ReLU()
  )
  (fc): Linear(in_features=32, out_features=10, bias=True)
)>
```

3. Visualize a filter(kernel)

In [14]:

```
#extract the filter map of the convolution layer
filter_map = []
for param in list(model.parameters()):
  if param.dim() == 4:
    print(param.shape)
    filter_map.append(param)
```

```
torch.Size([32, 1, 5, 5])
torch.Size([16, 32, 5, 5])
```

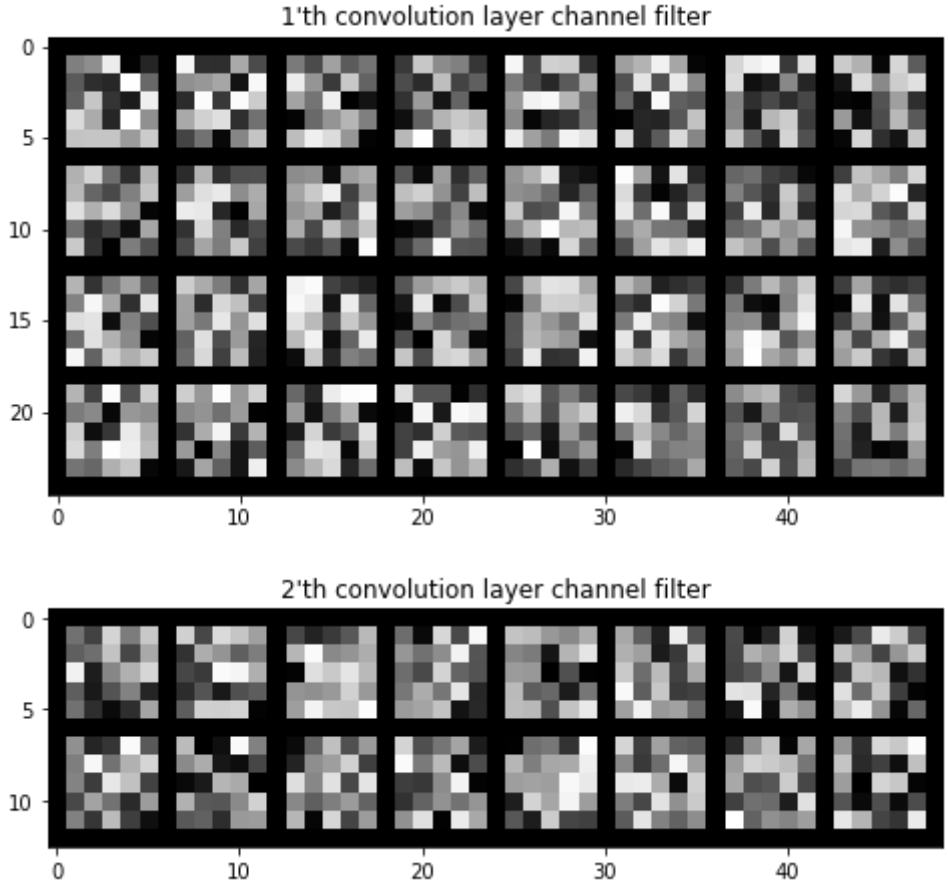
In [15]:

```
#Make a function for feature map visualization
def visTensor(filter_tensor):
  nrow = 8
  padding = 1
  #(64, 1, 5, 5)
  d,c,w,h = filter_tensor.shape
  #creat a dimension of size one inserted at the specified position(dim=1)
  tensor = filter_tensor[:,0,:,:].unsqueeze(dim=1)
  #make a grid of images
  grid = utils.make_grid(tensor, nrow=nrow, normalize=True, padding=padding)
  ncolumn = np.min((tensor.shape[0] // nrow + 1, 16))

  plt.figure(figsize=(nrow,ncolumn))
  plt.imshow(grid.numpy().transpose((1, 2, 0)))
```

In [16]:

```
#Visualize the kernels before training
for n, weight in enumerate(filter_map):
  visTensor(weight)
  plt.title(f'{n+1}W'th convolution layer channel filter')
```



4. Learning the mnist data using the CNN

In [17]:

```
#hyper-parameter allocation

learning_rate = 0.001
epochs = 10
batch_size = train_loader.batch_size
```

In [18]:

```
model = CNN()
criterion = nn.CrossEntropyLoss()
optimizer = torch.optim.Adam(model.parameters(), lr = learning_rate)
```

In [19]:

```
#Training
for epoch in range(epochs):
  t1 = time.time()
  avg_loss = 0
  for data, target in train_loader:
    y = model(data)
    loss = criterion(y, target)
    optimizer.zero_grad()
    loss.backward()
    optimizer.step()
    avg_loss += loss/ len(train_loader)

  print(f'epochs : {epoch}, loss : {avg_loss}, time : {time.time()-t1}')
```

```
스트리밍 출력 내용이 길어서 마지막 5000줄이 삭제되었습니다.
shape is :  torch.Size([128, 1, 28, 28])
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```

```
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shape is :  torch.Size([128, 32, 12, 12])
shape is :  torch.Size([128, 16, 4, 4])
shape is :  torch.Size([128, 256])
shape is :  torch.Size([128, 32])
shape is :  torch.Size([128, 10])
shape is :  torch.Size([128, 1, 28, 28])
shape is :  torch.Size([128, 32, 12, 12])
shape is :  torch.Size([128, 16, 4, 4])
shape is :  torch.Size([128, 256])
shape is :  torch.Size([128, 32])
shape is :  torch.Size([128, 10])
shape is :  torch.Size([128, 1, 28, 28])
shape is :  torch.Size([128, 32, 12, 12])
shape is :  torch.Size([128, 16, 4, 4])
shape is :  torch.Size([128, 256])
shape is :  torch.Size([128, 32])
shape is :  torch.Size([128, 10])
shape is :  torch.Size([128, 1, 28, 28])
shape is :  torch.Size([128, 32, 12, 12])
shape is :  torch.Size([128, 16, 4, 4])
shape is :  torch.Size([128, 256])
shape is :  torch.Size([128, 32])
shape is :  torch.Size([128, 10])
shape is :  torch.Size([128, 1, 28, 28])
shape is :  torch.Size([128, 32, 12, 12])
shape is :  torch.Size([128, 16, 4, 4])
shape is :  torch.Size([128, 256])
shape is :  torch.Size([128, 32])
shape is :  torch.Size([128, 10])
shape is :  torch.Size([128, 1, 28, 28])
shape is :  torch.Size([128, 32, 12, 12])
shape is :  torch.Size([128, 16, 4, 4])
shape is :  torch.Size([128, 256])
shape is :  torch.Size([128, 32])
shape is :  torch.Size([128, 10])
epochs : 9, loss : 0.02345510944724083, time : 40.44709372520447
```

In [20]:

```
#Test
with torch.no_grad():
  prediction = model(x_test)
  correct_prediction = torch.argmax(prediction, 1) == y_test
  accuracy = correct_prediction.float().mean()
  print('Accuracy:', accuracy.item())
```

```
shape is :  torch.Size([10000, 1, 28, 28])
shape is :  torch.Size([10000, 32, 12, 12])
shape is :  torch.Size([10000, 16, 4, 4])
shape is :  torch.Size([10000, 256])
shape is :  torch.Size([10000, 32])
shape is :  torch.Size([10000, 10])
Accuracy: 0.9879999756813049
```

Problem 3(10pt)

Visualize the filters after training

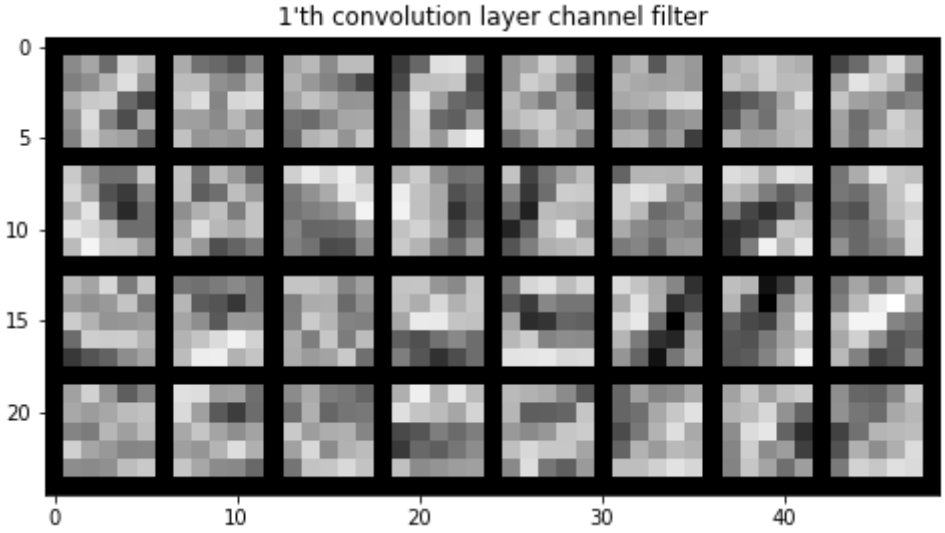
*Through comparison with filters visualized before learning, you can check whether the cnn model has been learned.

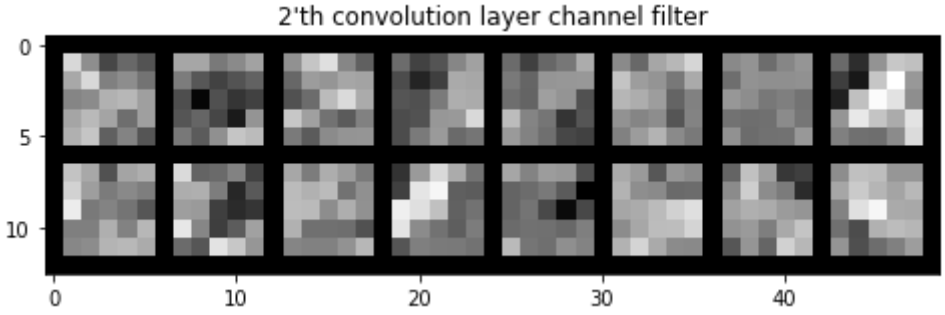
In [22]:

```
#Please write your code!
filter_map = []
for param in list(model.parameters()):
  if param.dim() == 4:
    print(param.shape)
    filter_map.append(param)

for n, weight in enumerate(filter_map):
  visTensor(weight)
  plt.title(f'{n+1}W'th convolution layer channel filter')
```

```
torch.Size([32, 1, 5, 5])
torch.Size([16, 32, 5, 5])
```





In [23]:

```
!apt-get install texlive texlive-xetex texlive-latex-extra pandoc
!pip install pypandoc
from google.colab import drive
drive.mount('/content/drive')
!jupyter nbconvert --to html '/content/drive/MyDrive/인공지능프로젝트/week5_lab.ipynb'
```

```
Reading package lists... Done
Building dependency tree
Reading state information... Done
pandoc is already the newest version (1.19.2.4~dfsg-1build4).
pandoc set to manually installed.
The following package was automatically installed and is no longer required:
  libnvidia-common-460
Use 'apt autoremove' to remove it.
The following additional packages will be installed:
  fonts-droid-fallback fonts-lato fonts-lmodern fonts-noto-mono fonts-texgyre
  javascript-common libcupsfilters1 libcupsimage2 libgs9 libgs9-common
  libijs-0.35 libjbig2dec0 libjs-jquery libkpathsea6 libpotrace0 libptexenc1
  libruby2.5 libsynctex1 libtexlua52 libtexluajit2 libzzip-0-13 lmodern
  poppler-data preview-latex-style rake ruby ruby-did-you-mean ruby-minitest
  ruby-net-telnet ruby-power-assert ruby-test-unit ruby2.5
  rubygems-integration t1utils tex-common tex-gyre texlive-base
  texlive-binaries texlive-fonts-recommended texlive-latex-base
  texlive-latex-recommended texlive-pictures texlive-plain-generic tipa
Suggested packages:
  fonts-noto apache2 | lighttpd | httpd poppler-utils ghostscript
  fonts-japanese-mincho | fonts-ipafont-mincho fonts-japanese-gothic
  | fonts-ipafont-gothic fonts-arphic-ukai fonts-arphic-uming fonts-nanum ri
  ruby-dev bundler debhelper gv | postscript-viewer perl-tk xpdf-reader
  | pdf-viewer texlive-fonts-recommended-doc texlive-latex-base-doc
  python-pygments icc-profiles libfile-which-perl
  libspreadsheet-parseexcel-perl texlive-latex-extra-doc
  texlive-latex-recommended-doc texlive-pstricks dot2tex prerex ruby-tcltk
  | libtcltk-ruby texlive-pictures-doc vprerex
The following NEW packages will be installed:
  fonts-droid-fallback fonts-lato fonts-lmodern fonts-noto-mono fonts-texgyre
  javascript-common libcupsfilters1 libcupsimage2 libgs9 libgs9-common
  libijs-0.35 libjbig2dec0 libjs-jquery libkpathsea6 libpotrace0 libptexenc1
  libruby2.5 libsynctex1 libtexlua52 libtexluajit2 libzzip-0-13 lmodern
  poppler-data preview-latex-style rake ruby ruby-did-you-mean ruby-minitest
  ruby-net-telnet ruby-power-assert ruby-test-unit ruby2.5
  rubygems-integration t1utils tex-common tex-gyre texlive texlive-base
  texlive-binaries texlive-fonts-recommended texlive-latex-base
  texlive-latex-extra texlive-latex-recommended texlive-pictures
  texlive-plain-generic texlive-xetex tipa
0 upgraded, 47 newly installed, 0 to remove and 20 not upgraded.
Need to get 146 MB of archives.
After this operation, 460 MB of additional disk space will be used.
Get:1 http://archive.ubuntu.com/ubuntu bionic/main amd64 fonts-droid-fallback all
1:6.0.1r16-1.1 [1,805 kB]
Get:2 http://archive.ubuntu.com/ubuntu bionic/main amd64 fonts-lato all 2.0-2 [2,6
98 kB]
Get:3 http://archive.ubuntu.com/ubuntu bionic/main amd64 poppler-data all 0.4.8-2
[1,479 kB]
Get:4 http://archive.ubuntu.com/ubuntu bionic/main amd64 tex-common all 6.09 [33.0
kB]
Get:5 http://archive.ubuntu.com/ubuntu bionic/main amd64 fonts-lmodern all 2.004.5
-3 [4,551 kB]
Get:6 http://archive.ubuntu.com/ubuntu bionic/main amd64 fonts-noto-mono all 20171
026-2 [75.5 kB]
Get:7 http://archive.ubuntu.com/ubuntu bionic/universe amd64 fonts-texgyre all 201
60520-1 [8,761 kB]
Get:8 http://archive.ubuntu.com/ubuntu bionic/main amd64 javascript-common all 11
[6,066 B]
Get:9 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libcupsfilters1 a
md64 1.20.2-0ubuntu3.1 [108 kB]
Get:10 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libcupsimage2 am
```

```
d64 2.2.7-1ubuntu2.9 [18.6 kB]
Get:11 http://archive.ubuntu.com/ubuntu bionic/main amd64 libijs-0.35 amd64 0.35-1
3 [15.5 kB]
Get:12 http://archive.ubuntu.com/ubuntu bionic/main amd64 libjbig2dec0 amd64 0.13-
6 [55.9 kB]
Ign:13 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libgs9-common al
l 9.26~dfsg+0-0ubuntu0.18.04.16
Ign:14 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libgs9 amd64 9.2
6~dfsg+0-0ubuntu0.18.04.16
Get:15 http://archive.ubuntu.com/ubuntu bionic/main amd64 libjs-jquery all 3.2.1-1
[152 kB]
Get:16 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libkpathsea6 amd
64 2017.20170613.44572-8ubuntu0.1 [54.9 kB]
Get:17 http://archive.ubuntu.com/ubuntu bionic/main amd64 libpotrace0 amd64 1.14-2
[17.4 kB]
Get:18 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libptexenc1 amd6
4 2017.20170613.44572-8ubuntu0.1 [34.5 kB]
Get:19 http://archive.ubuntu.com/ubuntu bionic/main amd64 rubygems-integration all
1.11 [4,994 B]
Get:20 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 ruby2.5 amd64 2.
5.1-1ubuntu1.12 [48.6 kB]
Get:21 http://archive.ubuntu.com/ubuntu bionic/main amd64 ruby amd64 1:2.5.1 [5,71
2 B]
Get:22 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 rake all 12.3.1-
1ubuntu0.1 [44.9 kB]
Get:23 http://archive.ubuntu.com/ubuntu bionic/main amd64 ruby-did-you-mean all 1.
2.0-2 [9,700 B]
Get:24 http://archive.ubuntu.com/ubuntu bionic/main amd64 ruby-minitest all 5.10.3
-1 [38.6 kB]
Get:25 http://archive.ubuntu.com/ubuntu bionic/main amd64 ruby-net-telnet all 0.1.
1-2 [12.6 kB]
Get:26 http://archive.ubuntu.com/ubuntu bionic/main amd64 ruby-power-assert all 0.
3.0-1 [7,952 B]
Err:13 http://security.ubuntu.com/ubuntu bionic-updates/main amd64 libgs9-common a
ll 9.26~dfsg+0-0ubuntu0.18.04.16
  404  Not Found [IP: 185.125.190.39 80]
Get:27 http://archive.ubuntu.com/ubuntu bionic/main amd64 ruby-test-unit all 3.2.5
-1 [61.1 kB]
Err:14 http://security.ubuntu.com/ubuntu bionic-updates/main amd64 libgs9 amd64 9.
26~dfsg+0-0ubuntu0.18.04.16
  404  Not Found [IP: 185.125.190.39 80]
Get:28 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libruby2.5 amd64
2.5.1-1ubuntu1.12 [3,073 kB]
Get:29 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libsynctex1 amd6
4 2017.20170613.44572-8ubuntu0.1 [41.4 kB]
Get:30 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libtexlua52 amd6
4 2017.20170613.44572-8ubuntu0.1 [91.2 kB]
Get:31 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libtexluajit2 am
d64 2017.20170613.44572-8ubuntu0.1 [230 kB]
Get:32 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libzzip-0-13 amd
64 0.13.62-3.1ubuntu0.18.04.1 [26.0 kB]
Get:33 http://archive.ubuntu.com/ubuntu bionic/main amd64 lmodern all 2.004.5-3
[9,631 kB]
Get:34 http://archive.ubuntu.com/ubuntu bionic/main amd64 preview-latex-style all
11.91-1ubuntu1 [185 kB]
Get:35 http://archive.ubuntu.com/ubuntu bionic/main amd64 t1utils amd64 1.41-2 [5
6.0 kB]
Get:36 http://archive.ubuntu.com/ubuntu bionic/universe amd64 tex-gyre all 2016052
0-1 [4,998 kB]
Get:37 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 texlive-binaries
amd64 2017.20170613.44572-8ubuntu0.1 [8,179 kB]
```

```
Get:38 http://archive.ubuntu.com/ubuntu bionic/main amd64 texlive-base all 2017.20
180305-1 [18.7 MB]
Get:39 http://archive.ubuntu.com/ubuntu bionic/universe amd64 texlive-fonts-recomm
ended all 2017.20180305-1 [5,262 kB]
Get:40 http://archive.ubuntu.com/ubuntu bionic/main amd64 texlive-latex-base all 2
017.20180305-1 [951 kB]
Get:41 http://archive.ubuntu.com/ubuntu bionic/main amd64 texlive-latex-recommende
d all 2017.20180305-1 [14.9 MB]
Get:42 http://archive.ubuntu.com/ubuntu bionic/universe amd64 texlive all 2017.201
80305-1 [14.4 kB]
Get:43 http://archive.ubuntu.com/ubuntu bionic/universe amd64 texlive-pictures all
2017.20180305-1 [4,026 kB]
Get:44 http://archive.ubuntu.com/ubuntu bionic/universe amd64 texlive-latex-extra
all 2017.20180305-2 [10.6 MB]
Get:45 http://archive.ubuntu.com/ubuntu bionic/universe amd64 texlive-plain-generi
c all 2017.20180305-2 [23.6 MB]
Get:46 http://archive.ubuntu.com/ubuntu bionic/universe amd64 tipa all 2:1.3-20
[2,978 kB]
Get:47 http://archive.ubuntu.com/ubuntu bionic/universe amd64 texlive-xetex all 20
17.20180305-1 [10.7 MB]
Fetched 138 MB in 6s (24.8 MB/s)
E: Failed to fetch http://security.ubuntu.com/ubuntu/pool/main/g/ghostscript/libgs
9-common_9.26~dfsg+0-0ubuntu0.18.04.16_all.deb  404  Not Found [IP: 185.125.190.39
80]
E: Failed to fetch http://security.ubuntu.com/ubuntu/pool/main/g/ghostscript/libgs
9_9.26~dfsg+0-0ubuntu0.18.04.16_amd64.deb  404  Not Found [IP: 185.125.190.39 80]
E: Unable to fetch some archives, maybe run apt-get update or try with --fix-missi
ng?
Looking in indexes: https://pypi.org/simple, https://us-python.pkg.dev/colab-wheel
s/public/simple/
Collecting pypandoc
  Downloading pypandoc-1.9-py3-none-any.whl (20 kB)
Installing collected packages: pypandoc
Successfully installed pypandoc-1.9
Mounted at /content/drive
[NbConvertApp] Converting notebook /content/drive/MyDrive/인공지능프로젝트/week5_l
ab.ipynb to html
[NbConvertApp] Writing 856521 bytes to /content/drive/MyDrive/인공지능프로젝트/wee
k5_lab.html
```