Cognitive Computing HW1

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Problem 4

1. Explain what is a residual network, and the basic motivation for using it. Also explain what are the main elements of resnet34 and resnet50. How many layers, how many neurons total, how many weights; and then anything else you want to say.

In [11]:
```
import torchvision
import torchsummary
from torchvision import models
from torchsummary import summary
from torchvision import models
```

In [12]:
```
summary(models.resnet34(), input_size = (3, 224, 224))
```

Layer (type)	Output Shape	Param #
Conv2d-1	[-1, 64, 112, 112]	9,408
BatchNorm2d-2	[-1, 64, 112, 112]	128
ReLU-3	[-1, 64, 112, 112]	0
MaxPool2d-4	[-1, 64, 56, 56]	0
Conv2d-5	[-1, 64, 56, 56]	36,864
BatchNorm2d-6	[-1, 64, 56, 56]	128
ReLU-7	[-1, 64, 56, 56]	0
Conv2d-8	[-1, 64, 56, 56]	36,864
BatchNorm2d-9	[-1, 64, 56, 56]	128
ReLU-10	[-1, 64, 56, 56]	0
BasicBlock-11	[-1, 64, 56, 56]	0
Conv2d-12	[-1, 64, 56, 56]	36,864
BatchNorm2d-13	[-1, 64, 56, 56]	128
ReLU-14	[-1, 64, 56, 56]	0
Conv2d-15	[-1, 64, 56, 56]	36,864
BatchNorm2d-16	[-1, 64, 56, 56]	128
ReLU-17	[-1, 64, 56, 56]	0
BasicBlock-18	[-1, 64, 56, 56]	0
Conv2d-19	[-1, 64, 56, 56]	36,864
BatchNorm2d-20	[-1, 64, 56, 56]	128
ReLU-21	[-1, 64, 56, 56]	0
Conv2d-22	[-1, 64, 56, 56]	36,864
BatchNorm2d-23	[-1, 64, 56, 56]	128
ReLU-24	[-1, 64, 56, 56]	0
BasicBlock-25	[-1, 64, 56, 56]	0
Conv2d-26	[-1, 128, 28, 28]	73,728
BatchNorm2d-27	[-1, 128, 28, 28]	256
ReLU-28	[-1, 128, 28, 28]	0
Conv2d-29	[-1, 128, 28, 28]	147,456
BatchNorm2d-30	[-1, 128, 28, 28]	256
Conv2d-31	[-1, 128, 28, 28]	8,192
BatchNorm2d-32	[-1, 128, 28, 28]	256
ReLU-33	[-1, 128, 28, 28]	0
BasicBlock-34	[-1, 128, 28, 28]	0
Conv2d-35	[-1, 128, 28, 28]	147,456
BatchNorm2d-36	[-1, 128, 28, 28]	256
ReLU-37	[-1, 128, 28, 28]	0
Conv2d-38	[-1, 128, 28, 28]	147,456
BatchNorm2d-39	[-1, 128, 28, 28]	256
ReLU-40	[-1, 128, 28, 28]	0
BasicBlock-41	[-1, 128, 28, 28]	0
Conv2d-42	[-1, 128, 28, 28]	147,456
BatchNorm2d-43	[-1, 128, 28, 28]	256
ReLU-44	[-1, 128, 28, 28]	0
Conv2d-45	[-1, 128, 28, 28]	147,456
BatchNorm2d-46	[-1, 128, 28, 28]	256
ReLU-47	[-1, 128, 28, 28]	0
BasicBlock-48	[-1, 128, 28, 28]	0
Conv2d-49	[-1, 128, 28, 28]	147,456
BatchNorm2d-50	[-1, 128, 28, 28]	256
ReLU-51	[-1, 128, 28, 28]	0
Conv2d-52	[-1, 128, 28, 28]	147,456
BatchNorm2d-53	[-1, 128, 28, 28]	256
ReLU-54	[-1, 128, 28, 28]	0

BasicBlock-55	[-1, 128, 28, 28]	0
Conv2d-56	[-1, 256, 14, 14]	294,912
BatchNorm2d-57	[-1, 256, 14, 14]	512
ReLU-58	[-1, 256, 14, 14]	0
Conv2d-59	[-1, 256, 14, 14]	589,824
BatchNorm2d-60	[-1, 256, 14, 14]	512
Conv2d-61	[-1, 256, 14, 14]	32,768
BatchNorm2d-62	[-1, 256, 14, 14]	512
ReLU-63	[-1, 256, 14, 14]	0
BasicBlock-64	[-1, 256, 14, 14]	0
Conv2d-65	[-1, 256, 14, 14]	589,824
BatchNorm2d-66	[-1, 256, 14, 14]	512
ReLU-67	[-1, 256, 14, 14]	0
Conv2d-68	[-1, 256, 14, 14]	589,824
BatchNorm2d-69	[-1, 256, 14, 14]	512
ReLU-70	[-1, 256, 14, 14]	0
BasicBlock-71	[-1, 256, 14, 14]	0
Conv2d-72	[-1, 256, 14, 14]	589,824
BatchNorm2d-73	[-1, 256, 14, 14]	512
ReLU-74	[-1, 256, 14, 14]	0
Conv2d-75	[-1, 256, 14, 14]	589,824
BatchNorm2d-76	[-1, 256, 14, 14]	512
ReLU-77	[-1, 256, 14, 14]	0
BasicBlock-78	[-1, 256, 14, 14]	0
Conv2d-79	[-1, 256, 14, 14]	589,824
BatchNorm2d-80	[-1, 256, 14, 14]	512
ReLU-81	[-1, 256, 14, 14]	0
Conv2d-82	[-1, 256, 14, 14]	589,824
BatchNorm2d-83	[-1, 256, 14, 14]	512
ReLU-84	[-1, 256, 14, 14]	0
BasicBlock-85	[-1, 256, 14, 14]	0
Conv2d-86	[-1, 256, 14, 14]	589,824
BatchNorm2d-87	[-1, 256, 14, 14]	512
ReLU-88	[-1, 256, 14, 14]	0
Conv2d-89	[-1, 256, 14, 14]	589,824
BatchNorm2d-90	[-1, 256, 14, 14]	512
ReLU-91	[-1, 256, 14, 14]	0
BasicBlock-92	[-1, 256, 14, 14]	0
Conv2d-93	[-1, 256, 14, 14]	589,824
BatchNorm2d-94	[-1, 256, 14, 14]	512
ReLU-95	[-1, 256, 14, 14]	0
Conv2d-96	[-1, 256, 14, 14]	589,824
BatchNorm2d-97	[-1, 256, 14, 14]	512
ReLU-98	[-1, 256, 14, 14]	0
BasicBlock-99	[-1, 256, 14, 14]	0
Conv2d-100	[-1, 512, 7, 7]	1,179,648
BatchNorm2d-101	[-1, 512, 7, 7]	1,024
ReLU-102	[-1, 512, 7, 7]	0
Conv2d-103	[-1, 512, 7, 7]	2,359,296
BatchNorm2d-104	[-1, 512, 7, 7]	1,024
Conv2d-105	[-1, 512, 7, 7]	131,072
BatchNorm2d-106	[-1, 512, 7, 7]	1,024
ReLU-107	[-1, 512, 7, 7]	0
BasicBlock-108	[-1, 512, 7, 7]	0
Conv2d-109	[-1, 512, 7, 7]	2,359,296
BatchNorm2d-110	[-1, 512, 7, 7]	1,024
ReLU-111	[-1, 512, 7, 7]	0

```
            Conv2d-112            [-1, 512, 7, 7]       2,359,296
       BatchNorm2d-113            [-1, 512, 7, 7]           1,024
              ReLU-114            [-1, 512, 7, 7]               0
        BasicBlock-115            [-1, 512, 7, 7]               0
            Conv2d-116            [-1, 512, 7, 7]       2,359,296
       BatchNorm2d-117            [-1, 512, 7, 7]           1,024
              ReLU-118            [-1, 512, 7, 7]               0
            Conv2d-119            [-1, 512, 7, 7]       2,359,296
       BatchNorm2d-120            [-1, 512, 7, 7]           1,024
              ReLU-121            [-1, 512, 7, 7]               0
        BasicBlock-122            [-1, 512, 7, 7]               0
        AvgPool2d-123            [-1, 512, 1, 1]               0
           Linear-124                  [-1, 1000]         513,000
================================================================
Total params: 21,797,672
Trainable params: 21,797,672
Non-trainable params: 0
----------------------------------------------------------------
Input size (MB): 0.57
Forward/backward pass size (MB): 96.29
Params size (MB): 83.15
Estimated Total Size (MB): 180.01
----------------------------------------------------------------
```

In [13]:
```
summary(models.resnet50(), input_size = (3, 224, 224))
```

Layer (type)	Output Shape	Param #
Conv2d-1	[-1, 64, 112, 112]	9,408
BatchNorm2d-2	[-1, 64, 112, 112]	128
ReLU-3	[-1, 64, 112, 112]	0
MaxPool2d-4	[-1, 64, 56, 56]	0
Conv2d-5	[-1, 64, 56, 56]	4,096
BatchNorm2d-6	[-1, 64, 56, 56]	128
ReLU-7	[-1, 64, 56, 56]	0
Conv2d-8	[-1, 64, 56, 56]	36,864
BatchNorm2d-9	[-1, 64, 56, 56]	128
ReLU-10	[-1, 64, 56, 56]	0
Conv2d-11	[-1, 256, 56, 56]	16,384
BatchNorm2d-12	[-1, 256, 56, 56]	512
Conv2d-13	[-1, 256, 56, 56]	16,384
BatchNorm2d-14	[-1, 256, 56, 56]	512
ReLU-15	[-1, 256, 56, 56]	0
Bottleneck-16	[-1, 256, 56, 56]	0
Conv2d-17	[-1, 64, 56, 56]	16,384
BatchNorm2d-18	[-1, 64, 56, 56]	128
ReLU-19	[-1, 64, 56, 56]	0
Conv2d-20	[-1, 64, 56, 56]	36,864
BatchNorm2d-21	[-1, 64, 56, 56]	128
ReLU-22	[-1, 64, 56, 56]	0
Conv2d-23	[-1, 256, 56, 56]	16,384
BatchNorm2d-24	[-1, 256, 56, 56]	512
ReLU-25	[-1, 256, 56, 56]	0
Bottleneck-26	[-1, 256, 56, 56]	0
Conv2d-27	[-1, 64, 56, 56]	16,384
BatchNorm2d-28	[-1, 64, 56, 56]	128
ReLU-29	[-1, 64, 56, 56]	0
Conv2d-30	[-1, 64, 56, 56]	36,864
BatchNorm2d-31	[-1, 64, 56, 56]	128
ReLU-32	[-1, 64, 56, 56]	0
Conv2d-33	[-1, 256, 56, 56]	16,384
BatchNorm2d-34	[-1, 256, 56, 56]	512
ReLU-35	[-1, 256, 56, 56]	0
Bottleneck-36	[-1, 256, 56, 56]	0
Conv2d-37	[-1, 128, 56, 56]	32,768
BatchNorm2d-38	[-1, 128, 56, 56]	256
ReLU-39	[-1, 128, 56, 56]	0
Conv2d-40	[-1, 128, 28, 28]	147,456
BatchNorm2d-41	[-1, 128, 28, 28]	256
ReLU-42	[-1, 128, 28, 28]	0
Conv2d-43	[-1, 512, 28, 28]	65,536
BatchNorm2d-44	[-1, 512, 28, 28]	1,024
Conv2d-45	[-1, 512, 28, 28]	131,072
BatchNorm2d-46	[-1, 512, 28, 28]	1,024
ReLU-47	[-1, 512, 28, 28]	0
Bottleneck-48	[-1, 512, 28, 28]	0
Conv2d-49	[-1, 128, 28, 28]	65,536
BatchNorm2d-50	[-1, 128, 28, 28]	256
ReLU-51	[-1, 128, 28, 28]	0
Conv2d-52	[-1, 128, 28, 28]	147,456
BatchNorm2d-53	[-1, 128, 28, 28]	256
ReLU-54	[-1, 128, 28, 28]	0

Conv2d-55	[-1, 512, 28, 28]	65,536
BatchNorm2d-56	[-1, 512, 28, 28]	1,024
ReLU-57	[-1, 512, 28, 28]	0
Bottleneck-58	[-1, 512, 28, 28]	0
Conv2d-59	[-1, 128, 28, 28]	65,536
BatchNorm2d-60	[-1, 128, 28, 28]	256
ReLU-61	[-1, 128, 28, 28]	0
Conv2d-62	[-1, 128, 28, 28]	147,456
BatchNorm2d-63	[-1, 128, 28, 28]	256
ReLU-64	[-1, 128, 28, 28]	0
Conv2d-65	[-1, 512, 28, 28]	65,536
BatchNorm2d-66	[-1, 512, 28, 28]	1,024
ReLU-67	[-1, 512, 28, 28]	0
Bottleneck-68	[-1, 512, 28, 28]	0
Conv2d-69	[-1, 128, 28, 28]	65,536
BatchNorm2d-70	[-1, 128, 28, 28]	256
ReLU-71	[-1, 128, 28, 28]	0
Conv2d-72	[-1, 128, 28, 28]	147,456
BatchNorm2d-73	[-1, 128, 28, 28]	256
ReLU-74	[-1, 128, 28, 28]	0
Conv2d-75	[-1, 512, 28, 28]	65,536
BatchNorm2d-76	[-1, 512, 28, 28]	1,024
ReLU-77	[-1, 512, 28, 28]	0
Bottleneck-78	[-1, 512, 28, 28]	0
Conv2d-79	[-1, 256, 28, 28]	131,072
BatchNorm2d-80	[-1, 256, 28, 28]	512
ReLU-81	[-1, 256, 28, 28]	0
Conv2d-82	[-1, 256, 14, 14]	589,824
BatchNorm2d-83	[-1, 256, 14, 14]	512
ReLU-84	[-1, 256, 14, 14]	0
Conv2d-85	[-1, 1024, 14, 14]	262,144
BatchNorm2d-86	[-1, 1024, 14, 14]	2,048
Conv2d-87	[-1, 1024, 14, 14]	524,288
BatchNorm2d-88	[-1, 1024, 14, 14]	2,048
ReLU-89	[-1, 1024, 14, 14]	0
Bottleneck-90	[-1, 1024, 14, 14]	0
Conv2d-91	[-1, 256, 14, 14]	262,144
BatchNorm2d-92	[-1, 256, 14, 14]	512
ReLU-93	[-1, 256, 14, 14]	0
Conv2d-94	[-1, 256, 14, 14]	589,824
BatchNorm2d-95	[-1, 256, 14, 14]	512
ReLU-96	[-1, 256, 14, 14]	0
Conv2d-97	[-1, 1024, 14, 14]	262,144
BatchNorm2d-98	[-1, 1024, 14, 14]	2,048
ReLU-99	[-1, 1024, 14, 14]	0
Bottleneck-100	[-1, 1024, 14, 14]	0
Conv2d-101	[-1, 256, 14, 14]	262,144
BatchNorm2d-102	[-1, 256, 14, 14]	512
ReLU-103	[-1, 256, 14, 14]	0
Conv2d-104	[-1, 256, 14, 14]	589,824
BatchNorm2d-105	[-1, 256, 14, 14]	512
ReLU-106	[-1, 256, 14, 14]	0
Conv2d-107	[-1, 1024, 14, 14]	262,144
BatchNorm2d-108	[-1, 1024, 14, 14]	2,048
ReLU-109	[-1, 1024, 14, 14]	0
Bottleneck-110	[-1, 1024, 14, 14]	0
Conv2d-111	[-1, 256, 14, 14]	262,144

BatchNorm2d-112	[-1, 256, 14, 14]	512
ReLU-113	[-1, 256, 14, 14]	0
Conv2d-114	[-1, 256, 14, 14]	589,824
BatchNorm2d-115	[-1, 256, 14, 14]	512
ReLU-116	[-1, 256, 14, 14]	0
Conv2d-117	[-1, 1024, 14, 14]	262,144
BatchNorm2d-118	[-1, 1024, 14, 14]	2,048
ReLU-119	[-1, 1024, 14, 14]	0
Bottleneck-120	[-1, 1024, 14, 14]	0
Conv2d-121	[-1, 256, 14, 14]	262,144
BatchNorm2d-122	[-1, 256, 14, 14]	512
ReLU-123	[-1, 256, 14, 14]	0
Conv2d-124	[-1, 256, 14, 14]	589,824
BatchNorm2d-125	[-1, 256, 14, 14]	512
ReLU-126	[-1, 256, 14, 14]	0
Conv2d-127	[-1, 1024, 14, 14]	262,144
BatchNorm2d-128	[-1, 1024, 14, 14]	2,048
ReLU-129	[-1, 1024, 14, 14]	0
Bottleneck-130	[-1, 1024, 14, 14]	0
Conv2d-131	[-1, 256, 14, 14]	262,144
BatchNorm2d-132	[-1, 256, 14, 14]	512
ReLU-133	[-1, 256, 14, 14]	0
Conv2d-134	[-1, 256, 14, 14]	589,824
BatchNorm2d-135	[-1, 256, 14, 14]	512
ReLU-136	[-1, 256, 14, 14]	0
Conv2d-137	[-1, 1024, 14, 14]	262,144
BatchNorm2d-138	[-1, 1024, 14, 14]	2,048
ReLU-139	[-1, 1024, 14, 14]	0
Bottleneck-140	[-1, 1024, 14, 14]	0
Conv2d-141	[-1, 512, 14, 14]	524,288
BatchNorm2d-142	[-1, 512, 14, 14]	1,024
ReLU-143	[-1, 512, 14, 14]	0
Conv2d-144	[-1, 512, 7, 7]	2,359,296
BatchNorm2d-145	[-1, 512, 7, 7]	1,024
ReLU-146	[-1, 512, 7, 7]	0
Conv2d-147	[-1, 2048, 7, 7]	1,048,576
BatchNorm2d-148	[-1, 2048, 7, 7]	4,096
Conv2d-149	[-1, 2048, 7, 7]	2,097,152
BatchNorm2d-150	[-1, 2048, 7, 7]	4,096
ReLU-151	[-1, 2048, 7, 7]	0
Bottleneck-152	[-1, 2048, 7, 7]	0
Conv2d-153	[-1, 512, 7, 7]	1,048,576
BatchNorm2d-154	[-1, 512, 7, 7]	1,024
ReLU-155	[-1, 512, 7, 7]	0
Conv2d-156	[-1, 512, 7, 7]	2,359,296
BatchNorm2d-157	[-1, 512, 7, 7]	1,024
ReLU-158	[-1, 512, 7, 7]	0
Conv2d-159	[-1, 2048, 7, 7]	1,048,576
BatchNorm2d-160	[-1, 2048, 7, 7]	4,096
ReLU-161	[-1, 2048, 7, 7]	0
Bottleneck-162	[-1, 2048, 7, 7]	0
Conv2d-163	[-1, 512, 7, 7]	1,048,576
BatchNorm2d-164	[-1, 512, 7, 7]	1,024
ReLU-165	[-1, 512, 7, 7]	0
Conv2d-166	[-1, 512, 7, 7]	2,359,296
BatchNorm2d-167	[-1, 512, 7, 7]	1,024
ReLU-168	[-1, 512, 7, 7]	0

```
          Conv2d-169           [-1, 2048, 7, 7]       1,048,576
     BatchNorm2d-170           [-1, 2048, 7, 7]           4,096
            ReLU-171           [-1, 2048, 7, 7]               0
      Bottleneck-172           [-1, 2048, 7, 7]               0
       AvgPool2d-173           [-1, 2048, 1, 1]               0
          Linear-174                 [-1, 1000]       2,049,000
================================================================
Total params: 25,557,032
Trainable params: 25,557,032
Non-trainable params: 0
----------------------------------------------------------------
Input size (MB): 0.57
Forward/backward pass size (MB): 286.56
Params size (MB): 97.49
Estimated Total Size (MB): 384.62
----------------------------------------------------------------
```

Answer:

A residual neural network is an artificial neural network that utilizes skip connections or short-cuts to jump over some layers.

The basix motivation for using it-- skipping over layers can avoid the problem of vanishing gradients by reusing activations from a previous layer until the layer next to the current one learns its weights.

The main element of ResNet34 and ResNet50 include convolutional layer, batch normalization layer and maxpooling layer.

According to the summary statistics above--ResNet34 has 124 layers, 21,797,672 weights. ResNet50 has 174 layers, 25,557,032 weights.

Number of neurons is calculated by multiplying the last two number in output shape. Ex., output shape is [-1, 512, 7, 7] , number of neurons is 7 x 7 = 49.

Problem 5

1. Transfer learning using Fast.ai and create cnn: Please explain how pretrained resnet34 is modified to get the network that the notebook ultimately trains (i.e., explain what are the last layers that are added).

Answer:

Using pretrained ResNet34 means that only the top layers (a.k.a fully connected layers) are trained while the bottom layers are freezed during the training process. Pretrained ResNet34 reuses the weights of a network already trained on the ImageNet dataset to train a new model more quickly. The pre-trained weights trained by ImageNet are good enough to capture the patterns and concepts of the images.

Therefore, when using pre-trained ResNet34 to train new categories, the bottom layers stay unchanged because they represent basic elements in normal images. This makes training a lot easier.

The last layers added are softmax layers, the final output layers that perform multi-class classification, using softmax function to calculate the posterior probability.

Problem 6

1. Download a NOT pre-trained resnet34, and then by playing with the number of epochs and learning rates (possibly different learning rates across layers), see how low you can get the error. Can you get below 20%?

In [34]:
```
learn10 = create_cnn(data, models.resnet34, metrics=error_rate, pretrain
ed=False)
learn10.fit_one_cycle(80)
```

Total time: 25:54

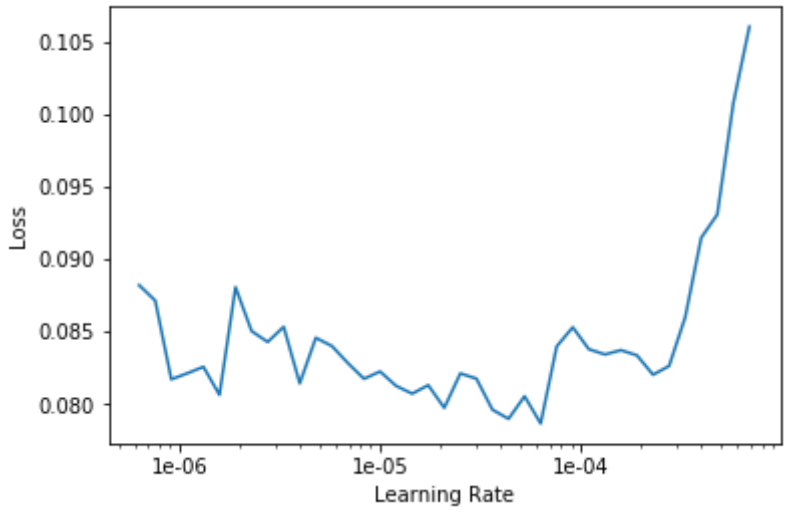
epoch	train_loss	valid_loss	error_rate
1	4.056545	3.630543	0.952528
2	3.973528	3.568042	0.942208
3	3.886120	3.494400	0.919505
4	3.827003	3.467771	0.931889
5	3.764698	3.411618	0.914345
6	3.684624	3.364495	0.913313
7	3.633096	3.325620	0.898865
8	3.570601	3.275699	0.878225
9	3.500774	3.221737	0.857585
10	3.440326	3.159937	0.853457
11	3.322066	3.173569	0.872033
12	3.256376	3.007703	0.839009
13	3.172946	2.943367	0.809082
14	3.042713	2.932861	0.808050
15	2.952368	3.646343	0.858617
16	2.821288	2.713745	0.769866
17	2.713567	2.683564	0.762642
18	2.649132	3.193289	0.793602
19	2.509062	3.417436	0.793602
20	2.409271	2.664897	0.729618
21	2.350594	3.324619	0.797730
22	2.245717	2.941207	0.782250
23	2.123869	2.346397	0.640867
24	2.015064	2.137753	0.638803
25	1.909992	2.172231	0.635707
26	1.788359	2.796607	0.749226
27	1.693725	2.155843	0.625387
28	1.603373	1.864032	0.547988
29	1.493444	1.783323	0.499484
30	1.391592	1.649185	0.487100
31	1.333886	1.911506	0.539732

32	1.242301	2.422167	0.624355
33	1.171661	1.837347	0.526316
34	1.111735	1.688485	0.472652
35	1.080447	2.169622	0.574819
36	1.010138	1.539629	0.450980
37	0.968046	2.075136	0.524252
38	0.952255	1.610554	0.457172
39	0.883863	1.694439	0.435501
40	0.834345	1.468765	0.423117
41	0.786808	1.519712	0.410733
42	0.719176	1.611195	0.413829
43	0.683608	1.296435	0.344685
44	0.636078	1.514351	0.406605
45	0.614833	1.669127	0.430341
46	0.570265	1.257626	0.345717
47	0.532046	1.342686	0.372549
48	0.512615	1.355319	0.347781
49	0.466091	1.445621	0.357069
50	0.438318	1.470576	0.373581
51	0.414701	1.188639	0.311662
52	0.387296	1.341196	0.330237
53	0.376872	1.432254	0.344685
54	0.356549	1.311961	0.320949
55	0.303543	1.322648	0.331269
56	0.294804	1.356344	0.338493
57	0.286384	1.304062	0.329205
58	0.256464	1.116014	0.289990
59	0.236284	1.148087	0.281734
60	0.234216	1.215144	0.295150
61	0.212737	1.163136	0.287926
62	0.183069	1.185906	0.294118
63	0.180596	1.171786	0.291022
64	0.173563	1.189398	0.281734

65	0.150998	1.196216	0.283798
66	0.145589	1.145611	0.272446
67	0.128590	1.120918	0.274510
68	0.120511	1.111596	0.257998
69	0.111083	1.120328	0.264190
70	0.105663	1.118477	0.257998
71	0.101440	1.080247	0.250774
72	0.097934	1.098420	0.262126
73	0.100307	1.107517	0.259030
74	0.097187	1.103087	0.262126
75	0.090620	1.089937	0.256966
76	0.084463	1.088481	0.252838
77	0.085628	1.092262	0.259030
78	0.091057	1.086617	0.259030
79	0.084496	1.083575	0.255934
80	0.080733	1.086958	0.253870

In [35]:
```
learn10.lr_find()
learn10.recorder.plot()
```

```
LR Finder is complete, type {learner_name}.recorder.plot() to see the g
raph.
```



In [36]:
```
learn10.unfreeze()
learn10.fit_one_cycle(10, max_lr=slice(1e-5,1e-4))
```

Total time: 03:13

epoch	train_loss	valid_loss	error_rate
1	0.089600	1.081636	0.256966
2	0.084913	1.082306	0.253870
3	0.079089	1.094282	0.251806
4	0.087491	1.086579	0.249742
5	0.088503	1.126861	0.259030
6	0.087549	1.087911	0.250774
7	0.087181	1.081520	0.256966
8	0.070337	1.075405	0.247678
9	0.074320	1.069876	0.246646
10	0.072498	1.079156	0.251806

I have tried over 10 times playing with different number of epochs and different learning rates. The error rate varies from 0.23 to 0.25 time to time.

Problem 7 Build a classifier

I used google-image-download to create a dataset including 7 artists' paintings (around 100 paintings per artists including Cezanne, Dali, Durer, Monet, Picasso, Rembrandt and Van Gogh).

I ran the following commands in virtual terminal.

In [14]:
```
#googleimagesdownload -k "van gogh painting" -l 100
#googleimagesdownload -k "monet" -l 100
#googleimagesdownload -k "Durer" -l 100
#googleimagesdownload -k "Dali" -l 100
#googleimagesdownload -k "Cezanne" -l 100
#googleimagesdownload -k "Picasso" -l 100
#googleimagesdownload -k "Rembrandt" -l 100
```

In [4]:
```
import os
import re
```

I renamed every image to include artists' names.

In [13]:
```
path_read = '/notebooks/downloads/van gogh/'
files = os. listdir(path_read)
cursor = 1
for pic in files:
    os.rename(path_read + pic, path_read + 'vangogh' + str(cursor) + '.j
pg')
    cursor += 1
```

In [258]:
```
path_read2 = '/notebooks/downloads/Dali/'
files2 = os. listdir(path_read2)
cursor2 = 1
for pic in files2:
    os.rename(path_read2 + pic, path_read2 + 'dali' + str(cursor2) + '.j
pg')
    cursor2 += 1
```

In [259]:
```
path_read3 = '/notebooks/downloads/Cezanne/'
files3 = os. listdir(path_read3)
cursor3 = 1
for pic in files3:
    os.rename(path_read3 + pic, path_read3 + 'cezanne' + str(cursor3) +
'.jpg')
    cursor3 += 1
```

In [113]:
```
path_read = '/notebooks/downloads/paintings/Durer/'
files = os. listdir(path_read)
cursor = 1
for pic in files:
    os.rename(path_read + pic, path_read + 'durer' + str(cursor) + '.jp
g')
    cursor += 1
```

In [21]:
```
path_read = '/notebooks/downloads/monet/'
files = os. listdir(path_read)
cursor = 1
for pic in files:
    suffix = re.search(r'\.[a-z]+', pic).group()
    os.rename(path_read + pic, path_read + 'monet' + str(cursor) + suffi
x)
    cursor += 1
```

In [115]:
```
path_read = '/notebooks/downloads/paintings/Picasso/'
files = os. listdir(path_read)
cursor = 1
for pic in files:
    os.rename(path_read + pic, path_read + 'picasso' + str(cursor) + '.j
pg')
    cursor += 1
```

In [116]:
```
path_read = '/notebooks/downloads/paintings/Rembrandt/'
files = os. listdir(path_read)
cursor = 1
for pic in files:
    os.rename(path_read + pic, path_read + 'rembrandt' + str(cursor) +
'.jpg')
    cursor += 1
```

Then I used a for-loop to read 7 folders of images.

In [49]:
```
path_img = '/notebooks/downloads/classifier/'
files2 = os.listdir(path_img)
fnames = []
for file in files2:
    fnames = fnames + get_image_files(path_img + file)
len(fnames)
```

Out[49]:
```
645
```

In [23]:
```
fnames[:5]
```

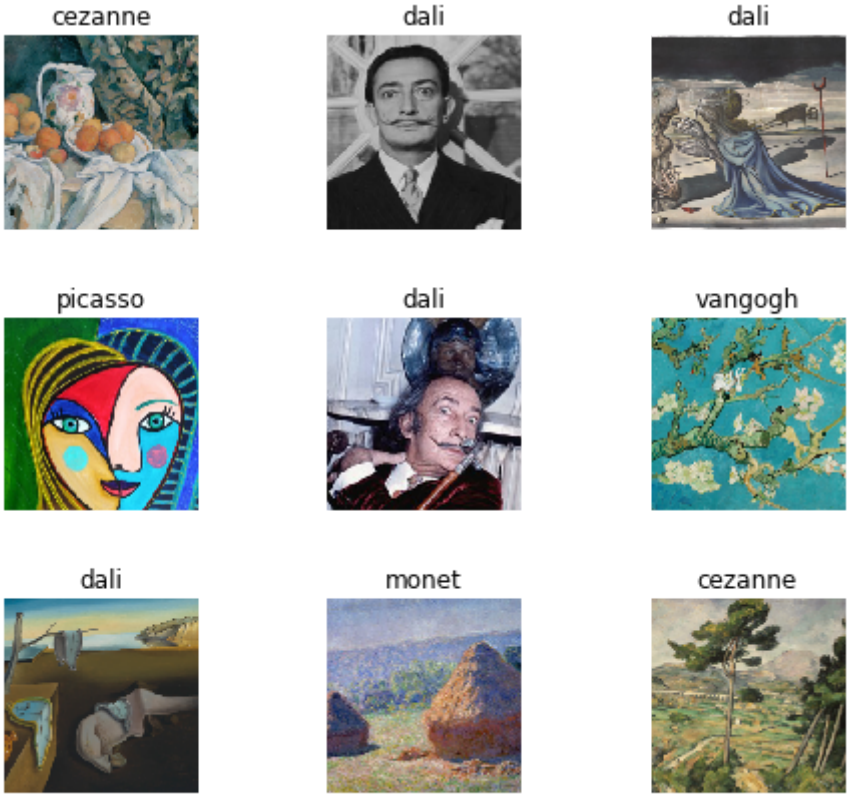
Out[23]:
```
[PosixPath('/notebooks/downloads/classifier/Picasso/picasso56.jpg'),
 PosixPath('/notebooks/downloads/classifier/Picasso/picasso93.jpg'),
 PosixPath('/notebooks/downloads/classifier/Picasso/picasso64.jpg'),
 PosixPath('/notebooks/downloads/classifier/Picasso/picasso20.jpg'),
 PosixPath('/notebooks/downloads/classifier/Picasso/picasso60.jpg')]
```

In [24]:
```
np.random.seed(2)
pat = re.compile(r'/([A-Za-z]+)\d+')
```

In [50]:
```
data = ImageDataBunch.from_name_re(path_img, fnames, pat, ds_tfms=get_tr
ansforms(), size=224, bs=bs
                                   ).normalize(imagenet_stats)
```

In [26]:
```
data.show_batch(rows=3, figsize=(7,6))
```

```
/opt/conda/envs/fastai/lib/python3.6/site-packages/PIL/Image.py:2600: D
ecompressionBombWarning: Image size (101352316 pixels) exceeds limit of
89478485 pixels, could be decompression bomb DOS attack.
  DecompressionBombWarning)
```



In [27]:
```
print(data.classes)
len(data.classes),data.c
```

```
['cezanne', 'dali', 'durer', 'monet', 'picasso', 'rembrandt', 'vangog
h']
```

Out[27]: (7, 7)

Training: resnet34

In [51]:
```
learn = create_cnn(data, models.resnet34, metrics=error_rate)
```

In [29]:
```
learn.model
```

```
Out[29]: Sequential(
           (0): Sequential(
             (0): Conv2d(3, 64, kernel_size=(7, 7), stride=(2, 2), padding=(3,
         3), bias=False)
             (1): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, track_ru
         nning_stats=True)
             (2): ReLU(inplace)
             (3): MaxPool2d(kernel_size=3, stride=2, padding=1, dilation=1, ceil
         _mode=False)
             (4): Sequential(
               (0): BasicBlock(
                 (conv1): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padd
         ing=(1, 1), bias=False)
                 (bn1): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, tr
         ack_running_stats=True)
                 (relu): ReLU(inplace)
                 (conv2): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padd
         ing=(1, 1), bias=False)
                 (bn2): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, tr
         ack_running_stats=True)
               )
               (1): BasicBlock(
                 (conv1): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padd
         ing=(1, 1), bias=False)
                 (bn1): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, tr
         ack_running_stats=True)
                 (relu): ReLU(inplace)
                 (conv2): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padd
         ing=(1, 1), bias=False)
                 (bn2): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, tr
         ack_running_stats=True)
               )
               (2): BasicBlock(
                 (conv1): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padd
         ing=(1, 1), bias=False)
                 (bn1): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, tr
         ack_running_stats=True)
                 (relu): ReLU(inplace)
                 (conv2): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padd
         ing=(1, 1), bias=False)
                 (bn2): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, tr
         ack_running_stats=True)
               )
             )
             (5): Sequential(
               (0): BasicBlock(
                 (conv1): Conv2d(64, 128, kernel_size=(3, 3), stride=(2, 2), pad
         ding=(1, 1), bias=False)
                 (bn1): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, t
         rack_running_stats=True)
                 (relu): ReLU(inplace)
                 (conv2): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), pa
         dding=(1, 1), bias=False)
                 (bn2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, t
         rack_running_stats=True)
                 (downsample): Sequential(
                   (0): Conv2d(64, 128, kernel_size=(1, 1), stride=(2, 2), bias=
```

```
False)
          (1): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, t
rack_running_stats=True)
        )
      )
      (1): BasicBlock(
        (conv1): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), pa
dding=(1, 1), bias=False)
        (bn1): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, t
rack_running_stats=True)
        (relu): ReLU(inplace)
        (conv2): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), pa
dding=(1, 1), bias=False)
        (bn2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, t
rack_running_stats=True)
      )
      (2): BasicBlock(
        (conv1): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), pa
dding=(1, 1), bias=False)
        (bn1): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, t
rack_running_stats=True)
        (relu): ReLU(inplace)
        (conv2): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), pa
dding=(1, 1), bias=False)
        (bn2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, t
rack_running_stats=True)
      )
      (3): BasicBlock(
        (conv1): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), pa
dding=(1, 1), bias=False)
        (bn1): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, t
rack_running_stats=True)
        (relu): ReLU(inplace)
        (conv2): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), pa
dding=(1, 1), bias=False)
        (bn2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, t
rack_running_stats=True)
      )
    )
    (6): Sequential(
      (0): BasicBlock(
        (conv1): Conv2d(128, 256, kernel_size=(3, 3), stride=(2, 2), pa
dding=(1, 1), bias=False)
        (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, t
rack_running_stats=True)
        (relu): ReLU(inplace)
        (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), pa
dding=(1, 1), bias=False)
        (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, t
rack_running_stats=True)
        (downsample): Sequential(
          (0): Conv2d(128, 256, kernel_size=(1, 1), stride=(2, 2), bias
=False)
          (1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, t
rack_running_stats=True)
        )
      )
```

```
      (1): BasicBlock(
        (conv1): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), pa
dding=(1, 1), bias=False)
        (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, t
rack_running_stats=True)
        (relu): ReLU(inplace)
        (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), pa
dding=(1, 1), bias=False)
        (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, t
rack_running_stats=True)
      )
      (2): BasicBlock(
        (conv1): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), pa
dding=(1, 1), bias=False)
        (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, t
rack_running_stats=True)
        (relu): ReLU(inplace)
        (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), pa
dding=(1, 1), bias=False)
        (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, t
rack_running_stats=True)
      )
      (3): BasicBlock(
        (conv1): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), pa
dding=(1, 1), bias=False)
        (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, t
rack_running_stats=True)
        (relu): ReLU(inplace)
        (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), pa
dding=(1, 1), bias=False)
        (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, t
rack_running_stats=True)
      )
      (4): BasicBlock(
        (conv1): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), pa
dding=(1, 1), bias=False)
        (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, t
rack_running_stats=True)
        (relu): ReLU(inplace)
        (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), pa
dding=(1, 1), bias=False)
        (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, t
rack_running_stats=True)
      )
      (5): BasicBlock(
        (conv1): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), pa
dding=(1, 1), bias=False)
        (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, t
rack_running_stats=True)
        (relu): ReLU(inplace)
        (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), pa
dding=(1, 1), bias=False)
        (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, t
rack_running_stats=True)
      )
    )
    (7): Sequential(
```

```
      (0): BasicBlock(
        (conv1): Conv2d(256, 512, kernel_size=(3, 3), stride=(2, 2), pa
dding=(1, 1), bias=False)
        (bn1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, t
rack_running_stats=True)
        (relu): ReLU(inplace)
        (conv2): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), pa
dding=(1, 1), bias=False)
        (bn2): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, t
rack_running_stats=True)
        (downsample): Sequential(
          (0): Conv2d(256, 512, kernel_size=(1, 1), stride=(2, 2), bias
=False)
          (1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, t
rack_running_stats=True)
        )
      )
      (1): BasicBlock(
        (conv1): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), pa
dding=(1, 1), bias=False)
        (bn1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, t
rack_running_stats=True)
        (relu): ReLU(inplace)
        (conv2): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), pa
dding=(1, 1), bias=False)
        (bn2): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, t
rack_running_stats=True)
      )
      (2): BasicBlock(
        (conv1): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), pa
dding=(1, 1), bias=False)
        (bn1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, t
rack_running_stats=True)
        (relu): ReLU(inplace)
        (conv2): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), pa
dding=(1, 1), bias=False)
        (bn2): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, t
rack_running_stats=True)
      )
    )
  )
  (1): Sequential(
    (0): AdaptiveConcatPool2d(
      (ap): AdaptiveAvgPool2d(output_size=1)
      (mp): AdaptiveMaxPool2d(output_size=1)
    )
    (1): Flatten()
    (2): BatchNorm1d(1024, eps=1e-05, momentum=0.1, affine=True, track_
running_stats=True)
    (3): Dropout(p=0.25)
    (4): Linear(in_features=1024, out_features=512, bias=True)
    (5): ReLU(inplace)
    (6): BatchNorm1d(512, eps=1e-05, momentum=0.1, affine=True, track_r
unning_stats=True)
    (7): Dropout(p=0.5)
    (8): Linear(in_features=512, out_features=7, bias=True)
```

```
        )
    )
```

In [52]:
```
learn.fit_one_cycle(4)
```

Total time: 01:29

epoch	train_loss	valid_loss	error_rate
1	2.136025	1.116152	0.348837
2	1.367974	0.529772	0.170543
3	0.996522	0.411708	0.100775
4	0.793505	0.404235	0.124031

```
/opt/conda/envs/fastai/lib/python3.6/site-packages/PIL/Image.py:2600: D
ecompressionBombWarning: Image size (101352316 pixels) exceeds limit of
89478485 pixels, could be decompression bomb DOS attack.
  DecompressionBombWarning)
/opt/conda/envs/fastai/lib/python3.6/site-packages/PIL/Image.py:2600: D
ecompressionBombWarning: Image size (163328704 pixels) exceeds limit of
89478485 pixels, could be decompression bomb DOS attack.
  DecompressionBombWarning)
Exception ignored in: <bound method _DataLoaderIter.__del__ of <torch.u
tils.data.dataloader._DataLoaderIter object at 0x7fe777873b38>>
Exception ignored in: <bound method _DataLoaderIter.__del__ of <torch.u
tils.data.dataloader._DataLoaderIter object at 0x7fe777873b38>>
Traceback (most recent call last):
Traceback (most recent call last):
  File "/opt/conda/envs/fastai/lib/python3.6/site-packages/torch/utils/
data/dataloader.py", line 717, in __del__
  File "/opt/conda/envs/fastai/lib/python3.6/site-packages/torch/utils/
data/dataloader.py", line 717, in __del__
    self._shutdown_workers()
    self._shutdown_workers()
  File "/opt/conda/envs/fastai/lib/python3.6/site-packages/torch/utils/
data/dataloader.py", line 713, in _shutdown_workers
  File "/opt/conda/envs/fastai/lib/python3.6/site-packages/torch/utils/
data/dataloader.py", line 713, in _shutdown_workers
    w.join()
  File "/opt/conda/envs/fastai/lib/python3.6/multiprocessing/process.p
y", line 122, in join
    w.join()
    assert self._parent_pid == os.getpid(), 'can only join a child proc
ess'
  File "/opt/conda/envs/fastai/lib/python3.6/multiprocessing/process.p
y", line 122, in join
    assert self._parent_pid == os.getpid(), 'can only join a child proc
ess'
AssertionError: can only join a child process
AssertionError: can only join a child process
Exception ignored in: <bound method _DataLoaderIter.__del__ of <torch.u
tils.data.dataloader._DataLoaderIter object at 0x7fe777873b38>>
Traceback (most recent call last):
  File "/opt/conda/envs/fastai/lib/python3.6/site-packages/torch/utils/
data/dataloader.py", line 717, in __del__
    self._shutdown_workers()
  File "/opt/conda/envs/fastai/lib/python3.6/site-packages/torch/utils/
data/dataloader.py", line 713, in _shutdown_workers
    w.join()
  File "/opt/conda/envs/fastai/lib/python3.6/multiprocessing/process.p
y", line 122, in join
    assert self._parent_pid == os.getpid(), 'can only join a child proc
ess'
AssertionError: can only join a child process
Exception ignored in: <bound method _DataLoaderIter.__del__ of <torch.u
tils.data.dataloader._DataLoaderIter object at 0x7fe777873b38>>
Traceback (most recent call last):
  File "/opt/conda/envs/fastai/lib/python3.6/site-packages/torch/utils/
data/dataloader.py", line 717, in __del__
    self._shutdown_workers()
  File "/opt/conda/envs/fastai/lib/python3.6/site-packages/torch/utils/
```

```
data/dataloader.py", line 713, in _shutdown_workers
    w.join()
  File "/opt/conda/envs/fastai/lib/python3.6/multiprocessing/process.p
y", line 122, in join
    assert self._parent_pid == os.getpid(), 'can only join a child proc
ess'
AssertionError: can only join a child process
Exception ignored in: <bound method _DataLoaderIter.__del__ of <torch.u
tils.data.dataloader._DataLoaderIter object at 0x7fe777873b38>>
Traceback (most recent call last):
  File "/opt/conda/envs/fastai/lib/python3.6/site-packages/torch/utils/
data/dataloader.py", line 717, in __del__
    self._shutdown_workers()
  File "/opt/conda/envs/fastai/lib/python3.6/site-packages/torch/utils/
data/dataloader.py", line 713, in _shutdown_workers
    w.join()
  File "/opt/conda/envs/fastai/lib/python3.6/multiprocessing/process.p
y", line 122, in join
    assert self._parent_pid == os.getpid(), 'can only join a child proc
ess'
AssertionError: can only join a child process
Exception ignored in: <bound method _DataLoaderIter.__del__ of <torch.u
tils.data.dataloader._DataLoaderIter object at 0x7fe777873b38>>
Traceback (most recent call last):
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AssertionError: can only join a child process
Exception ignored in: <bound method _DataLoaderIter.__del__ of <torch.u
tils.data.dataloader._DataLoaderIter object at 0x7fe777873b38>>
Traceback (most recent call last):
  File "/opt/conda/envs/fastai/lib/python3.6/site-packages/torch/utils/
data/dataloader.py", line 717, in __del__
    self._shutdown_workers()
  File "/opt/conda/envs/fastai/lib/python3.6/site-packages/torch/utils/
data/dataloader.py", line 713, in _shutdown_workers
    w.join()
  File "/opt/conda/envs/fastai/lib/python3.6/multiprocessing/process.p
y", line 122, in join
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data/dataloader.py", line 713, in _shutdown_workers
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```

```
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    w.join()
  File "/opt/conda/envs/fastai/lib/python3.6/multiprocessing/process.p
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    assert self._parent_pid == os.getpid(), 'can only join a child proc
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AssertionError: can only join a child process
Exception ignored in: <bound method _DataLoaderIter.__del__ of <torch.u
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    self._shutdown_workers()
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data/dataloader.py", line 713, in _shutdown_workers
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  File "/opt/conda/envs/fastai/lib/python3.6/multiprocessing/process.p
y", line 122, in join
    assert self._parent_pid == os.getpid(), 'can only join a child proc
ess'
AssertionError: can only join a child process
```

In [54]:
```
learn.save('stage-1')
```

Results

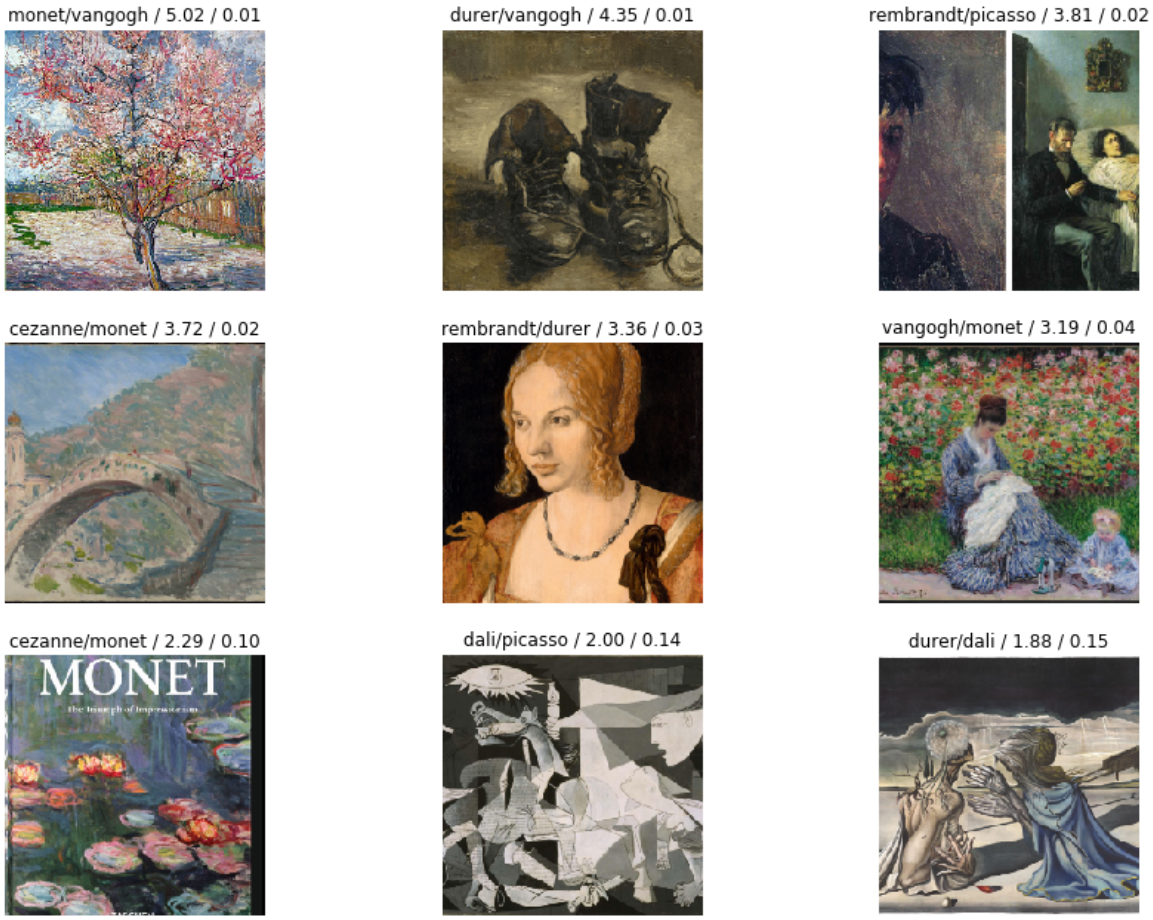
In [56]:
```
interp = ClassificationInterpretation.from_learner(learn)

losses,idxs = interp.top_losses()

len(data.valid_ds)==len(losses)==len(idxs)
```

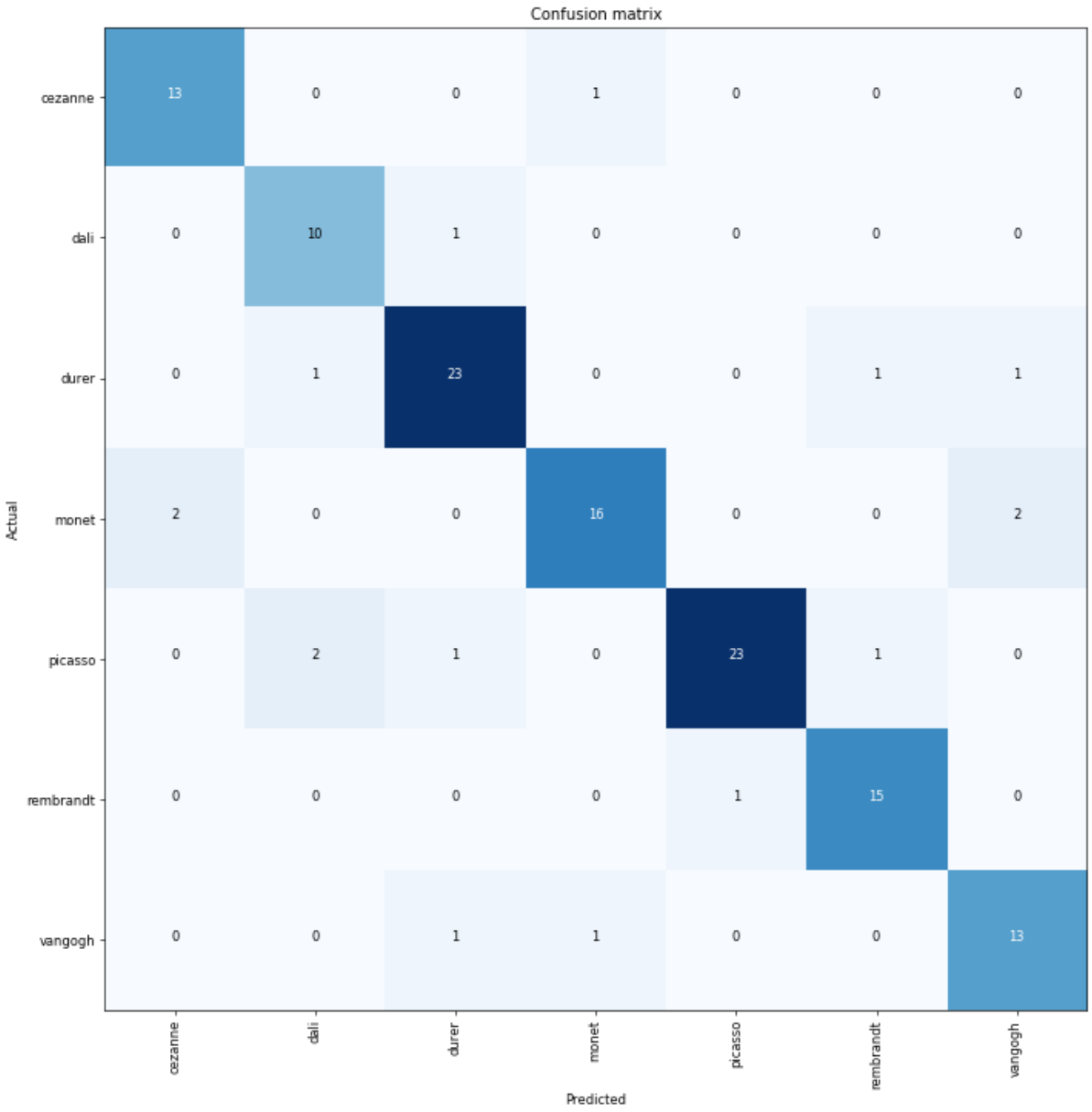
Out[56]: True

In [85]:
```
interp.plot_top_losses(9, figsize=(15,11))
```



In [82]:
```
doc(interp.plot_top_losses)
```

In [83]:
```
interp.plot_confusion_matrix(figsize=(12,12), dpi=60)
```



In [87]:
```
interp.most_confused()
```

Out[87]:
```
[('monet', 'cezanne', 2), ('monet', 'vangogh', 2), ('picasso', 'dali',
2)]
```

Unfreezing, fine-tuning, and learning rates

In [88]:
```
learn.unfreeze()
```

In [89]:
```
learn.fit_one_cycle(1)
```

Total time: 00:29

epoch	train_loss	valid_loss	error_rate
1	0.394682	0.562551	0.170543

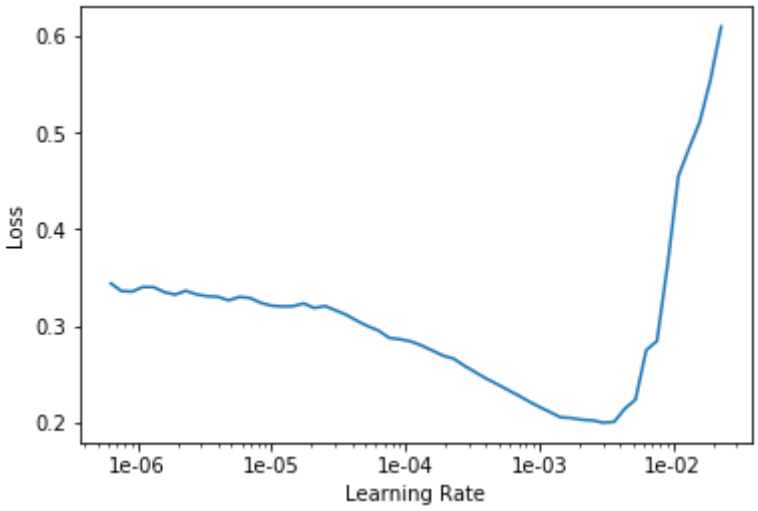
```
/opt/conda/envs/fastai/lib/python3.6/site-packages/PIL/Image.py:2600: D
ecompressionBombWarning: Image size (163328704 pixels) exceeds limit of
89478485 pixels, could be decompression bomb DOS attack.
  DecompressionBombWarning)
/opt/conda/envs/fastai/lib/python3.6/site-packages/PIL/Image.py:2600: D
ecompressionBombWarning: Image size (101352316 pixels) exceeds limit of
89478485 pixels, could be decompression bomb DOS attack.
  DecompressionBombWarning)
```

In [90]:
```
learn.load('stage-1');
```

In [91]:
```
learn.lr_find()
```

```
LR Finder is complete, type {learner_name}.recorder.plot() to see the g
raph.
```

In [92]:
```
learn.recorder.plot()
```



In [113]:
```
learn.unfreeze()
learn.fit_one_cycle(5, max_lr=slice(1e-4,1e-3))
```

Total time: 02:09

epoch	train_loss	valid_loss	error_rate
1	0.100504	0.370431	0.077519
2	0.134235	0.460950	0.131783
3	0.176719	0.468623	0.147287
4	0.187360	0.372870	0.093023
5	0.151633	0.302346	0.077519

```
/opt/conda/envs/fastai/lib/python3.6/site-packages/PIL/Image.py:2600: D
ecompressionBombWarning: Image size (101352316 pixels) exceeds limit of
89478485 pixels, could be decompression bomb DOS attack.
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ecompressionBombWarning: Image size (163328704 pixels) exceeds limit of
89478485 pixels, could be decompression bomb DOS attack.
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/opt/conda/envs/fastai/lib/python3.6/site-packages/PIL/Image.py:2600: D
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/opt/conda/envs/fastai/lib/python3.6/site-packages/PIL/Image.py:2600: D
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ecompressionBombWarning: Image size (163328704 pixels) exceeds limit of
89478485 pixels, could be decompression bomb DOS attack.
  DecompressionBombWarning)
```

The model is pretty accurate!

Training: resnet50

In [106]:
```
data = ImageDataBunch.from_name_re(path_img, fnames, pat, ds_tfms=get_transforms(),
                                   size=299, bs=bs//2).normalize(imagenet_stats)
```

In [107]:
```
learn = create_cnn(data, models.resnet50, metrics=error_rate)
```

```
Downloading: "https://download.pytorch.org/models/resnet50-19c8e357.pth" to /root/.torch/models/resnet50-19c8e357.pth
100%|██████████| 102502400/102502400 [00:02<00:00, 48684508.67it/s]
```

In [109]:
```
learn.fit_one_cycle(8)
```

Total time: 03:18

epoch	train_loss	valid_loss	error_rate
1	1.530996	0.611331	0.193798
2	0.891055	0.356511	0.124031
3	0.610084	0.302471	0.085271
4	0.446745	0.295163	0.085271
5	0.339774	0.270981	0.085271
6	0.266592	0.269017	0.085271
7	0.207799	0.262172	0.069767
8	0.170429	0.272044	0.069767

```
/opt/conda/envs/fastai/lib/python3.6/site-packages/PIL/Image.py:2600: D
ecompressionBombWarning: Image size (101352316 pixels) exceeds limit of
89478485 pixels, could be decompression bomb DOS attack.
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  DecompressionBombWarning)
/opt/conda/envs/fastai/lib/python3.6/site-packages/PIL/Image.py:2600: D
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/opt/conda/envs/fastai/lib/python3.6/site-packages/PIL/Image.py:2600: D
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/opt/conda/envs/fastai/lib/python3.6/site-packages/PIL/Image.py:2600: D
```

```
ecompressionBombWarning: Image size (101352316 pixels) exceeds limit of
89478485 pixels, could be decompression bomb DOS attack.
  DecompressionBombWarning)
/opt/conda/envs/fastai/lib/python3.6/site-packages/PIL/Image.py:2600: D
ecompressionBombWarning: Image size (163328704 pixels) exceeds limit of
89478485 pixels, could be decompression bomb DOS attack.
  DecompressionBombWarning)
```

It gets even more accurate using ResNet50!

In [112]:
```
learn.save('stage-1-50')
```

In [114]:
```
interp = ClassificationInterpretation.from_learner(learn)
```

In [116]:
```
interp.most_confused()
```

Out[116]:
```
[('cezanne', 'picasso', 2)]
```

Putting my model into real prediction

In [117]:
```
learn.export()
```

In [118]:
```
defaults.device = torch.device('cpu')
```

In [123]:
```
img = open_image('/notebooks/downloads/''van gogh.jpg')
img
```

Out[123]:

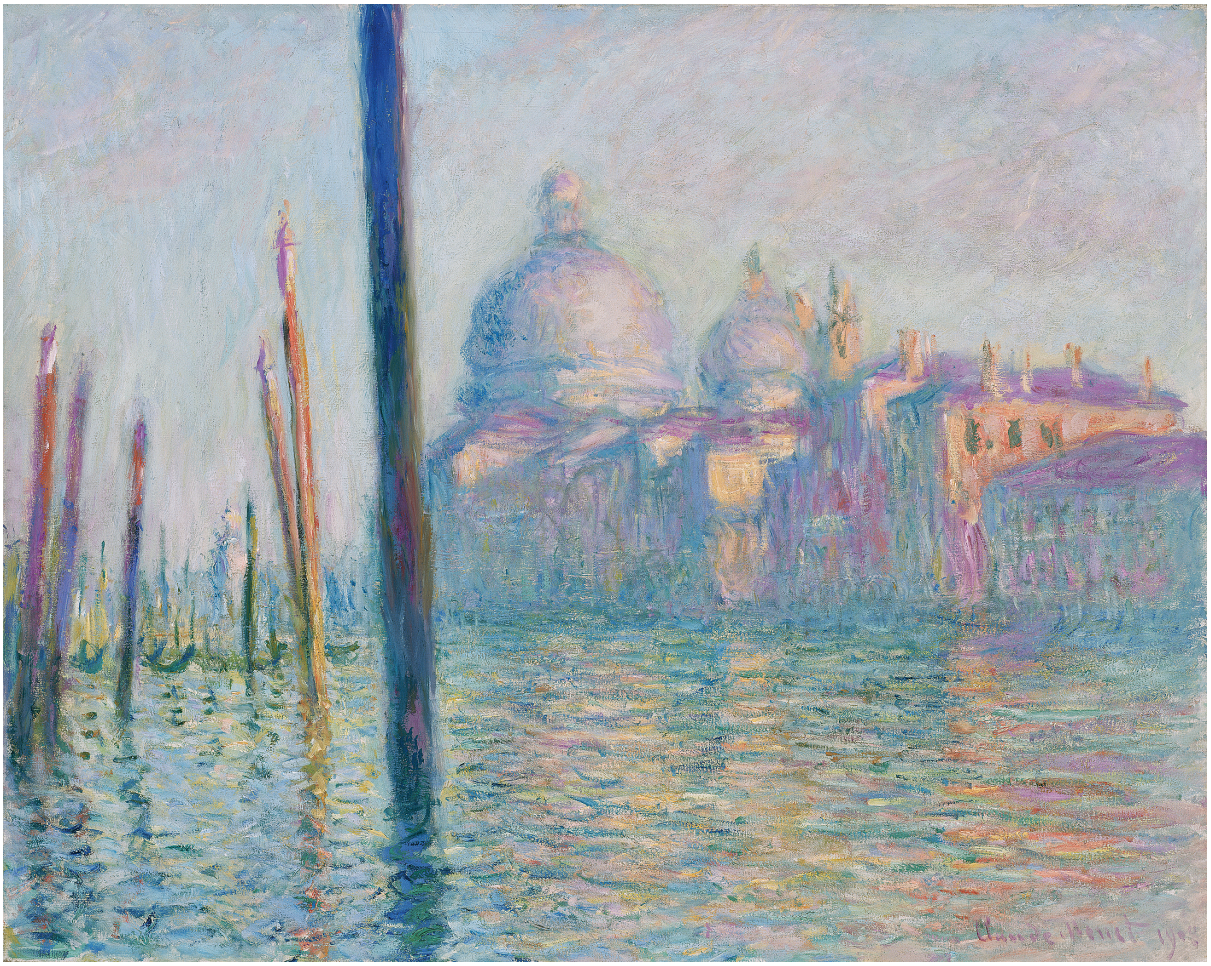
In [133]:
```
path = '/notebooks/downloads/classifier'
learn = load_learner(path)
```

In [134]:
```
pred_class,pred_idx,outputs = learn.predict(img)
pred_class
```

Out[134]: Category vangogh

In [135]:
```
img2 = open_image('/notebooks/downloads/''Claude_Monet,_Le_Grand_Canal.jpg')
img2
```

Out[135]:



In [136]:
```
pred_class,pred_idx,outputs = learn.predict(img2)
pred_class
```

Out[136]: Category monet

In [137]:
```
img3 = open_image('/notebooks/downloads/''01picasso1-articleLarge.jpg')
img3
```

Out[137]:

In [138]:
```
pred_class,pred_idx,outputs = learn.predict(img3)
pred_class
```

Out[138]: Category picasso

The predictions so far are all correct!