# Project: Applying various deep learning models & hyperparameters tuning on CIFAR dataset

### Import packages

Keras and CIFAR dataset

In [ ]:

```
! nvidia-smi -L
```

```
GPU 0: Tesla T4 (UUID: GPU-b1afd126-2ebd-f024-4d5c-967fe687d151)
```

In [1]:

```
import tensorflow as tf
from tensorflow import keras
from keras.callbacks import ModelCheckpoint, EarlyStopping
from keras.layers import BatchNormalization
from keras.preprocessing.image import ImageDataGenerator

import numpy as np
import matplotlib.pyplot as plt
from matplotlib.ticker import MaxNLocator

%matplotlib inline
%config InlineBackend.figure_format = 'retina'
plt.style.use('ggplot')
```

Defining our CIFAR image dimensions with 3 RBG channels, making the overall shape of a image to be 28x28x3

In [2]:

```
img_rows, img_cols, channels = 32, 32, 3
input_shape=(img_rows,img_cols,channels) # shape of input as a tuple

input_shape
```

Out[2]:

```
(32, 32, 3)
```

### Load data

Load the CIFAR 10 dataset from keras built-in datasets

In [3]:

```
(x_train, y_train), (x_test, y_test) = keras.datasets.cifar10.load_data()
```

```
Downloading data from https://www.cs.toronto.edu/~kriz/cifar-10-python.tar.g
z (https://www.cs.toronto.edu/~kriz/cifar-10-python.tar.gz)
170500096/170498071 [==============================] - 4s 0us/step
```

In [4]:

```
print (x_train.shape)
print (y_train.shape)
print (x_test.shape)
print (y_test.shape)
```

```
(50000, 32, 32, 3)
(50000, 1)
(10000, 32, 32, 3)
(10000, 1)
```

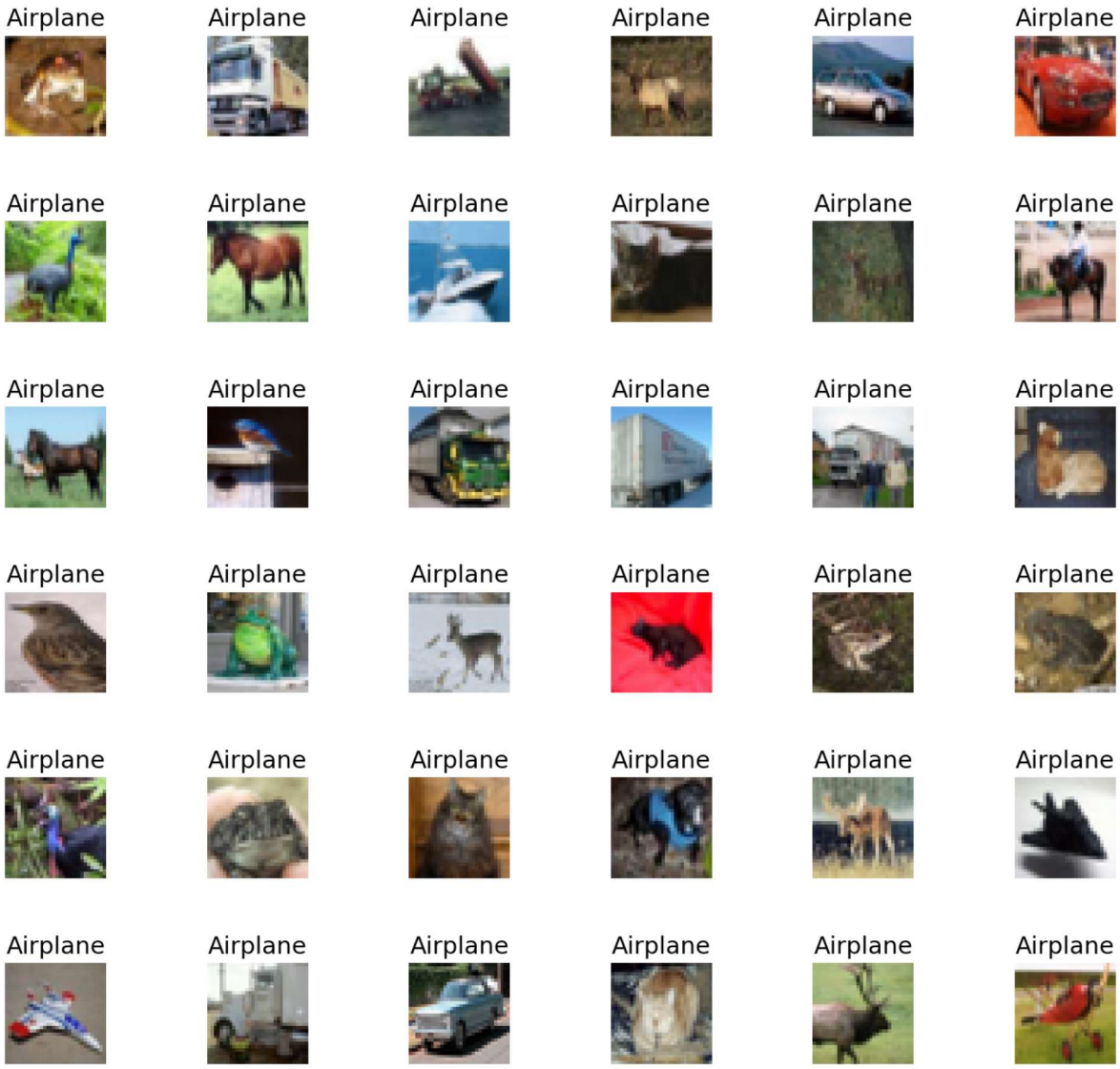
In [5]:

```
# Visualising the dataset

labels = ['Airplane', 'Automobile', 'Bird', 'Cat', 'Deer', 'Dog', 'Frog', 'Horse', 'Ship',

R = 6
C = 6
fig, axes = plt.subplots(R, C, figsize=(12,12))
axes = axes.ravel()
Y_true = np.argmax(y_train, axis=1)

for i in np.arange(0, R*C):
    axes[i].imshow(x_train[i])
    axes[i].set_title(labels[Y_true[i]])
    axes[i].axis('off')
    plt.subplots_adjust(wspace=1)
```




**Data preprocessing**

Normalisation on x dataset and use one-hot encoding on the categorical values in y

In [6]:

```
num_classes = 10

x_train = x_train.astype('float32')
x_test = x_test.astype('float32')

x_train /= 255
x_test /= 255

print('x_train shape:', x_train.shape)
print(x_train.shape[0], 'train samples')
print(x_test.shape[0], 'test samples')

y_train = keras.utils.to_categorical(y_train, num_classes)
y_test = keras.utils.to_categorical(y_test, num_classes)
```

```
x_train shape: (50000, 32, 32, 3)
50000 train samples
10000 test samples
```

## Model 1: Multi-Layer Perceptron

In [20]:

```
model = keras.Sequential()

model.add(keras.layers.Dense(128, activation='relu', input_shape=input_shape))
model.add(BatchNormalization())
model.add(keras.layers.Dropout(0.2))

model.add(keras.layers.Dense(128, activation='relu'))
model.add(BatchNormalization())
model.add(keras.layers.Dropout(0.4))

model.add(tf.keras.layers.Flatten())
model.add(keras.layers.Dense(num_classes, activation='softmax'))
```

In [21]:

```
model.summary()
```

```
Model: "sequential_2"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
dense_6 (Dense)              (None, 32, 32, 128)       512
_________________________________________________________________
batch_normalization_4 (Batch (None, 32, 32, 128)       512
_________________________________________________________________
dropout_4 (Dropout)          (None, 32, 32, 128)       0
_________________________________________________________________
dense_7 (Dense)              (None, 32, 32, 128)       16512
_________________________________________________________________
batch_normalization_5 (Batch (None, 32, 32, 128)       512
_________________________________________________________________
dropout_5 (Dropout)          (None, 32, 32, 128)       0
_________________________________________________________________
flatten_2 (Flatten)          (None, 131072)            0
_________________________________________________________________
dense_8 (Dense)              (None, 10)                1310730
=================================================================
Total params: 1,328,778
Trainable params: 1,328,266
Non-trainable params: 512
_________________________________________________________________
```

In [22]:

```
model.compile(loss='categorical_crossentropy',
              optimizer='adam',
              metrics=['accuracy'])
```

In [23]:

```
batch_size = 100
epochs = 100
```

In [24]:

```
es = EarlyStopping(monitor='val_accuracy', mode='max', min_delta=0.01, patience=5, verbose=

model_log = model.fit(x_train, y_train,
                      batch_size=batch_size,
                      epochs=epochs,
                      validation_split = 0.1,
                      callbacks=[es])
```

```
Epoch 1/100
450/450 [==============================] - 12s 25ms/step - loss: 6.9604 - ac
curacy: 0.3006 - val_loss: 3.5947 - val_accuracy: 0.1716
Epoch 2/100
450/450 [==============================] - 11s 24ms/step - loss: 2.0942 - ac
curacy: 0.3845 - val_loss: 1.5738 - val_accuracy: 0.4508
Epoch 3/100
450/450 [==============================] - 11s 24ms/step - loss: 1.5435 - ac
curacy: 0.4581 - val_loss: 1.4987 - val_accuracy: 0.4858
Epoch 4/100
450/450 [==============================] - 11s 24ms/step - loss: 1.4606 - ac
curacy: 0.4919 - val_loss: 1.4596 - val_accuracy: 0.4954
Epoch 5/100
450/450 [==============================] - 11s 24ms/step - loss: 1.4217 - ac
curacy: 0.5033 - val_loss: 1.4678 - val_accuracy: 0.4828
Epoch 6/100
450/450 [==============================] - 11s 24ms/step - loss: 1.3973 - ac
curacy: 0.5148 - val_loss: 1.4464 - val_accuracy: 0.4970
Epoch 7/100
450/450 [==============================] - 11s 24ms/step - loss: 1.3821 - ac
curacy: 0.5208 - val_loss: 1.4664 - val_accuracy: 0.4874
Epoch 8/100
450/450 [==============================] - 11s 24ms/step - loss: 1.3754 - ac
curacy: 0.5165 - val_loss: 1.4754 - val_accuracy: 0.4894
Epoch 9/100
450/450 [==============================] - 11s 24ms/step - loss: 1.3674 - ac
curacy: 0.5207 - val_loss: 1.5325 - val_accuracy: 0.4742
Epoch 10/100
450/450 [==============================] - 11s 24ms/step - loss: 1.3471 - ac
curacy: 0.5273 - val_loss: 1.4554 - val_accuracy: 0.4902
Epoch 11/100
450/450 [==============================] - 11s 24ms/step - loss: 1.3386 - ac
curacy: 0.5334 - val_loss: 1.4589 - val_accuracy: 0.4840
Restoring model weights from the end of the best epoch.
Epoch 00011: early stopping
```

In [25]:

```
score = model.evaluate(x_test, y_test, verbose=0)
print('Test loss:', score[0])
print('Test accuracy:', score[1])
```

```
Test loss: 1.450524091720581
Test accuracy: 0.49140000343322754
```

In [ ]:

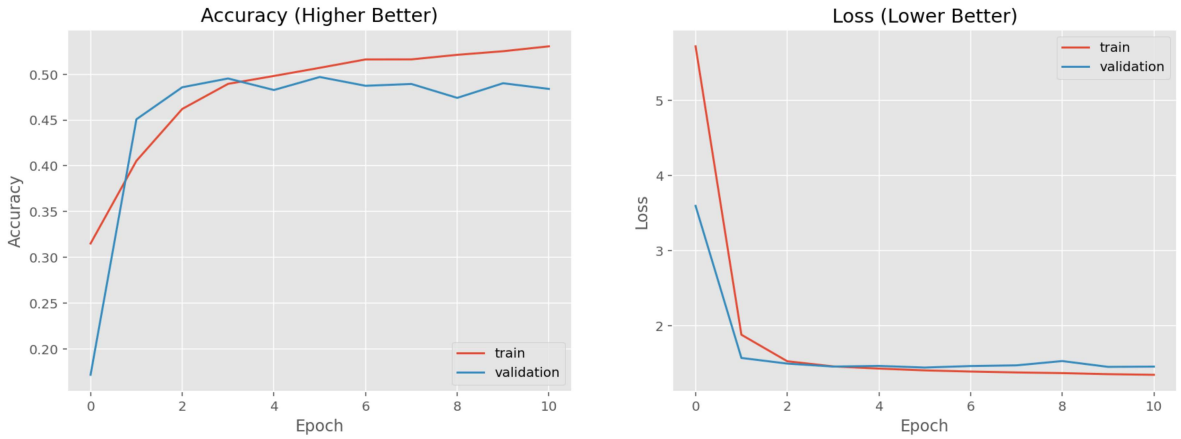
```
model.save("MLPmodel.h5")
```

In [26]:

```
f, (ax1, ax2) = plt.subplots(1, 2,figsize=(15,5))

ax1.plot(model_log.history['accuracy'])
ax1.plot(model_log.history['val_accuracy'])
ax1.set_title('Accuracy (Higher Better)')
ax1.set(xlabel='Epoch', ylabel='Accuracy')
ax1.legend(['train', 'validation'], loc='lower right')

ax2.plot(model_log.history['loss'])
ax2.plot(model_log.history['val_loss'])
ax2.set_title('Loss (Lower Better)')
ax2.set(xlabel='Epoch', ylabel='Loss')
ax2.legend(['train', 'validation'], loc='upper right')
ax2.xaxis.set_major_locator(MaxNLocator(integer=True))
```




## Model 2: Convulational Neural Network with LeNet

In [ ]:

```
# Lenet-5

model = tf.keras.Sequential()

model.add(tf.keras.layers.Conv2D(6, kernel_size=(5,5),
                         strides=(1,1),
                         padding='same',
                         input_shape=input_shape,
                         use_bias=True,
                         kernel_initializer='glorot_uniform',
                         bias_initializer='zeros'))

model.add(tf.keras.layers.Activation('relu'))
model.add(tf.keras.layers.MaxPooling2D(pool_size=(2, 2), strides=(2, 2)))

model.add(tf.keras.layers.Conv2D(16, kernel_size=(5,5),
                         padding='valid'))
model.add(tf.keras.layers.Activation('relu'))
model.add(tf.keras.layers.MaxPooling2D(pool_size=(2, 2), strides=(2, 2)))
model.add(tf.keras.layers.Dropout(0.2))

model.add(tf.keras.layers.Conv2D(120, kernel_size=(5,5),
                 padding='valid'))
model.add(tf.keras.layers.Activation('relu'))
model.add(tf.keras.layers.Dropout(0.4))

model.add(tf.keras.layers.Flatten())
model.add(tf.keras.layers.Dense(84))

model.add(tf.keras.layers.Dense(num_classes))
model.add(tf.keras.layers.Activation('softmax'))
```

In [ ]:

```
model.summary()
```

```
Model: "sequential_1"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d (Conv2D)              (None, 32, 32, 6)         456
_________________________________________________________________
activation (Activation)      (None, 32, 32, 6)         0
_________________________________________________________________
max_pooling2d (MaxPooling2D) (None, 16, 16, 6)         0
_________________________________________________________________
conv2d_1 (Conv2D)            (None, 12, 12, 16)        2416
_________________________________________________________________
activation_1 (Activation)    (None, 12, 12, 16)        0
_________________________________________________________________
max_pooling2d_1 (MaxPooling2 (None, 6, 6, 16)          0
_________________________________________________________________
dropout_2 (Dropout)          (None, 6, 6, 16)          0
_________________________________________________________________
conv2d_2 (Conv2D)            (None, 2, 2, 120)         48120
_________________________________________________________________
activation_2 (Activation)    (None, 2, 2, 120)         0
_________________________________________________________________
dropout_3 (Dropout)          (None, 2, 2, 120)         0
_________________________________________________________________
flatten_1 (Flatten)          (None, 480)               0
_________________________________________________________________
dense_3 (Dense)              (None, 84)                40404
_________________________________________________________________
dense_4 (Dense)              (None, 10)                850
_________________________________________________________________
activation_3 (Activation)    (None, 10)                0
=================================================================
Total params: 92,246
Trainable params: 92,246
Non-trainable params: 0
_________________________________________________________________
```

In [ ]:

```
model.compile(optimizer='adam',
              loss='categorical_crossentropy',
              metrics=['accuracy'])
```

In [ ]:

```
batch_size = 100
num_classes = 10
epochs = 100
```

In [ ]:

```
es = EarlyStopping(monitor='val_accuracy', mode='max', min_delta=0.01, patience=10, verbose

model_log = model.fit(x_train, y_train,
                      batch_size=batch_size,
                      epochs=epochs,
                      validation_split = 0.1,
                      callbacks=[es]
                     )
```

```
Epoch 1/50
450/450 [==============================] - 32s 5ms/step - loss: 1.9666 - a
ccuracy: 0.2709 - val_loss: 1.5181 - val_accuracy: 0.4460
Epoch 2/50
450/450 [==============================] - 2s 4ms/step - loss: 1.5142 - ac
curacy: 0.4530 - val_loss: 1.3070 - val_accuracy: 0.5216
Epoch 3/50
450/450 [==============================] - 2s 4ms/step - loss: 1.3660 - ac
curacy: 0.5120 - val_loss: 1.2481 - val_accuracy: 0.5540
Epoch 4/50
450/450 [==============================] - 2s 5ms/step - loss: 1.3037 - ac
curacy: 0.5308 - val_loss: 1.1796 - val_accuracy: 0.5812
Epoch 5/50
450/450 [==============================] - 2s 4ms/step - loss: 1.2498 - ac
curacy: 0.5549 - val_loss: 1.1560 - val_accuracy: 0.5920
Epoch 6/50
450/450 [==============================] - 2s 4ms/step - loss: 1.1992 - ac
curacy: 0.5710 - val_loss: 1.0993 - val_accuracy: 0.6110
Epoch 7/50
```

In [ ]:

```
score = model.evaluate(x_test, y_test, verbose=0)
print('Test loss:', score[0])
print('Test accuracy:', score[1])
```

```
Test loss: 0.8936426639556885
Test accuracy: 0.6919999718666077
```

In [ ]:

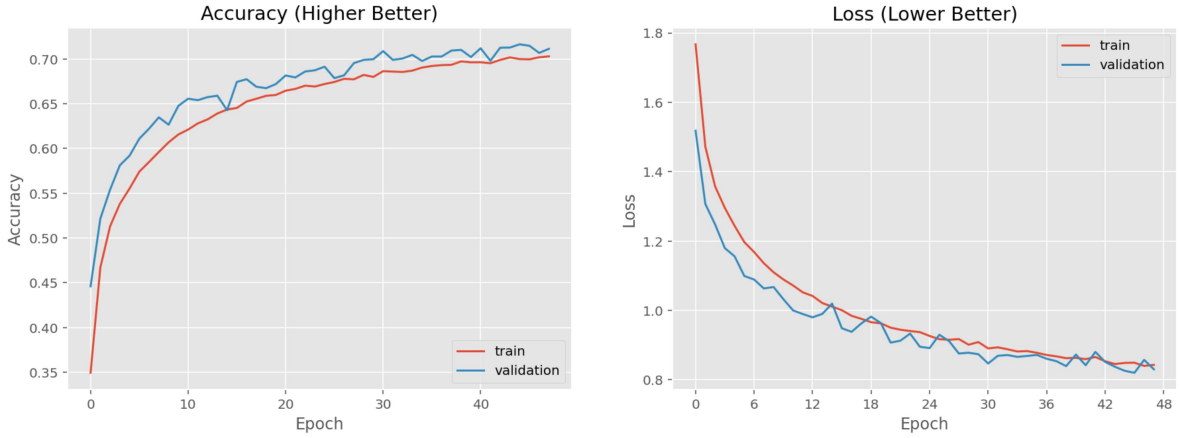
```
model.save("CNNmodel.h5")
```

In [ ]:

```
f, (ax1, ax2) = plt.subplots(1, 2,figsize=(15,5))

ax1.plot(model_log.history['accuracy'])
ax1.plot(model_log.history['val_accuracy'])
ax1.set_title('Accuracy (Higher Better)')
ax1.set(xlabel='Epoch', ylabel='Accuracy')
ax1.legend(['train', 'validation'], loc='lower right')

ax2.plot(model_log.history['loss'])
ax2.plot(model_log.history['val_loss'])
ax2.set_title('Loss (Lower Better)')
ax2.set(xlabel='Epoch', ylabel='Loss')
ax2.legend(['train', 'validation'], loc='upper right')
ax2.xaxis.set_major_locator(MaxNLocator(integer=True))
```




## Model 3: Three-Block VGG Architecture

In [ ]:

```
model = keras.Sequential()

model.add(keras.layers.Conv2D(32, (3,3), activation='relu', input_shape=input_shape, paddin
model.add(BatchNormalization())
model.add(keras.layers.Conv2D(32, (3,3), activation='relu', padding = 'same'))
model.add(BatchNormalization())
model.add(keras.layers.MaxPooling2D((2, 2)))
model.add(keras.layers.Dropout(0.2))

model.add(keras.layers.Conv2D(64, (3, 3), activation='relu',padding='same'))
model.add(BatchNormalization())
model.add(keras.layers.Conv2D(64, (3, 3), activation='relu',padding='same'))
model.add(BatchNormalization())
model.add(keras.layers.MaxPooling2D((2, 2)))
model.add(keras.layers.Dropout(0.4))

model.add(keras.layers.Conv2D(128, (3, 3), activation='relu',padding='same'))
model.add(BatchNormalization())
model.add(keras.layers.Conv2D(128, (3, 3), activation='relu',padding='same'))
model.add(BatchNormalization())
model.add(keras.layers.MaxPooling2D((2, 2)))
model.add(keras.layers.Dropout(0.5))

model.add(keras.layers.Flatten())
model.add(keras.layers.Dense(128, activation='relu'))
model.add(BatchNormalization())
model.add(keras.layers.Dropout(0.5))

model.add(keras.layers.Dense(num_classes, activation='softmax'))
```

In [ ]:

```
model.summary()
```

```
Model: "sequential_10"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_47 (Conv2D)           (None, 32, 32, 32)        896
_________________________________________________________________
batch_normalization_40 (Batc (None, 32, 32, 32)        128
_________________________________________________________________
conv2d_48 (Conv2D)           (None, 32, 32, 32)        9248
_________________________________________________________________
batch_normalization_41 (Batc (None, 32, 32, 32)        128
_________________________________________________________________
max_pooling2d_23 (MaxPooling (None, 16, 16, 32)        0
_________________________________________________________________
dropout_32 (Dropout)         (None, 16, 16, 32)        0
_________________________________________________________________
conv2d_49 (Conv2D)           (None, 16, 16, 64)        18496
_________________________________________________________________
batch_normalization_42 (Batc (None, 16, 16, 64)        256
_________________________________________________________________
conv2d_50 (Conv2D)           (None, 16, 16, 64)        36928
_________________________________________________________________
batch_normalization_43 (Batc (None, 16, 16, 64)        256
_________________________________________________________________
max_pooling2d_24 (MaxPooling (None, 8, 8, 64)          0
_________________________________________________________________
dropout_33 (Dropout)         (None, 8, 8, 64)          0
_________________________________________________________________
conv2d_51 (Conv2D)           (None, 8, 8, 128)         73856
_________________________________________________________________
batch_normalization_44 (Batc (None, 8, 8, 128)         512
_________________________________________________________________
conv2d_52 (Conv2D)           (None, 8, 8, 128)         147584
_________________________________________________________________
batch_normalization_45 (Batc (None, 8, 8, 128)         512
_________________________________________________________________
max_pooling2d_25 (MaxPooling (None, 4, 4, 128)         0
_________________________________________________________________
dropout_34 (Dropout)         (None, 4, 4, 128)         0
_________________________________________________________________
flatten_9 (Flatten)          (None, 2048)              0
_________________________________________________________________
dense_19 (Dense)             (None, 128)               262272
_________________________________________________________________
batch_normalization_46 (Batc (None, 128)               512
_________________________________________________________________
dropout_35 (Dropout)         (None, 128)               0
_________________________________________________________________
dense_20 (Dense)             (None, 10)                1290
=================================================================
Total params: 552,874
Trainable params: 551,722
Non-trainable params: 1,152
_________________________________________________________________
```

In [ ]:

```
# opt = keras.optimizers.SGD(learning_rate=0.001, momentum=0.9)

model.compile(optimizer="adam",
              loss='categorical_crossentropy',
              metrics=['accuracy'])
```

In [ ]:

```
batch_size = 100
num_classes = 10
epochs = 100
```

In [ ]:

```
es = EarlyStopping(monitor='val_accuracy', mode='max', min_delta=0.01, patience=10, verbose

model_log = model.fit(x_train, y_train,
                      batch_size=batch_size,
                      epochs=epochs,
                      validation_split = 0.1,
                      callbacks=[es]
                     )
```

```
Epoch 1/100
450/450 [==============================] - 7s 13ms/step - loss: 2.1703 - a
ccuracy: 0.3228 - val_loss: 2.2065 - val_accuracy: 0.2778
Epoch 2/100
450/450 [==============================] - 6s 12ms/step - loss: 1.2921 - a
ccuracy: 0.5336 - val_loss: 1.0135 - val_accuracy: 0.6388
Epoch 3/100
450/450 [==============================] - 6s 13ms/step - loss: 1.0433 - a
ccuracy: 0.6285 - val_loss: 0.9237 - val_accuracy: 0.6754
Epoch 4/100
450/450 [==============================] - 6s 13ms/step - loss: 0.9130 - a
ccuracy: 0.6769 - val_loss: 0.9453 - val_accuracy: 0.6742
Epoch 5/100
450/450 [==============================] - 6s 13ms/step - loss: 0.8251 - a
ccuracy: 0.7091 - val_loss: 0.7566 - val_accuracy: 0.7334
Epoch 6/100
450/450 [==============================] - 6s 13ms/step - loss: 0.7512 - a
ccuracy: 0.7383 - val_loss: 0.7229 - val_accuracy: 0.7552
Epoch 7/100
```

In [ ]:

```
score = model.evaluate(x_test, y_test, verbose=0)
print('Test loss:', score[0])
print('Test accuracy:', score[1])
```

```
Test loss: 0.47637563943862915
Test accuracy: 0.8496999740600586
```

In [ ]:

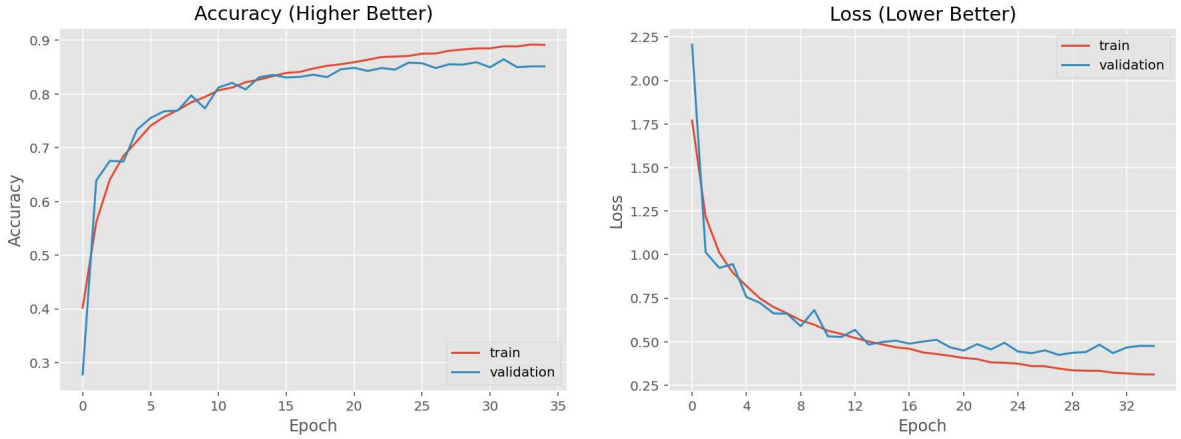
```
model.save("VGGmodel.h5")
```

In [ ]:

```
f, (ax1, ax2) = plt.subplots(1, 2,figsize=(15,5))

ax1.plot(model_log.history['accuracy'])
ax1.plot(model_log.history['val_accuracy'])
ax1.set_title('Accuracy (Higher Better)')
ax1.set(xlabel='Epoch', ylabel='Accuracy')
ax1.legend(['train', 'validation'], loc='lower right')
# ax1.xaxis.set_major_locator(MaxNLocator(integer=True))

ax2.plot(model_log.history['loss'])
ax2.plot(model_log.history['val_loss'])
ax2.set_title('Loss (Lower Better)')
ax2.set(xlabel='Epoch', ylabel='Loss')
ax2.legend(['train', 'validation'], loc='upper right')
ax2.xaxis.set_major_locator(MaxNLocator(integer=True))
```




## Data Augmentation

Data augmentation using keras Image Data Generator on VGG model

In [13]:

```
model = keras.Sequential()

model.add(keras.layers.Conv2D(32, (3,3), activation='relu', input_shape=input_shape, paddin
model.add(BatchNormalization())
model.add(keras.layers.Conv2D(32, (3,3), activation='relu', padding = 'same'))
model.add(BatchNormalization())
model.add(keras.layers.MaxPooling2D((2, 2)))
model.add(keras.layers.Dropout(0.2))

model.add(keras.layers.Conv2D(64, (3, 3), activation='relu',padding='same'))
model.add(BatchNormalization())
model.add(keras.layers.Conv2D(64, (3, 3), activation='relu',padding='same'))
model.add(BatchNormalization())
model.add(keras.layers.MaxPooling2D((2, 2)))
model.add(keras.layers.Dropout(0.3))

model.add(keras.layers.Conv2D(128, (3, 3), activation='relu',padding='same'))
model.add(BatchNormalization())
model.add(keras.layers.Conv2D(128, (3, 3), activation='relu',padding='same'))
model.add(BatchNormalization())
model.add(keras.layers.MaxPooling2D((2, 2)))
model.add(keras.layers.Dropout(0.4))

model.add(keras.layers.Flatten())
model.add(keras.layers.Dense(128, activation='relu'))
model.add(BatchNormalization())
model.add(keras.layers.Dropout(0.5))

model.add(keras.layers.Dense(num_classes, activation='softmax'))
```

In [14]:

```
model.summary()
```

```
Model: "sequential_1"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_6 (Conv2D)            (None, 32, 32, 32)        896
_________________________________________________________________
batch_normalization_7 (Batch (None, 32, 32, 32)        128
_________________________________________________________________
conv2d_7 (Conv2D)            (None, 32, 32, 32)        9248
_________________________________________________________________
batch_normalization_8 (Batch (None, 32, 32, 32)        128
_________________________________________________________________
max_pooling2d_3 (MaxPooling2 (None, 16, 16, 32)        0
_________________________________________________________________
dropout_4 (Dropout)          (None, 16, 16, 32)        0
_________________________________________________________________
conv2d_8 (Conv2D)            (None, 16, 16, 64)        18496
_________________________________________________________________
batch_normalization_9 (Batch (None, 16, 16, 64)        256
_________________________________________________________________
conv2d_9 (Conv2D)            (None, 16, 16, 64)        36928
_________________________________________________________________
batch_normalization_10 (Batc (None, 16, 16, 64)        256
_________________________________________________________________
max_pooling2d_4 (MaxPooling2 (None, 8, 8, 64)          0
_________________________________________________________________
dropout_5 (Dropout)          (None, 8, 8, 64)          0
_________________________________________________________________
conv2d_10 (Conv2D)           (None, 8, 8, 128)         73856
_________________________________________________________________
batch_normalization_11 (Batc (None, 8, 8, 128)         512
_________________________________________________________________
conv2d_11 (Conv2D)           (None, 8, 8, 128)         147584
_________________________________________________________________
batch_normalization_12 (Batc (None, 8, 8, 128)         512
_________________________________________________________________
max_pooling2d_5 (MaxPooling2 (None, 4, 4, 128)         0
_________________________________________________________________
dropout_6 (Dropout)          (None, 4, 4, 128)         0
_________________________________________________________________
flatten_1 (Flatten)          (None, 2048)              0
_________________________________________________________________
dense_2 (Dense)              (None, 128)               262272
_________________________________________________________________
batch_normalization_13 (Batc (None, 128)               512
_________________________________________________________________
dropout_7 (Dropout)          (None, 128)               0
_________________________________________________________________
dense_3 (Dense)              (None, 10)                1290
=================================================================
Total params: 552,874
Trainable params: 551,722
Non-trainable params: 1,152
_________________________________________________________________
```

In [15]:

```
# opt = keras.optimizers.SGD(learning_rate=0.001, momentum=0.9)

model.compile(optimizer="adam",
              loss='categorical_crossentropy',
              metrics=['accuracy'])

batch_size = 100
num_classes = 10
epochs = 100
```

In [16]:

```
datagen = ImageDataGenerator(
    # featurewise_center=True,
    # featurewise_std_normalization=True,
    rotation_range=15,
    width_shift_range=0.1,
    height_shift_range=0.1,
    horizontal_flip=True,
    validation_split=0.0)

# compute quantities required for featurewise normalization
# (std, mean, and principal components if ZCA whitening is applied)
datagen.fit(x_train)

es = EarlyStopping(monitor='val_accuracy', mode='max', min_delta=0.01, patience=5, verbose=

# fits the model on batches with real-time data augmentation:
model_log=model.fit(datagen.flow(x_train, y_train, batch_size=batch_size),
          steps_per_epoch=len(x_train) /batch_size, epochs=epochs,
          validation_data=(x_test,y_test),
          callbacks=[es])
```

```
Epoch 1/100
500/500 [==============================] - 26s 50ms/step - loss: 2.1648 - ac
curacy: 0.3082 - val_loss: 1.5311 - val_accuracy: 0.4442
Epoch 2/100
500/500 [==============================] - 25s 50ms/step - loss: 1.3347 - ac
curacy: 0.5162 - val_loss: 1.3702 - val_accuracy: 0.5492
Epoch 3/100
500/500 [==============================] - 25s 50ms/step - loss: 1.1237 - ac
curacy: 0.5979 - val_loss: 0.9982 - val_accuracy: 0.6584
Epoch 4/100
500/500 [==============================] - 24s 49ms/step - loss: 1.0026 - ac
curacy: 0.6491 - val_loss: 0.8909 - val_accuracy: 0.6901
Epoch 5/100
500/500 [==============================] - 25s 50ms/step - loss: 0.9166 - ac
curacy: 0.6777 - val_loss: 0.9179 - val_accuracy: 0.6884
Epoch 6/100
500/500 [==============================] - 25s 50ms/step - loss: 0.8550 - ac
curacy: 0.7046 - val_loss: 0.9841 - val_accuracy: 0.6825
Epoch 7/100
500/500 [==============================] - 25s 50ms/step - loss: 0.7880 - ac
curacy: 0.7310 - val_loss: 0.7366 - val_accuracy: 0.7442
Epoch 8/100
500/500 [==============================] - 25s 49ms/step - loss: 0.7555 - ac
curacy: 0.7390 - val_loss: 0.6518 - val_accuracy: 0.7757
Epoch 9/100
500/500 [==============================] - 25s 49ms/step - loss: 0.7290 - ac
curacy: 0.7509 - val_loss: 0.7363 - val_accuracy: 0.7505
Epoch 10/100
500/500 [==============================] - 25s 50ms/step - loss: 0.7040 - ac
curacy: 0.7599 - val_loss: 0.7704 - val_accuracy: 0.7398
Epoch 11/100
500/500 [==============================] - 25s 49ms/step - loss: 0.6792 - ac
curacy: 0.7632 - val_loss: 0.6213 - val_accuracy: 0.7893
Epoch 12/100
500/500 [==============================] - 25s 50ms/step - loss: 0.6562 - ac
curacy: 0.7761 - val_loss: 0.7071 - val_accuracy: 0.7668
Epoch 13/100
```

```
500/500 [==============================] - 25s 50ms/step - loss: 0.6299 - ac
curacy: 0.7846 - val_loss: 0.5605 - val_accuracy: 0.8092
Epoch 14/100
500/500 [==============================] - 25s 49ms/step - loss: 0.6189 - ac
curacy: 0.7900 - val_loss: 0.5936 - val_accuracy: 0.8005
Epoch 15/100
500/500 [==============================] - 25s 49ms/step - loss: 0.6034 - ac
curacy: 0.7940 - val_loss: 0.5924 - val_accuracy: 0.8032
Epoch 16/100
500/500 [==============================] - 25s 50ms/step - loss: 0.5923 - ac
curacy: 0.7967 - val_loss: 0.4953 - val_accuracy: 0.8343
Epoch 17/100
500/500 [==============================] - 25s 50ms/step - loss: 0.5744 - ac
curacy: 0.8037 - val_loss: 0.5454 - val_accuracy: 0.8148
Epoch 18/100
500/500 [==============================] - 25s 49ms/step - loss: 0.5693 - ac
curacy: 0.8050 - val_loss: 0.7702 - val_accuracy: 0.7523
Epoch 19/100
500/500 [==============================] - 25s 50ms/step - loss: 0.5504 - ac
curacy: 0.8135 - val_loss: 0.5374 - val_accuracy: 0.8190
Epoch 20/100
500/500 [==============================] - 25s 50ms/step - loss: 0.5562 - ac
curacy: 0.8096 - val_loss: 0.4751 - val_accuracy: 0.8406
Epoch 21/100
500/500 [==============================] - 25s 50ms/step - loss: 0.5440 - ac
curacy: 0.8159 - val_loss: 0.5357 - val_accuracy: 0.8253
Restoring model weights from the end of the best epoch.
Epoch 00021: early stopping
```

In [17]:

```
score = model.evaluate(x_test, y_test, verbose=0)
print('Test loss:', score[0])
print('Test accuracy:', score[1])
```

```
Test loss: 0.4953373074531555
Test accuracy: 0.8342999815940857
```

In [ ]:

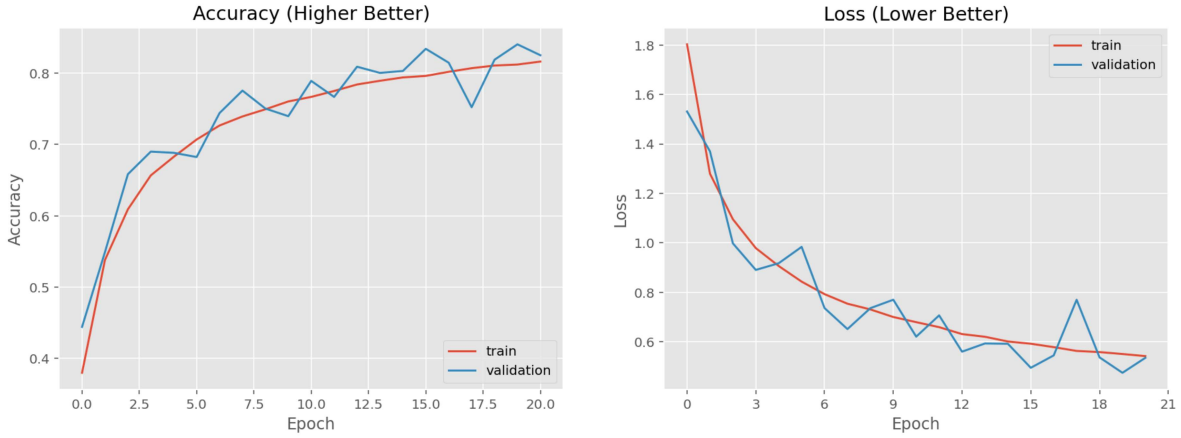
```
model.save("DataAugmentVGG.h5")
```

In [18]:

```
f, (ax1, ax2) = plt.subplots(1, 2,figsize=(15,5))

ax1.plot(model_log.history['accuracy'])
ax1.plot(model_log.history['val_accuracy'])
ax1.set_title('Accuracy (Higher Better)')
ax1.set(xlabel='Epoch', ylabel='Accuracy')
ax1.legend(['train', 'validation'], loc='lower right')
# ax1.xaxis.set_major_locator(MaxNLocator(integer=True))

ax2.plot(model_log.history['loss'])
ax2.plot(model_log.history['val_loss'])
ax2.set_title('Loss (Lower Better)')
ax2.set(xlabel='Epoch', ylabel='Loss')
ax2.legend(['train', 'validation'], loc='upper right')
ax2.xaxis.set_major_locator(MaxNLocator(integer=True))
```




### Check the Predictions

In [ ]:

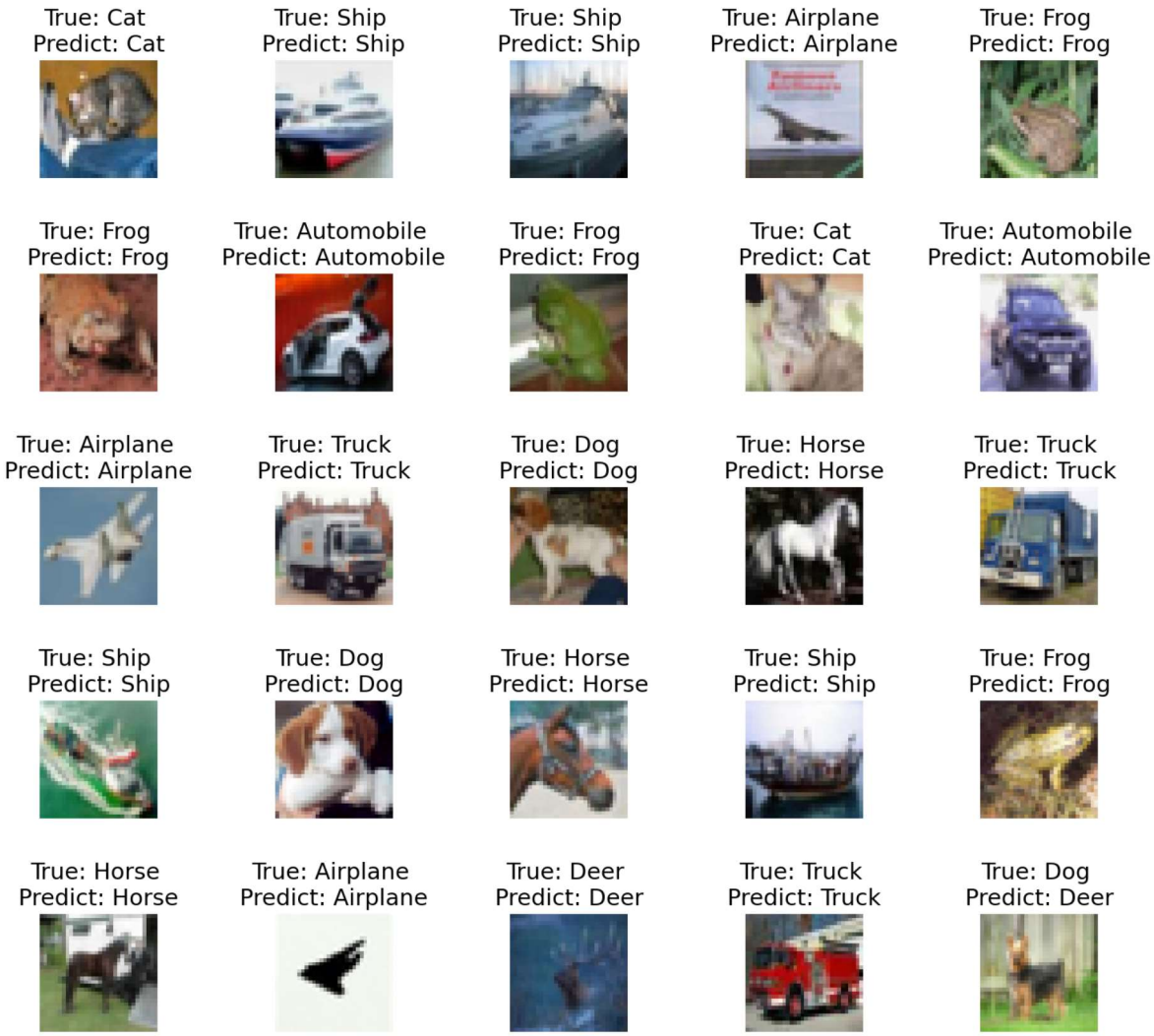
```
pred = model.predict(x_test)

# Convert predictions classes to one hot vectors
Y_pred_classes = np.argmax(pred, axis=1)
# Convert validation observations to one hot vectors
Y_true = np.argmax(y_test, axis=1)
```

In [ ]:

```
R = 5
C = 5
fig, axes = plt.subplots(R, C, figsize=(12,12))
axes = axes.ravel()

for i in np.arange(0, R*C):
    axes[i].imshow(x_test[i])
    axes[i].set_title("True: %s \nPredict: %s" % (labels[Y_true[i]], labels[Y_pred_classes[
    axes[i].axis('off')
    plt.subplots_adjust(wspace=1)
```



## Check the wrong Predictions

In [ ]:

```
R = 5
C = 5
fig, axes = plt.subplots(R, C, figsize=(12,12))
axes = axes.ravel()

misclassified_idx = np.where(Y_pred_classes != Y_true)[0]
for i in np.arange(0, R*C):
    axes[i].imshow(x_test[misclassified_idx[i]])
    axes[i].set_title("True: %s \nPredicted: %s" % (labels[Y_true[misclassified_idx[i]]],
                                                   labels[Y_pred_classes[misclassified_idx[i
    axes[i].axis('off')
    plt.subplots_adjust(wspace=1)
```