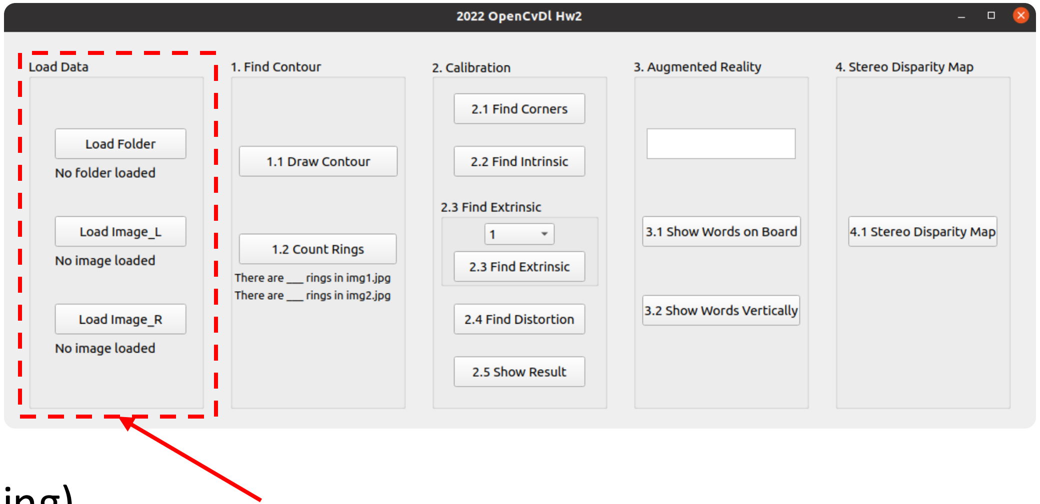
Notice (2/2)

- Python
  - Python 3.7 (https://www.python.org/downloads/)
  - opencv-contrib-python (3.4.2.17)
  - Matplotlib 3.1.1
  - UI framework: pyqt5 (5.15.1)

Assignment scoring (Total: 100%)

1. (20%) Image Processing (出題：Mei)
    - 1.1 (15%) Draw Contour
    - 1.2 (5%) Count Rings
2. (20%) Camera Calibration (出題：Jessica)
    - 2.1 (4%) Corner detection
    - 2.2 (4%) Find the intrinsic matrix
    - 2.3 (4%) Find the extrinsic matrix
    - 2.4 (4%) Find the distortion matrix
    - 2.5 (4%) Show the undistorted result
3. (20%) Augmented Reality (出題：Ming)
    - 3.1 (10%) Show words on board
    - 3.2 (10%) Show words vertically
4. (20%) Stereo Disparity Map (出題：Maton)
    - 4.1 (10%) Stereo Disparity Map
    - 4.2 (10%) Checking the Disparity Value
5. (20%) Train a Cat-Dog Classifier Using ResNet50 (出題：Benjamin)
    - 5.1 (3%) Load the dataset and resize images
    - 5.2 (3%) Plot class distribution of training dataset
    - 5.3 (3%) Show the structure of ResNet50 model
    - 5.4 (3%) Set up 2 kinds of loss functions to train 2 ResNet50 models
    - 5.5 (3%) Compare the accuracies of 2 ResNet50 models on validation dataset
    - 5.6 (4%) Use the better-trained model to run inference and show the predicted class label



Don't fix your data path
(There is another dataset for demonstration)

Question 5 needs to upload separately.

5. Train a Cat-Dog Classifier Using ResNet50 (20%) (出題：Benjamin)

5.1 (3%) Load the dataset and resize images

5.2 (3%) Plot class distribution of training dataset

5.3 (3%) Show the structure of ResNet50 model

5.4 (3%) Set up 2 kinds of loss functions to train 2 ResNet50 models

5.5 (4%) Compare the accuracies of 2 ResNet50 models on validation dataset

5.6 (4%) Use the better-trained model to run inference and show the predicted class label

5.0 Train a Cat-Dog Classifier Using ResNet50

(出題：Benjamin)

1. Objective

1) Learn how to train a ResNet50 model to classify images of cats and dogs
2) Learn how to deal with imbalanced data

2. ResNet50

1) Residual learning: avoid degradation problems
2) Bottleneck: build a deeper network without additional parameters

3. Cats and Dogs Dataset (modified from Kaggle Cats and Dogs Dataset)

1) Data type: JPG images
2) 2 classes: Cat and Dog
3) Datasets
   (1) Path: /Download/Homework/Hw2/Dataset_OpenCvDl_Hw2_Q5.zip
   (2) Training dataset: 16,200 JPG images in total. However, the dataset is imbalanced.
   (3) Validation dataset: 1,800 JPG images in total.
   (4) Inference dataset: 10 JPG images in total. It is for testing the inference function in your GUI program.

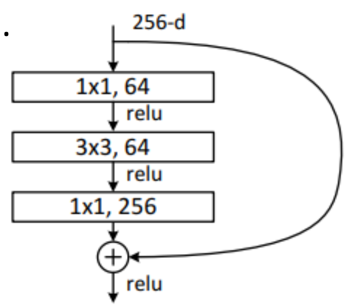


Figure: Residual Block (with bottleneck)

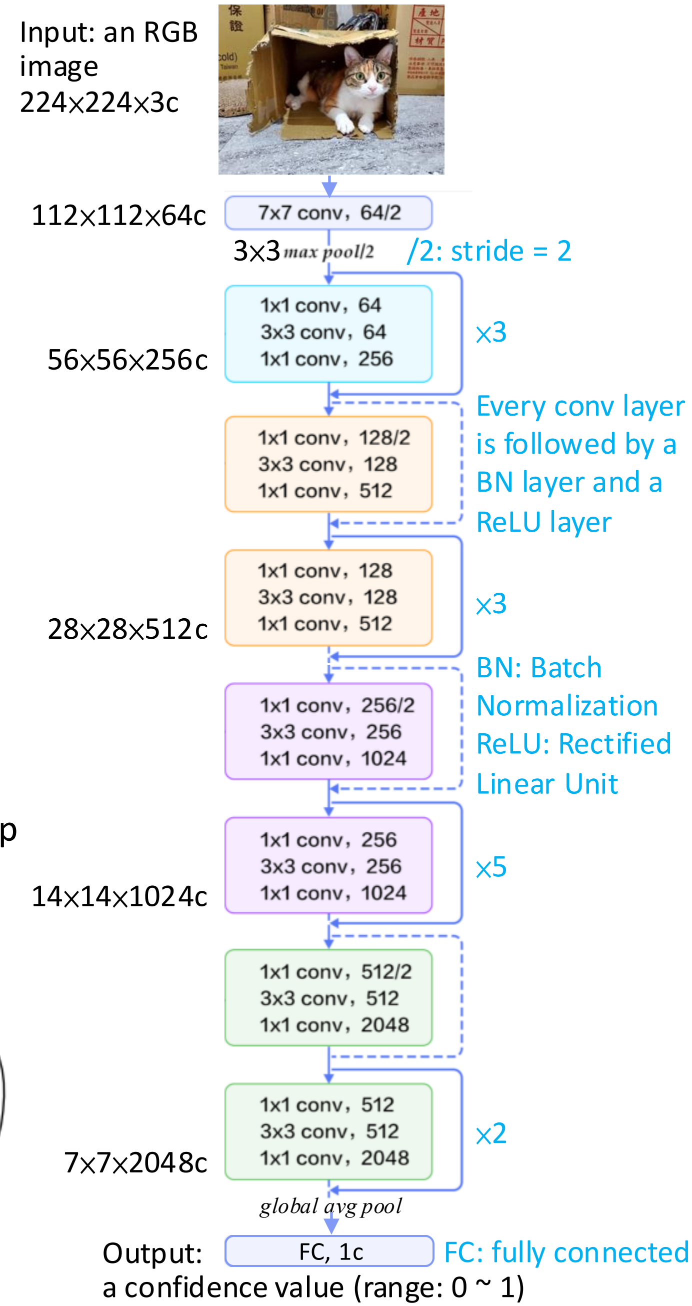


Figure: ResNet50 model structure

R. Reference

1) [Deep Residual Learning for Image Recognition]
2) [Kaggle Cats and Dogs Dataset]

5.0 Train a Cat-Dog Classifier Using ResNet50 (出題：Benjamin)

4. Requirements

1) Train ResNet50 models with TensorFlow or PyTorch
2) Every chart should have a chart title and axis titles
3) Organize the files in this structure:

```
Hw2_05_StudentID_Name_Version // project folder
|-- model                     // folder to put trained models
|-- inference_dataset
    |-- Cat
    |-- Dog
|-- main.py                   // codes for your GUI program
|-- train.py                  // codes for model training
|--  ⋮                        // other files or folders you need
```

Notice: Please include the inference dataset in your homework file.

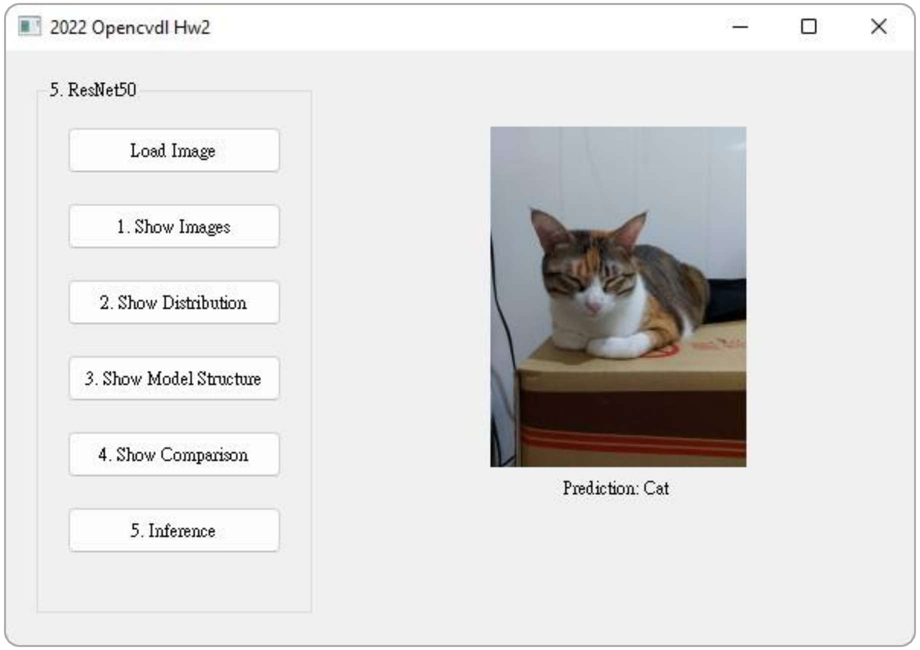


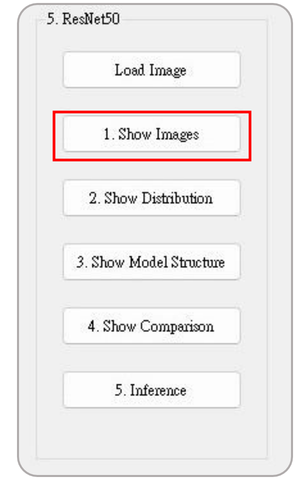
Figure: GUI example

5.1 (3%) Load the dataset and resize images

(出題：Benjamin)

1. Objective

1) At home:
   (1) Load the training dataset and validation dataset
   → Hint:
   (a) TensorFlow (tutorial): tf.keras.utils.image_dataset_from_directory()
   (b) PyTorch (tutorial): torch.utils.data.Dataset
   (2) Resize images to 224×224×3c (RGB)
   → Hint:
   (a) TensorFlow: tf.keras.utils.image_dataset_from_directory(image_size=(?, ?))
   (b) PyTorch (tutorial): torchvision.transform



2) When the demo:
   (1) Click the button "1. Show Images"
   (2) Load the inference dataset
   (3) Resize images to 224×224×3c (RGB)
   (4) Get 1 image from each class in the inference dataset
   (5) Show images in a new window
   → Hint: use matplotlib.pyplot functions to show images (tutorial):
   (a) figure()
   (b) imshow()
   (c) subplot()
   (d) title()

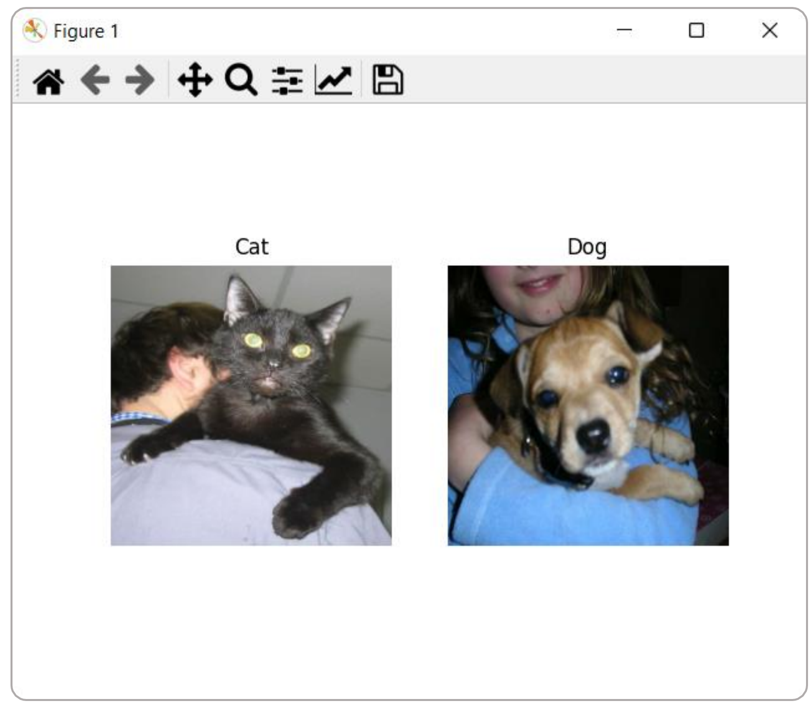


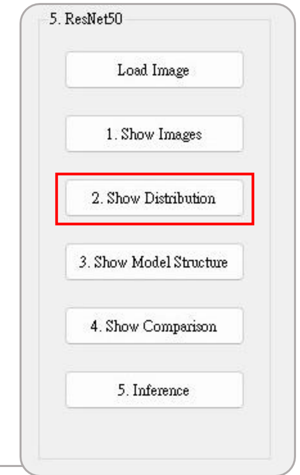
Figure: 1 image from each class
Notice: this is an example, the images might differ

5.2 (3%) Plot class distribution of training dataset (出題：Benjamin)

1. Objective

1) At home:
   (1) Load the training dataset
   (2) Iterate through the dataset and count the number of images of each class
   (3) Plot the class distribution
   → Hint: use matplotlib.pyplot functions to plot
   (a) figure()
   (b) bar()
   (c) xticks()
   (d) ylabel()
   (4) Save the figure

2) When the demo:
   (1) Click the button "2. Show Distribution"
   (2) Show the saved figure of class distribution in a new window



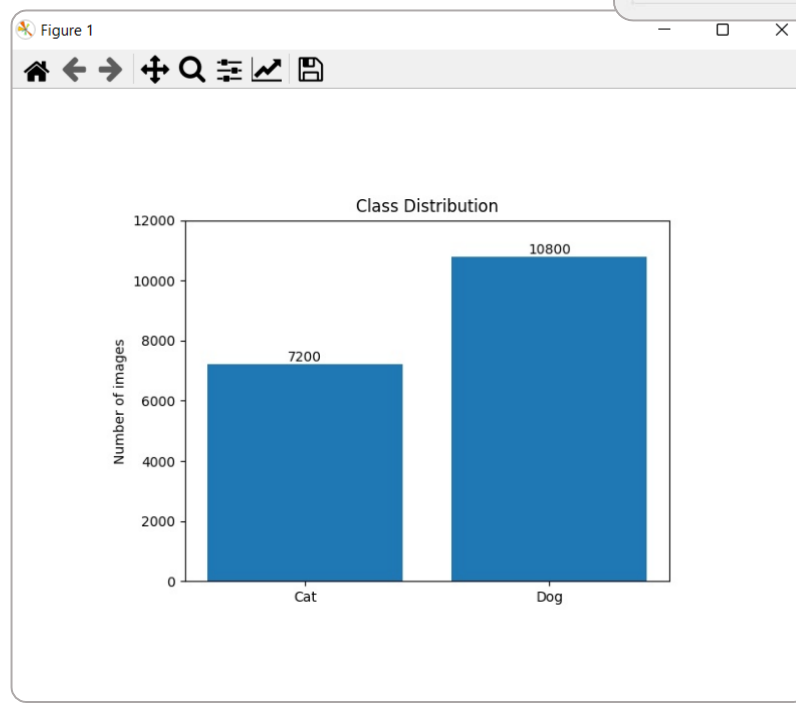


Figure: Class Distribution
Notice: this is an example, the numbers might differ

5.3 (3%) Show the structure of ResNet50 model (出題：Benjamin)

1. Objective

1) At home:
   (1) Build a ResNet50 model
   → Hint:
   (a) TensorFlow: tf.keras.applications.resnet50.ResNet50()
   (b) PyTorch: torchvision.models.resnet50()
   (2) Replace the output layer to a FC (Fully Connected) layer of 1 node with a Sigmoid activation function
   → Hint:
   (a) TensorFlow ([tutorial]): tf.keras.layers.Dense(1, activation='sigmoid')
   (b) PyTorch ([tutorial]): torch.nn.Linear(2048, 1), torch.nn.Sigmoid
   If the class label of Cat is 1, the output value (range: 0 ~ 1) should be close to 1 for cat images, and vice versa.
   (3) Run the function to show the structure in the terminal
   → Hint:
   (a) TensorFlow: tf.keras.Model.summary()
   (b) PyTorch: torchsummary
2) When the demo:
   (1) Click the button "3. Show Model Structure"
   (2) Run the function to show the structure in the terminal

Layer (type)	Feature map shape (B, H, W, C)	Num. of param.	Layer connecting to
input_1 (InputLayer)	[(None, 224, 224, 3)]	0	[]
conv1_pad (ZeroPadding2D)	(None, 230, 230, 3)	0	['input_1[0][0]']
conv1_conv (Conv2D)	(None, 112, 112, 64)	9472	['conv1_pad[0][0]']
conv1_bn (BatchNormalization)	(None, 112, 112, 64)	256	['conv1_conv[0][0]']
conv1_relu (Activation)	(None, 112, 112, 64)	0	['conv1_bn[0][0]']
pool1_pad (ZeroPadding2D)	(None, 114, 114, 64)	0	['conv1_relu[0][0]']
pool1_pool (MaxPooling2D)	(None, 56, 56, 64)	0	['pool1_pad[0][0]']
conv2_block1_1_conv (Conv2D)	(None, 56, 56, 64)	4160	['pool1_pool[0][0]']
conv2_block1_1_bn (BatchNormalization)	(None, 56, 56, 64)	256	['conv2_block1_1_conv[0][0]']
conv2_block1_1_relu (Activation)	(None, 56, 56, 64)	0	['conv2_block1_1_bn[0][0]']

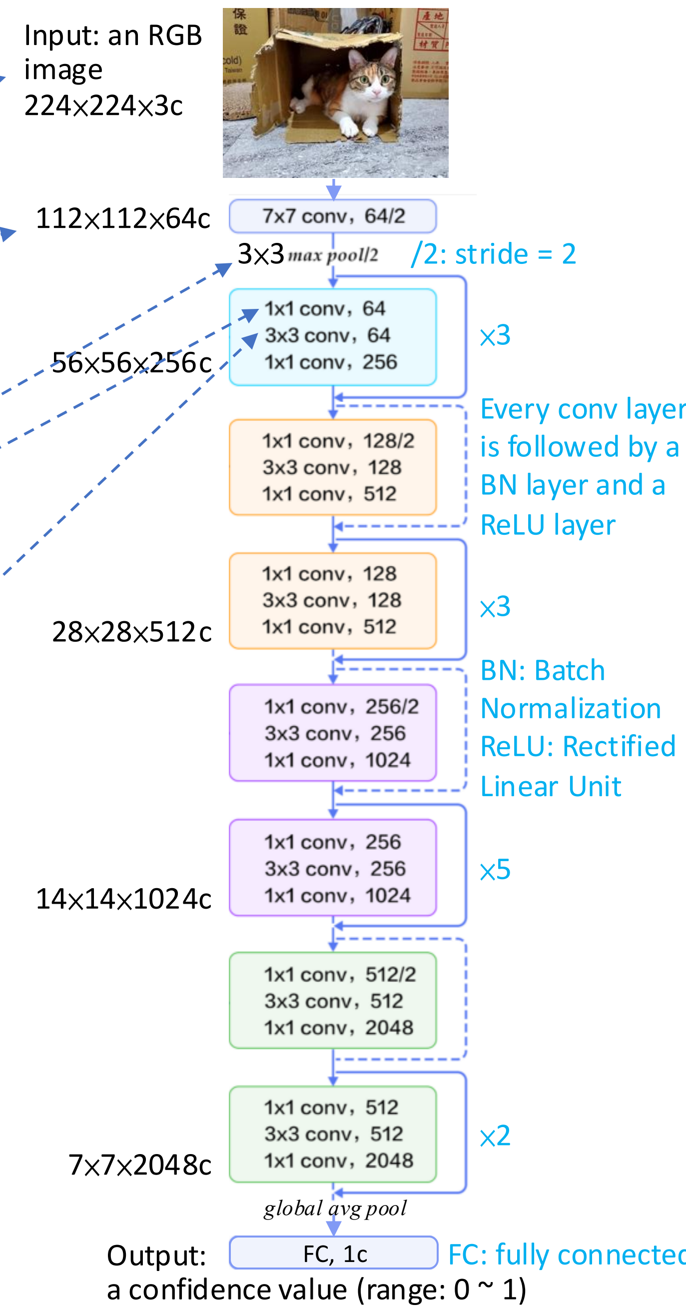
Figure: the structure of ResNet50 model

5.3 (3%) Show the structure of ResNet50 model (出題：Benjamin)

2. How to read the structure

Layer (type)	Feature map shape (B, H, W, C)	Num. of param.	Layer connecting to
input_1 (InputLayer)	[(None, 224, 224, 3)]	0	[]
conv1_pad (ZeroPadding2D)	(None, 230, 230, 3)	0	['input_1[0][0]']
conv1_conv (Conv2D)	(None, 112, 112, 64)	9472	['conv1_pad[0][0]']
conv1_bn (BatchNormalization)	(None, 112, 112, 64)	256	['conv1_conv[0][0]']
conv1_relu (Activation)	(None, 112, 112, 64)	0	['conv1_bn[0][0]']
pool1_pad (ZeroPadding2D)	(None, 114, 114, 64)	0	['conv1_relu[0][0]']
pool1_pool (MaxPooling2D)	(None, 56, 56, 64)	0	['pool1_pad[0][0]']
conv2_block1_1_conv (Conv2D)	(None, 56, 56, 64)	4160	['pool1_pool[0][0]']
conv2_block1_1_bn (BatchNormalization)	(None, 56, 56, 64)	256	['conv2_block1_1_conv[0][0]']
conv2_block1_1_relu (Activation)	(None, 56, 56, 64)	0	['conv2_block1_1_bn[0][0]']
conv2_block1_2_conv (Conv2D)	(None, 56, 56, 64)	36928	['conv2_block1_1_relu[0][0]']
conv2_block1_2_bn (BatchNormalization)	(None, 56, 56, 64)	256	['conv2_block1_2_conv[0][0]']
conv2_block1_2_relu (Activation)	(None, 56, 56, 64)	0	['conv2_block1_2_bn[0][0]']
conv2_block1_0_conv (Conv2D)	(None, 56, 56, 256)	16640	['pool1_pool[0][0]']
conv2_block1_3_conv (Conv2D)	(None, 56, 56, 256)	16640	['conv2_block1_2_relu[0][0]']
conv2_block1_0_bn (BatchNormalization)	(None, 56, 56, 256)	1024	['conv2_block1_0_conv[0][0]']
conv2_block1_3_bn (BatchNormalization)	(None, 56, 56, 256)	1024	['conv2_block1_3_conv[0][0]']

Figure: the structure of ResNet50 model



5.4 (3%) Set up 2 kinds of loss functions to train 2 ResNet50 models

(出題：Benjamin)

1. Objective
   1) At home:
      (1) Set up Focal Loss (α-balanced) and Binary Cross Entropy in codes for model training (train.py)
      → Hint:
      (a) TensorFlow: tfa.losses.SigmoidFocalCrossEntropy(), tf.keras.losses.BinaryCrossEntropy()
      (b) PyTorch: torchvision.ops.sigmoid_focal_loss(), torch.nn.function.binary_cross_entropy()
      Because you have to use Focal Loss, which accepts 1 confidence value, you may replace the output layer of ResNet50 model to a FC layer of 1 node with a Sigmoid activation function.
      (2) Train 2 ResNet50 models with training dataset using 2 loss functions
      → Hint:
      (a) TensorFlow: tf.keras.Model.fit()
      (b) PyTorch (tutorial): write a for loop to train the model
   2) When the demo:
      (1) Show your codes about loss functions in train.py

```
### Q5.4 Set up 2 kinds of loss functions to train 2 ResNet50 models
# 1st loss function
loss_function = tfa.losses.SigmoidFocalCrossEntropy(alpha=0.4, gamma=1.0)

# 2nd loss function
# loss_function = tf.keras.losses.BinaryCrossentropy()

optimizer = tf.keras.optimizers.Adam(learning_rate=8e-5)

# configure loss function and optimizer for training
model.compile(optimizer=optimizer, loss=loss_function, metrics=['accuracy'])
```

Train a model with Focal Loss

Train another model with Binary Cross Entropy

Figure: Code example (you can follow the hyperparameter settings)

5.4 (3%) Set up 2 kinds of loss functions to train 2 ResNet50 models

(出題：Benjamin)

2. What is Focal Loss?

- $\mathrm{FL}(p_\mathrm{t}) = -\alpha_\mathrm{t}(1 - p_\mathrm{t})^\gamma \log(p_\mathrm{t})$
  1) $p_\mathrm{t} = \begin{cases} p & \text{if } y = 1 \\ 1 - p & \text{otherwise,} \end{cases}$
  2) y: ground-truth class label (0 or 1)
  3) p: model's output confidence value for the input with class label y = 1 (range: $0 \sim 1$)
  4) $\alpha_t = \begin{cases} \alpha & \text{if } y = 1 \\ 1 - \alpha & \text{otherwise,} \end{cases}$
  5) α: class imbalance weighting factor (Usually set to $1 - \textit{frequency of } y = 1 \textit{ examples}$)
  6) γ: focusing parameter (Usually set to 2)
- Focal Loss mitigates class imbalance by assigning more weights to hard examples and less weights to easy examples.
- Focal Loss is for binary classification, ex: Foreground and Background, Face and Non-Face, or Cat and Dog.
- Reference: [Focal Loss for Dense Object Detection]

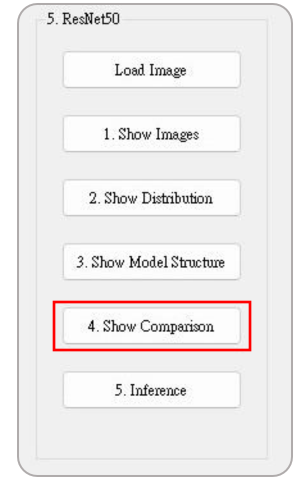
Ex: we have
1) 30 examples with $y = 0$
2) 70 examples with $y = 1$

→ Frequency of $y = 1$ examples is $\frac{70}{100} = 0.7$

→ $\alpha = 1 - 0.7 = 0.3$

5.5 (4%) Compare the accuracies of 2 ResNet50 models on validation dataset

(出題：Benjamin)



1. Objective

1) At home:
   (1) Validate 2 ResNet50 models with validation dataset
       → Hint:
          (a) TensorFlow: tf.keras.Model.evaluate()
          (b) PyTorch ([tutorial]()): write a for loop to validate the model
   (2) Plot the accuracy values with a bar chart
   (3) Save the figure
2) When the demo:
   (1) Click the button "4. Show Comparison"
   (2) Show the saved figure of class distribution in a new window

Figure: Accuracy Comparison

Notice: this is an example, the numbers might differ

5.6 (4%) Use the better-trained model to run inference and show the predicted class label

(出題：Benjamin)

1. Objective
   1) At home:
      (1) Load the trained model
         → Hint:
            (a) TensorFlow: tf.keras.Model.load_weights()
            (b) PyTorch: torch.nn.Module.load_state_dict()
      (2) Click the button "Load Image" to select 1 image arbitrarily
         → Hint: PyQt5.QtWidgets.QFileDialog.getOpenFileName()
      (3) Show the loaded image in the GUI
      (4) Resize the loaded image to 224×224×3c (RGB)
      (5) Click the button "5. Inference" to run inference on the resized image
         → Hint:
            (a) TensorFlow: tf.keras.Model.predict_step()
            (b) PyTorch: pass an image when calling torch.nn.M object to run inference, ex: trained_model(img)
      (6) Show the predicted class label
         → Hint: decide the class label with a threshold of the output value.

$$\text{Ex: class label} = \begin{cases} \text{Cat}, & output < thresh \\ \text{Dog}, & output \geq thresh \end{cases}$$

$$thresh = 0.5$$

   2) When the demo: repeat the process