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December 2, 2024

[2]:
```
import json
import numpy as np
import tensorflow as tf
import matplotlib.pyplot as plt
from sklearn.preprocessing import LabelEncoder
from tensorflow.keras.preprocessing.text import Tokenizer
from tensorflow.keras.preprocessing.sequence import pad_sequences
```

[3]:
```
from google.colab import drive
drive.mount('/content/drive')
```

```
Mounted at /content/drive
```

[4]:
```
import json

#                Google
train_scenes_path = '/content/drive/My Drive/CLEVR/scenes/CLEVR_train_scenes.
 ↪json'
train_questions_path = '/content/drive/My Drive/CLEVR/questions/
 ↪CLEVR_train_questions.json'
val_scenes_path = '/content/drive/My Drive/CLEVR/scenes/CLEVR_val_scenes.json'
val_questions_path = '/content/drive/My Drive/CLEVR/questions/
 ↪CLEVR_val_questions.json'

#       JSON-
with open(train_scenes_path, 'r') as f:
    train_scenes = json.load(f)

with open(train_questions_path, 'r') as f:
    train_questions = json.load(f)

with open(val_scenes_path, 'r') as f:
    val_scenes = json.load(f)

with open(val_questions_path, 'r') as f:
    val_questions = json.load(f)
```

```
#
print("              !")
```

              !

[5]:
```
all_questions = [q['question'] for q in train_questions['questions'] +␣
 ↪val_questions['questions']]
print("Combined questions for tokenization")

question_tokenizer = Tokenizer(oov_token='<OOV>')
question_tokenizer.fit_on_texts(all_questions)
print("Tokenizer initialized")

X_train_questions_seq = question_tokenizer.texts_to_sequences([q['question']␣
 ↪for q in train_questions['questions']])
X_val_questions_seq = question_tokenizer.texts_to_sequences([q['question'] for␣
 ↪q in val_questions['questions']])
print("Train & Val seq converted")

max_question_length = max(len(seq) for seq in X_train_questions_seq +␣
 ↪X_val_questions_seq) # max len for padding.
X_train_questions_padded = pad_sequences(X_train_questions_seq,␣
 ↪maxlen=max_question_length, padding='post')
X_val_questions_padded = pad_sequences(X_val_questions_seq,␣
 ↪maxlen=max_question_length, padding='post')
```

```
Combined questions for tokenization
Tokenizer initialized
Train & Val seq converted
```

[6]:
```
def extract_features(scene):
    features = []
    for obj in scene['objects']:
        attributes = [obj['size'], obj['color'], obj['material'], obj['shape']]␣
 ↪# size, color, shape etc...
        features.extend(attributes)
    return features

def prep_dataset(scenes, questions):
    X = []
    y = []
    s_dict = {scene['image_index']: scene for scene in scenes['scenes']} # dict␣
 ↪for quick access.
    for question in questions['questions']:
        image_index = question['image_index']
        if image_index in s_dict:
            scene = s_dict[image_index] # corresponding scene
```

```
            features = extract_features(scene)
            X.append(features)
            y.append(question['answer'])
    return X, y

X_train_scenes_raw, y_train_raw = prep_dataset(train_scenes, train_questions)
X_val_scenes_raw, y_val_raw = prep_dataset(val_scenes, val_questions)
print("Train & Val data extracted")

all_features = [item for sublist in X_train_scenes_raw + X_val_scenes_raw for␣
 ↪item in sublist] # combining features of scenes
scene_encoder = LabelEncoder() # labelencoder
scene_encoder.fit(all_features)

X_train_scenes_encoded = [scene_encoder.transform(features) for features in␣
 ↪X_train_scenes_raw]
X_val_scenes_encoded = [scene_encoder.transform(features) for features in␣
 ↪X_val_scenes_raw]

max_scene_length = max(len(seq) for seq in X_train_scenes_encoded +␣
 ↪X_val_scenes_encoded) # max len for padding.
X_train_scenes_padded = pad_sequences(X_train_scenes_encoded,␣
 ↪maxlen=max_scene_length, padding='post')
X_val_scenes_padded = pad_sequences(X_val_scenes_encoded,␣
 ↪maxlen=max_scene_length, padding='post')
```

```
Train & Val data extracted
```

[7]:
```
# label encoding
all_answers = y_train_raw + y_val_raw

label_encoder = LabelEncoder()
label_encoder.fit(all_answers)

y_train_encoded = label_encoder.transform(y_train_raw)
y_val_encoded = label_encoder.transform(y_val_raw)
```

0.0.1 Model

[8]:
```
# question
q_input = tf.keras.layers.Input(shape=(max_question_length,),␣
 ↪name='question_input')
q_embedding = tf.keras.layers.Embedding(
    input_dim=len(question_tokenizer.word_index) + 1,  # +1 for OOV (out of voc)
    output_dim=128, # dims
    mask_zero=True # mask
)(q_input)
```

```
question_lstm = tf.keras.layers.LSTM(64)(q_embedding) # lstm layer
```

[9]:
```
# scene
s_input = tf.keras.layers.Input(shape=(max_scene_length,), name='scene_input')
s_embedding = tf.keras.layers.Embedding(
    input_dim=len(scene_encoder.classes_),
    output_dim=128,
    mask_zero=True
)(s_input)
scene_lstm = tf.keras.layers.LSTM(64)(s_embedding)
```

[10]:
```
combined = tf.keras.layers.concatenate([question_lstm, scene_lstm])
fc1 = tf.keras.layers.Dense(64, activation='relu')(combined)
output = tf.keras.layers.Dense(len(label_encoder.classes_),␣
 ↪activation='softmax')(fc1)
model = tf.keras.models.Model(inputs=[q_input, s_input], outputs=output)
```

[11]:
```
model.compile(optimizer='adam', loss='sparse_categorical_crossentropy',␣
 ↪metrics=['accuracy'])
```

[12]:
```
model.summary()
```

```
Model: "functional"
```

Layer (type)	Output Shape	Param #	Connected to
question_input (InputLayer)	(None, 43)	0	-
scene_input (InputLayer)	(None, 40)	0	-
embedding (Embedding)	(None, 43, 128)	10,496	question_input[0][0]
not_equal (NotEqual)	(None, 43)	0	question_input[0][0]
embedding_1 (Embedding)	(None, 40, 128)	1,920	scene_input[0][0]

```
not_equal_1 (NotEqual)      (None, 40)                    0  ␣
↪scene_input[0][0]

lstm (LSTM)                 (None, 64)                49,408  ␣
↪embedding[0][0],
                                                            ␣
↪not_equal[0][0]

lstm_1 (LSTM)               (None, 64)                49,408  ␣
↪embedding_1[0][0],
                                                            ␣
↪not_equal_1[0][0]

concatenate (Concatenate)   (None, 128)                   0  ␣
↪lstm[0][0],
                                                            ␣
↪lstm_1[0][0]

dense (Dense)               (None, 64)                 8,256  ␣
↪concatenate[0][0]

dense_1 (Dense)             (None, 28)                 1,820  ␣
↪dense[0][0]


Total params: 121,308 (473.86 KB)


Trainable params: 121,308 (473.86 KB)


Non-trainable params: 0 (0.00 B)
```

[ ]:
```
history = model.fit(
    {'question_input': X_train_questions_padded, 'scene_input':␣
 ↪X_train_scenes_padded},
    y_train_encoded,
    epochs=10,
    batch_size=32,
    validation_data=(
        {'question_input': X_val_questions_padded, 'scene_input':␣
 ↪X_val_scenes_padded},
        y_val_encoded
    )
)
```

```
Epoch 1/10
21875/21875              1948s
89ms/step - accuracy: 0.4572 - loss: 1.0619 - val_accuracy: 0.5257 - val_loss:
0.8912
Epoch 2/10
21875/21875              1952s
87ms/step - accuracy: 0.5345 - loss: 0.8757 - val_accuracy: 0.5343 - val_loss:
0.8598
Epoch 3/10
21875/21875              1888s
86ms/step - accuracy: 0.5414 - loss: 0.8524 - val_accuracy: 0.5481 - val_loss:
0.8426
Epoch 4/10
21875/21875              1949s
87ms/step - accuracy: 0.5483 - loss: 0.8406 - val_accuracy: 0.5468 - val_loss:
0.8376
Epoch 5/10
21875/21875              1945s
87ms/step - accuracy: 0.5526 - loss: 0.8320 - val_accuracy: 0.5560 - val_loss:
0.8363
Epoch 6/10
21875/21875              1938s
87ms/step - accuracy: 0.5559 - loss: 0.8250 - val_accuracy: 0.5577 - val_loss:
0.8258
Epoch 7/10
21875/21875              1865s
85ms/step - accuracy: 0.5604 - loss: 0.8181 - val_accuracy: 0.5581 - val_loss:
0.8215
Epoch 8/10
21875/21875              1994s
90ms/step - accuracy: 0.5622 - loss: 0.8138 - val_accuracy: 0.5621 - val_loss:
0.8168
Epoch 9/10
21875/21875              1917s
88ms/step - accuracy: 0.5668 - loss: 0.8086 - val_accuracy: 0.5655 - val_loss:
0.8145
Epoch 10/10
21875/21875              1912s
87ms/step - accuracy: 0.5695 - loss: 0.8041 - val_accuracy: 0.5666 - val_loss:
0.8135
```

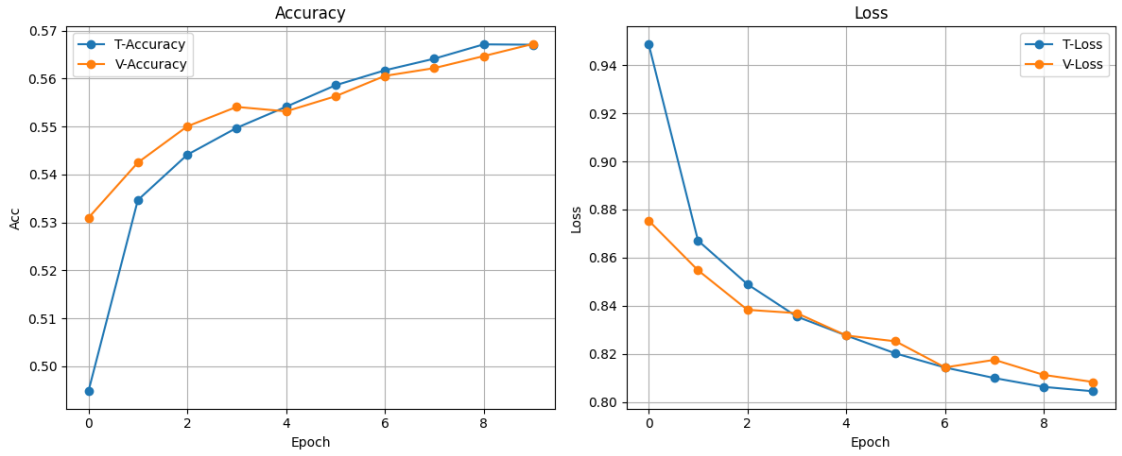
[ ]:
```
plt.figure(figsize=(12, 5))

plt.subplot(1, 2, 1)
plt.plot(history.history['accuracy'], label='T-Accuracy', marker='o')
plt.plot(history.history['val_accuracy'], label='V-Accuracy', marker='o')
plt.title('Accuracy')
```

```
plt.xlabel('Epoch')
plt.ylabel('Acc')
plt.legend()
plt.grid(True)

plt.subplot(1, 2, 2)
plt.plot(history.history['loss'], label='T-Loss', marker='o')
plt.plot(history.history['val_loss'], label='V-Loss', marker='o')
plt.title('Loss')
plt.xlabel('Epoch')
plt.ylabel('Loss')
plt.legend()
plt.grid(True)

plt.tight_layout()
plt.show()
```



[13]:
```
indices = np.random.choice(len(X_val_questions_padded), 5, replace=False)

test_questions = X_val_questions_padded[indices]
test_scenes = X_val_scenes_padded[indices]
test_labels = y_val_encoded[indices]

predict = model.predict({'question_input': test_questions, 'scene_input':␣
 ↪test_scenes})
predicted = np.argmax(predict, axis=1)

for i, idx in enumerate(indices):
    question_text = val_questions['questions'][idx]['question'] # original␣
 ↪question
    true_answer = label_encoder.inverse_transform([test_labels[i]])[0]
```

```
    pred_answer = label_encoder.inverse_transform([predicted[i]])[0]
    ␣
↪print(f"--------------------------------------------------------------------------------\nQuestio
↪ {question_text}\nTrue Answer: {true_answer}\nPredicted Answer:␣
↪{pred_answer}\n--------------------------------------------------------------------------------\n
```

```
1/1             1s 808ms/step
--------------------------------------------------------------------------------
Question: Are there more rubber blocks than gray metal spheres?
True Answer: yes
Predicted Answer: no
--------------------------------------------------------------------------------

--------------------------------------------------------------------------------
Question: Is the size of the rubber cube left of the purple metallic object the
same as the yellow cube?
True Answer: no
Predicted Answer: 6
--------------------------------------------------------------------------------

--------------------------------------------------------------------------------
Question: Do the rubber object that is left of the shiny object and the red cube
in front of the big blue object have the same size?
True Answer: no
Predicted Answer: purple
--------------------------------------------------------------------------------

--------------------------------------------------------------------------------
Question: There is a matte cylinder that is the same size as the cyan matte
object; what is its color?
True Answer: brown
Predicted Answer: purple
--------------------------------------------------------------------------------

--------------------------------------------------------------------------------
Question: Is the number of yellow rubber objects less than the number of cyan
matte things?
True Answer: no
Predicted Answer: 6
--------------------------------------------------------------------------------
```