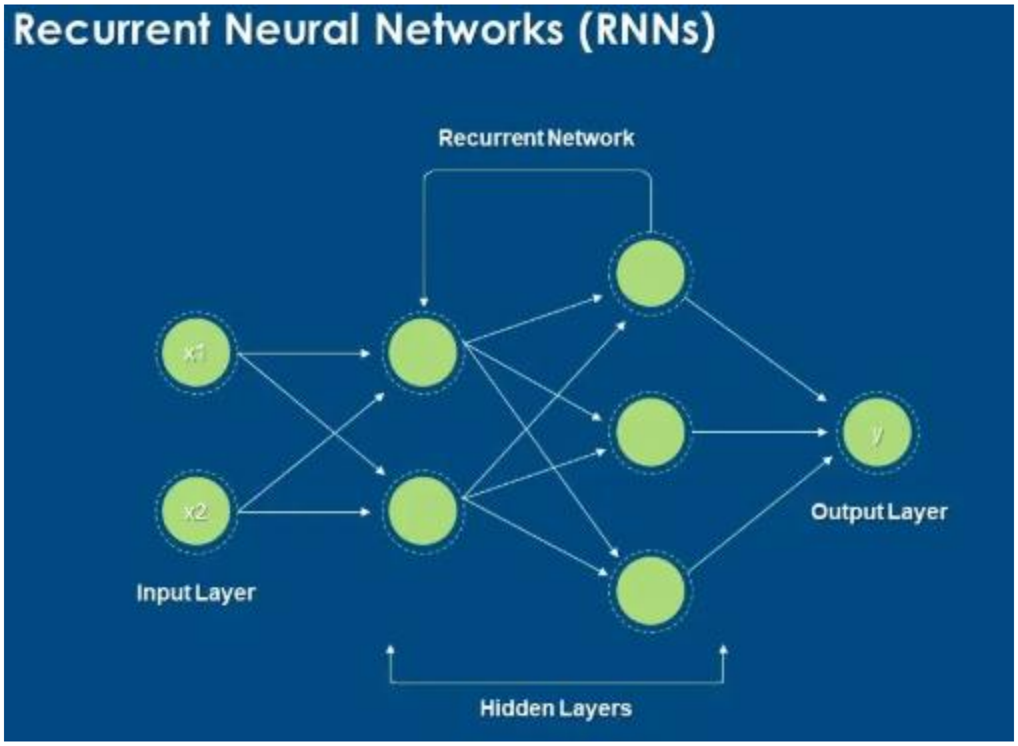
LAB No. 7

Implementation of Recurrent Neural Network (RNN)

In this lab, students will study and implement a Recurrent Neural Network (RNN), a deep learning model designed for sequential and time-dependent data. Unlike feedforward neural networks, RNNs have feedback connections that allow them to retain information from previous time steps. Students will begin with a simple RNN model to understand sequence processing and then apply RNNs to real-world problems such as sequence classification and text processing. Model performance will be evaluated using accuracy metrics.

Introduction

A **Recurrent Neural Network (RNN)** is a class of neural networks specifically designed to process **sequential data**, where the order of inputs matters. RNNs maintain a **hidden state (memory)** that captures information from previous inputs and influences current predictions.



Key Concepts:

- **Sequential Input** – time series or text data
- **Hidden State** – stores past information
- **Recurrent Connection** – connects previous output to current input
- **Activation Functions** – tanh, ReLU
- **Backpropagation Through Time (BPTT)** – training method for RNNs

RNNs are commonly used in **speech recognition, sentiment analysis, time-series forecasting, and natural language processing**. However, basic RNNs may suffer from the **vanishing gradient problem**, which is addressed by advanced variants like **LSTM and GRU**.

Solved Examples:

Example 1:

Simple RNN for Binary Sequence Classification

Build a simple RNN to classify whether a sequence indicates **Pass (1)** or **Fail (0)** based on study performance over time.

Solution:

```
import numpy as np
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import SimpleRNN, Dense

# Sample sequential data (5 students, 3 time steps, 1 feature)
X = np.array([
   [[1], [1], [0]],
   [[1], [1], [1]],
   [[0], [0], [1]],
   [[0], [0], [0]],
   [[1], [0], [1]]
])
```

```
y = np.array([1, 1, 0, 0, 1])

# Build RNN model
model = Sequential()
model.add(SimpleRNN(8, activation='tanh', input_shape=(3, 1)))
model.add(Dense(1, activation='sigmoid'))

# Compile and train
model.compile(optimizer='adam',                    loss='binary_crossentropy',
metrics=['accuracy'])
model.fit(X, y, epochs=100, verbose=0)

# Prediction
prediction = model.predict([[[1], [1], [1]]])
print("Predicted Result (1=Pass, 0=Fail):", int(prediction[0][0] > 0.5))
```

Explanation

The RNN processes input sequences and uses memory to capture temporal patterns before making a classification.

Example 2:

RNN for Time Series Prediction Predict the next value in a simple numerical sequence using an RNN.

Solution:

```
# Generate sequence data
X = np.array([
   [[1], [2], [3]],
   [[2], [3], [4]],
   [[3], [4], [5]],
   [[4], [5], [6]]
])

y = np.array([4, 5, 6, 7])
# Build RNN model
```

```
model = Sequential()
model.add(SimpleRNN(10, activation='tanh', input_shape=(3, 1)))
model.add(Dense(1))

# Compile and train
model.compile(optimizer='adam', loss='mse')
model.fit(X, y, epochs=200, verbose=0)

# Predict next value
prediction = model.predict([[[5], [6], [7]]])
print("Predicted Next Value:", prediction[0][0])
```

Explanation

The RNN learns temporal relationships in numeric sequences and predicts future values.

Example 3:

RNN for Text Classification (Simple Sentiment Analysis)

Build a simple RNN model to classify text sentiment as **positive or negative**.

Solution

```
from tensorflow.keras.preprocessing.text import Tokenizer
from tensorflow.keras.preprocessing.sequence import pad_sequences

# Sample text data
texts = [
    "I love this course",
    "This lab is very good",
    "I hate this subject",
    "This is boring",
    "Excellent explanation"
]
```

```
labels = [1, 1, 0, 0, 1]

# Tokenize text
tokenizer = Tokenizer(num_words=100)
tokenizer.fit_on_texts(texts)

sequences = tokenizer.texts_to_sequences(texts)
padded_sequences = pad_sequences(sequences, maxlen=5)

# Build RNN model
model = Sequential()
model.add(SimpleRNN(16, activation='tanh', input_shape=(5,)))
model.add(Dense(1, activation='sigmoid'))

# Compile and train
model.compile(optimizer='adam',                    loss='binary_crossentropy',
metrics=['accuracy'])
model.fit(padded_sequences, labels, epochs=100, verbose=0)

# Prediction
prediction = model.predict(padded_sequences)
print("Predicted Sentiments:", prediction.round())
```

The RNN processes text sequences word by word, capturing contextual meaning for sentiment classification.

Limitations of Basic RNN

- Vanishing gradient problem
- Difficulty learning long-term dependencies
- Slower training compared to feedforward networks

LAB Assignment No 7

Recurrent Neural Network (RNN)

LAB Task 1:

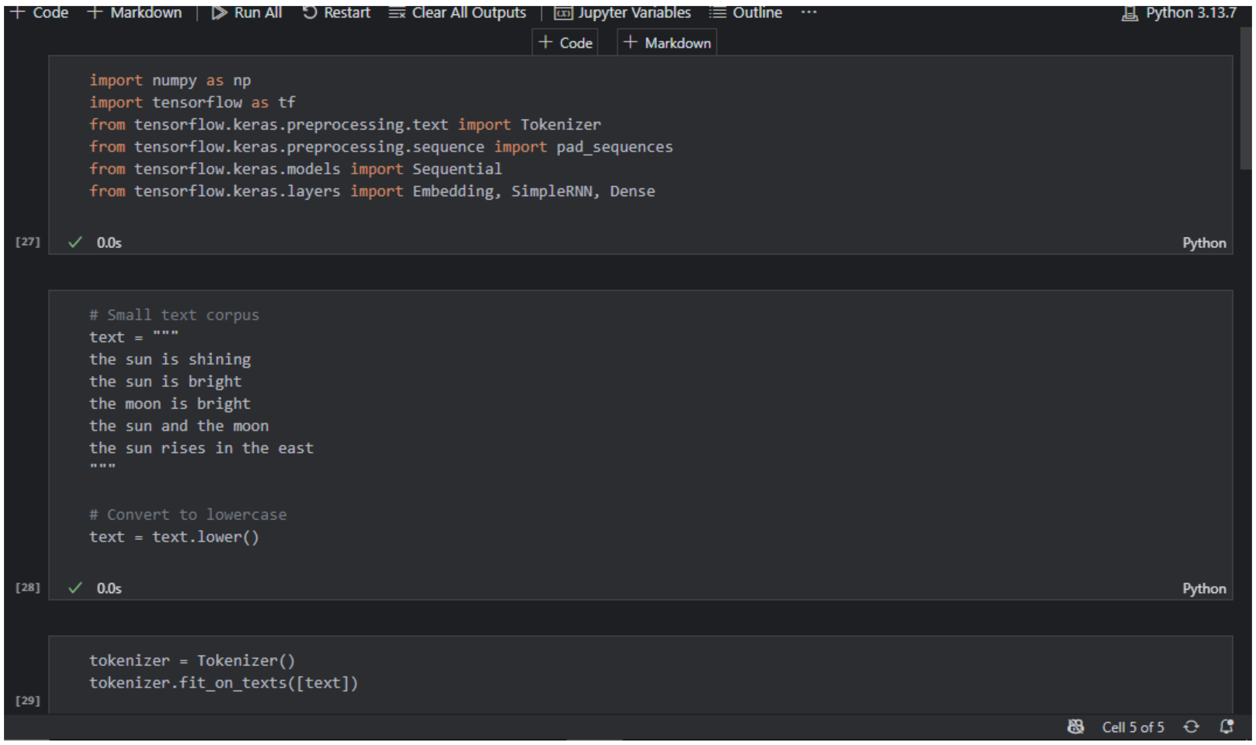
Next Word Prediction using RNN

Objective: Learn how RNNs can predict the next word in a sentence.
Dataset: Any small text corpus — e.g., *Shakespeare.txt* or *Wikipedia sample*.
Tasks:

1. Load and clean the text data.
2. Tokenize and convert text into sequences.
3. Build a simple **RNN model** using keras.layers.SimpleRNN.
4. Train it to predict the next word given previous 3–5 words.
5. Test by entering a custom text prompt and predict the next word.

Output:

Model predicts probable next word, e.g.,
Input: "The sun is" → **Output:** "shining"


+ Code + Markdown | Run All Restart Clear All Outputs | Jupyter Variables Outline ... Python 3.13.7
+ Code + Markdown

```python
import numpy as np
import tensorflow as tf
from tensorflow.keras.preprocessing.text import Tokenizer
from tensorflow.keras.preprocessing.sequence import pad_sequences
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Embedding, SimpleRNN, Dense
```

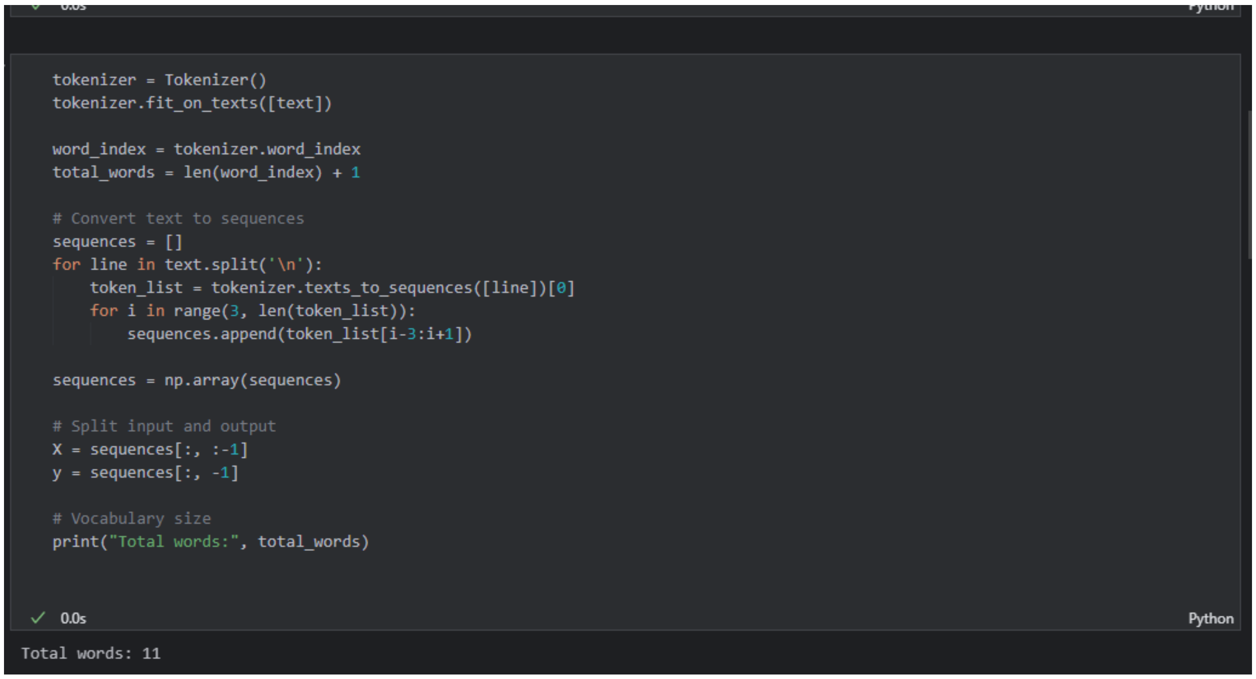
[27] ✓ 0.0s Python

```python
# Small text corpus
text = """
the sun is shining
the sun is bright
the moon is bright
the sun and the moon
the sun rises in the east
"""

# Convert to lowercase
text = text.lower()
```

[28] ✓ 0.0s Python

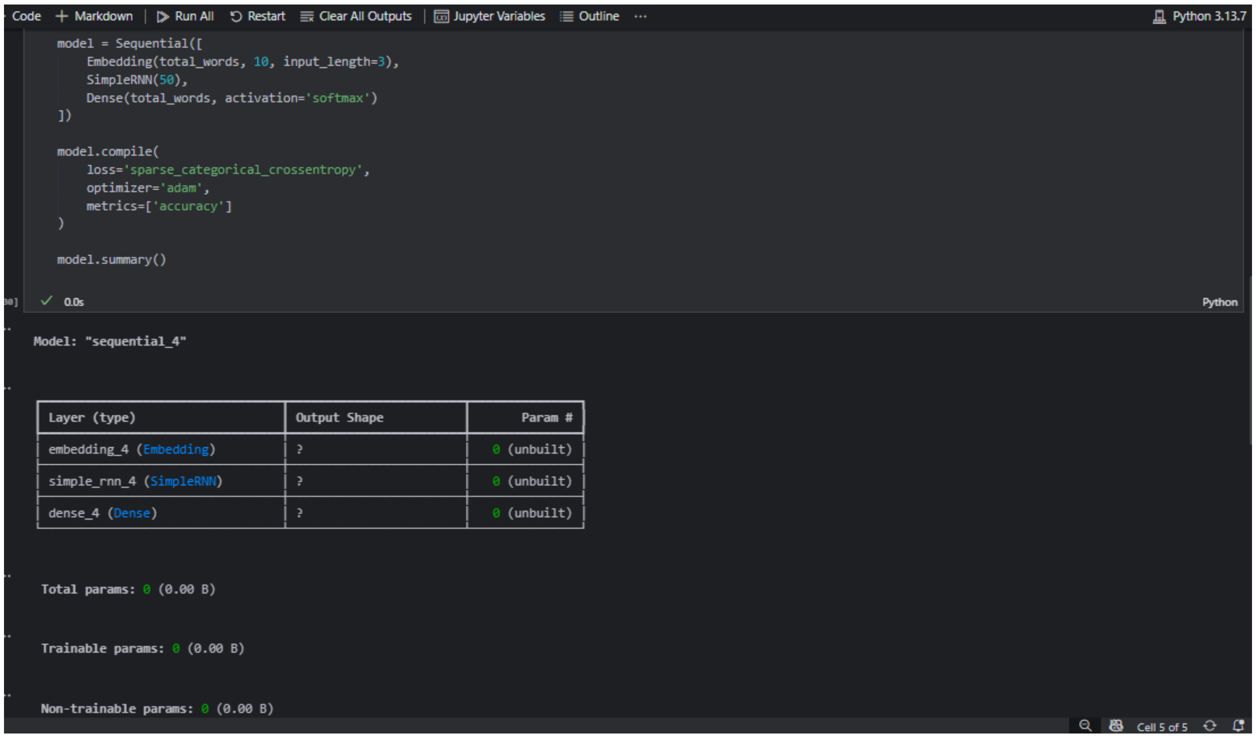
```python
tokenizer = Tokenizer()
tokenizer.fit_on_texts([text])
```

[29]



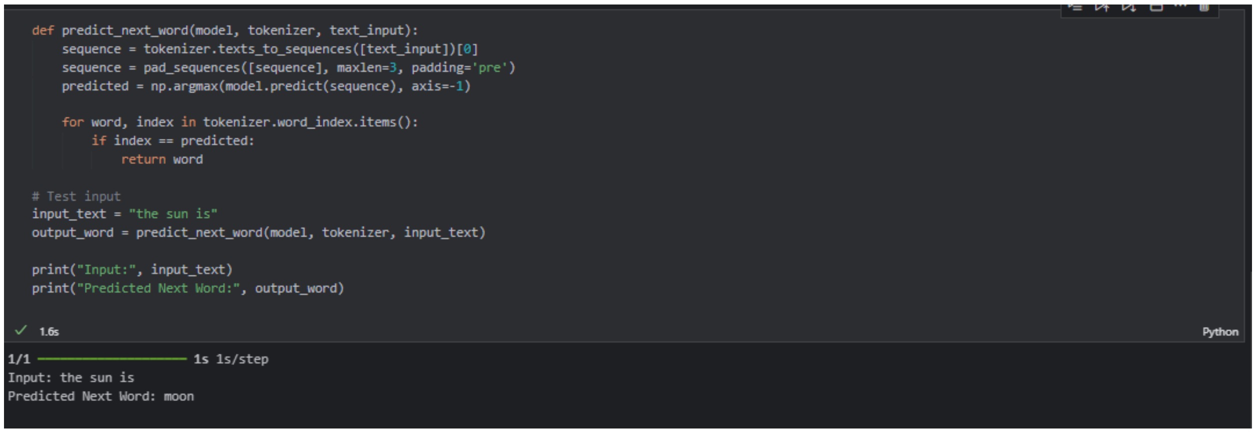
```python
tokenizer = Tokenizer()
tokenizer.fit_on_texts([text])

word_index = tokenizer.word_index
total_words = len(word_index) + 1

# Convert text to sequences
sequences = []
for line in text.split('\n'):
    token_list = tokenizer.texts_to_sequences([line])[0]
    for i in range(3, len(token_list)):
        sequences.append(token_list[i-3:i+1])

sequences = np.array(sequences)

# Split input and output
X = sequences[:, :-1]
y = sequences[:, -1]

# Vocabulary size
print("Total words:", total_words)
```

```
Total words: 11
```



```python
model = Sequential([
    Embedding(total_words, 10, input_length=3),
    SimpleRNN(50),
    Dense(total_words, activation='softmax')
])

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

model.summary()
```

```
Model: "sequential_4"

┌──────────────────────────────┬──────────────────────┬──────────────┐
│ Layer (type)                 │ Output Shape         │      Param # │
├──────────────────────────────┼──────────────────────┼──────────────┤
│ embedding_4 (Embedding)      │ ?                    │  0 (unbuilt) │
├──────────────────────────────┼──────────────────────┼──────────────┤
│ simple_rnn_4 (SimpleRNN)     │ ?                    │  0 (unbuilt) │
├──────────────────────────────┼──────────────────────┼──────────────┤
│ dense_4 (Dense)              │ ?                    │  0 (unbuilt) │
└──────────────────────────────┴──────────────────────┴──────────────┘

 Total params: 0 (0.00 B)

 Trainable params: 0 (0.00 B)

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



```python
def predict_next_word(model, tokenizer, text_input):
    sequence = tokenizer.texts_to_sequences([text_input])[0]
    sequence = pad_sequences([sequence], maxlen=3, padding='pre')
    predicted = np.argmax(model.predict(sequence), axis=-1)

    for word, index in tokenizer.word_index.items():
        if index == predicted:
            return word

# Test input
input_text = "the sun is"
output_word = predict_next_word(model, tokenizer, input_text)

print("Input:", input_text)
print("Predicted Next Word:", output_word)
```

```
1/1 ━━━━━━━━━━━━━━━━━━━━ 1s 1s/step
Input: the sun is
Predicted Next Word: moon
```

LAB Task 2:

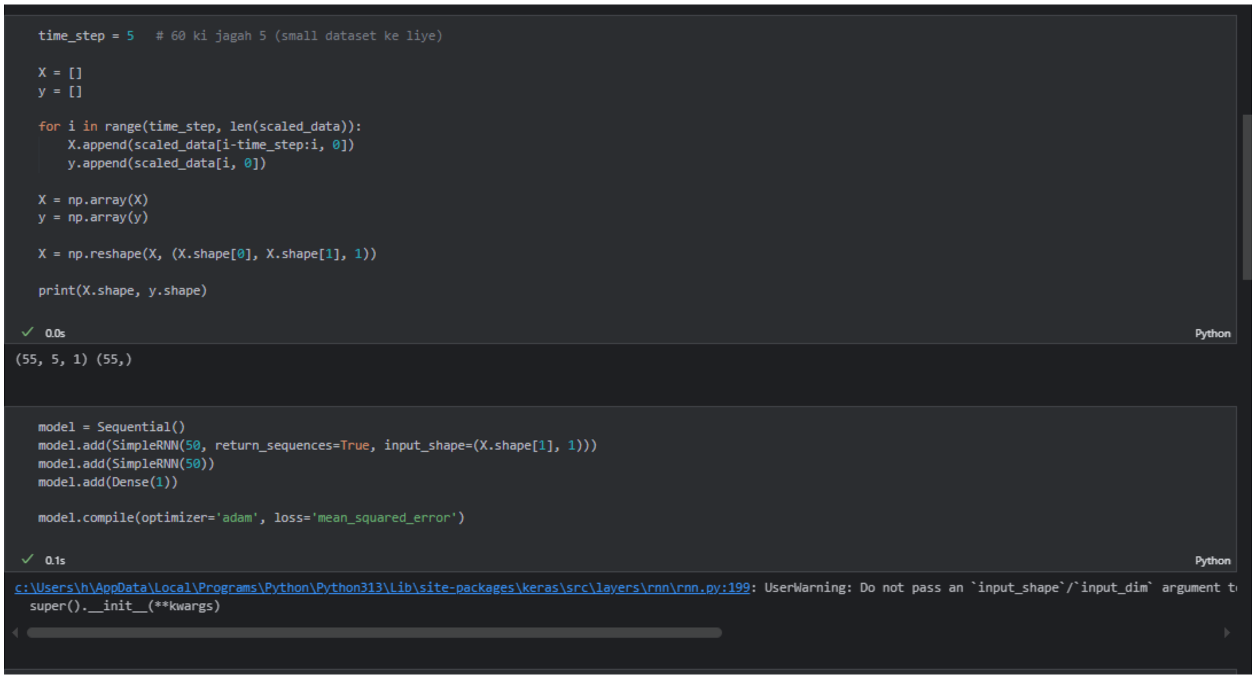
Stock Price Prediction using RNN

Objective: Predict future stock prices using time series data.
Dataset: Use *Google Stock Price* dataset (from Kaggle or Yahoo Finance).
Tasks:

1. Import dataset and normalize values.
2. Prepare time-step sequences (e.g., 60 previous days → next day price).
3. Build and train an **RNN model** using SimpleRNN layers.
4. Evaluate predictions vs actual prices (plot graph).

Output:

Line graph showing predicted vs real stock price trend.

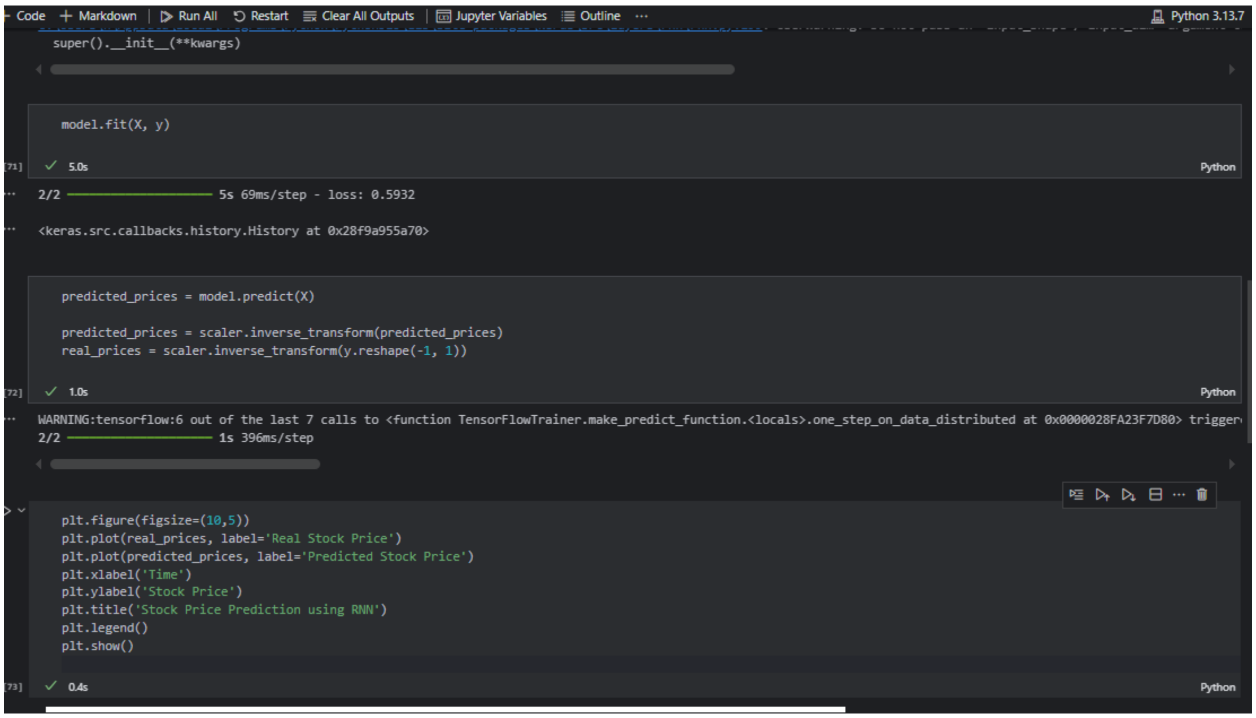


```
time_step = 5   # 60 ki jagah 5 (small dataset ke liye)

X = []
y = []

for i in range(time_step, len(scaled_data)):
    X.append(scaled_data[i-time_step:i, 0])
    y.append(scaled_data[i, 0])

X = np.array(X)
y = np.array(y)

X = np.reshape(X, (X.shape[0], X.shape[1], 1))

print(X.shape, y.shape)
```

```
(55, 5, 1) (55,)
```

```
model = Sequential()
model.add(SimpleRNN(50, return_sequences=True, input_shape=(X.shape[1], 1)))
model.add(SimpleRNN(50))
model.add(Dense(1))

model.compile(optimizer='adam', loss='mean_squared_error')
```

```
c:\Users\h\AppData\Local\Programs\Python\Python313\Lib\site-packages\keras\src\layers\rnn\rnn.py:199: UserWarning: Do not pass an `input_shape`/`input_dim` argument t
  super().__init__(**kwargs)
```



```
  super().__init__(**kwargs)
```

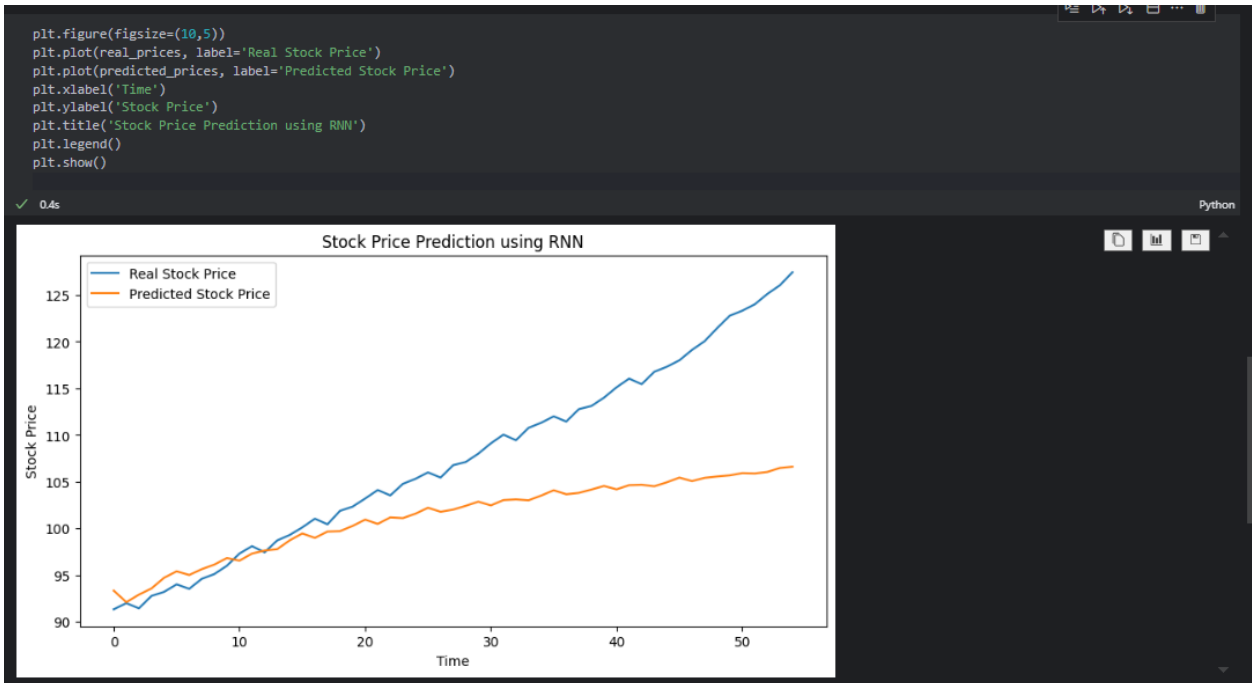
```
model.fit(X, y)
```

```
2/2 ━━━━━━━━━━━━━━━━━━━━ 5s 69ms/step - loss: 0.5932

<keras.src.callbacks.history.History at 0x28f9a955a70>
```

```
predicted_prices = model.predict(X)

predicted_prices = scaler.inverse_transform(predicted_prices)
real_prices = scaler.inverse_transform(y.reshape(-1, 1))
```

```
WARNING:tensorflow:6 out of the last 7 calls to <function TensorFlowTrainer.make_predict_function.<locals>.one_step_on_data_distributed at 0x0000028FA23F7D80> trigger
2/2 ━━━━━━━━━━━━━━━━━━━━ 1s 396ms/step
```

```
plt.figure(figsize=(10,5))
plt.plot(real_prices, label='Real Stock Price')
plt.plot(predicted_prices, label='Predicted Stock Price')
plt.xlabel('Time')
plt.ylabel('Stock Price')
plt.title('Stock Price Prediction using RNN')
plt.legend()
plt.show()
```



```
plt.figure(figsize=(10,5))
plt.plot(real_prices, label='Real Stock Price')
plt.plot(predicted_prices, label='Predicted Stock Price')
plt.xlabel('Time')
plt.ylabel('Stock Price')
plt.title('Stock Price Prediction using RNN')
plt.legend()
plt.show()
```

LAB Task 3:

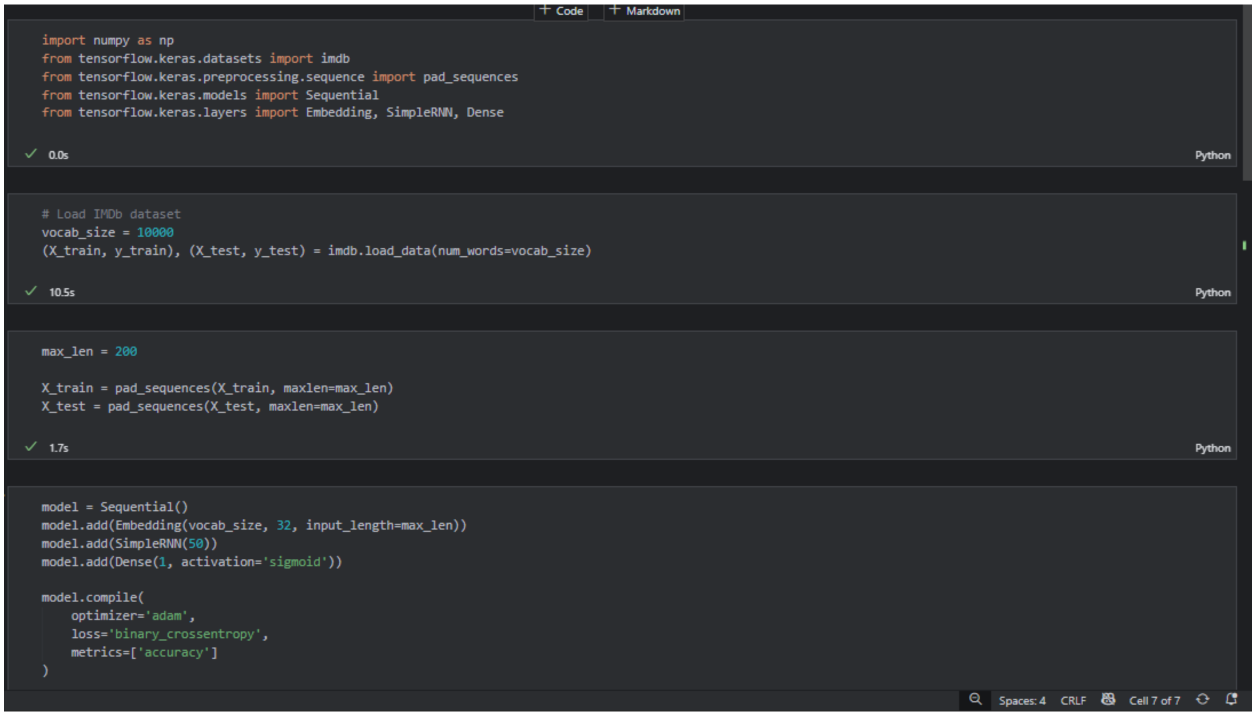
Sentiment Analysis using RNN

Objective: Classify movie reviews as positive or negative using RNN.
Dataset: *IMDb Movie Reviews* dataset (available in Keras).
Tasks:

1. Load dataset and preprocess text (tokenize and pad sequences).
2. Build RNN with Embedding + SimpleRNN layers.
3. Train for binary classification (positive/negative).
4. Evaluate accuracy on test data.

Output:

Accuracy score (e.g., 85%) and prediction for custom input text.

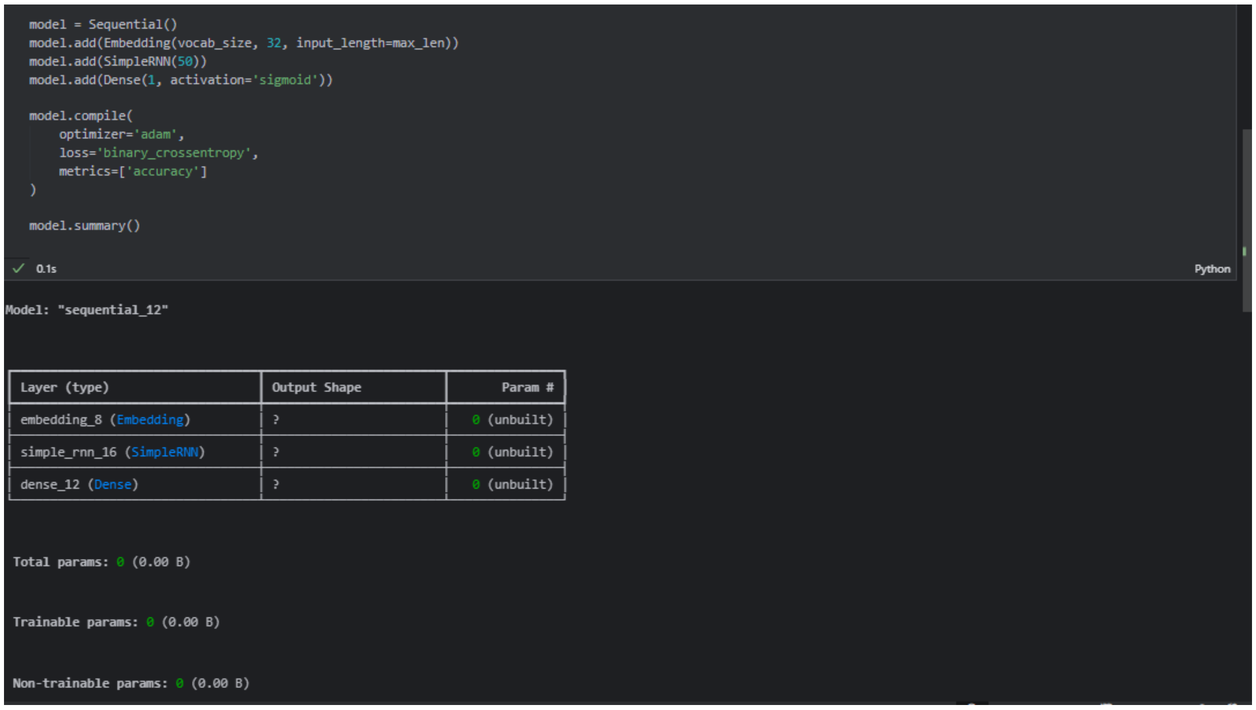


```
import numpy as np
from tensorflow.keras.datasets import imdb
from tensorflow.keras.preprocessing.sequence import pad_sequences
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Embedding, SimpleRNN, Dense
```

```
# Load IMDb dataset
vocab_size = 10000
(X_train, y_train), (X_test, y_test) = imdb.load_data(num_words=vocab_size)
```

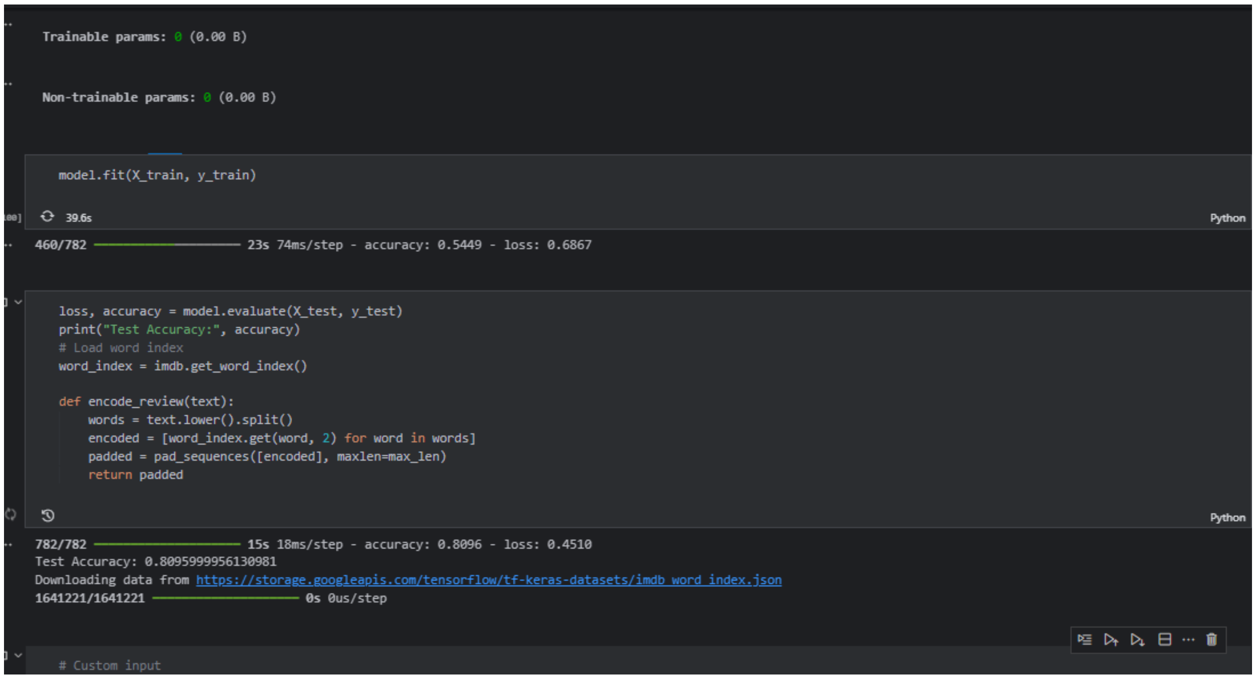
```
max_len = 200

X_train = pad_sequences(X_train, maxlen=max_len)
X_test = pad_sequences(X_test, maxlen=max_len)
```

```
model = Sequential()
model.add(Embedding(vocab_size, 32, input_length=max_len))
model.add(SimpleRNN(50))
model.add(Dense(1, activation='sigmoid'))

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



```
model = Sequential()
model.add(Embedding(vocab_size, 32, input_length=max_len))
model.add(SimpleRNN(50))
model.add(Dense(1, activation='sigmoid'))

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

model.summary()
```

```
Model: "sequential_12"

┏━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━┓
┃ Layer (type)                    ┃ Output Shape           ┃       Param # ┃
┡━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━┩
│ embedding_8 (Embedding)         │ ?                      │   0 (unbuilt) │
├─────────────────────────────────┼────────────────────────┼───────────────┤
│ simple_rnn_16 (SimpleRNN)       │ ?                      │   0 (unbuilt) │
├─────────────────────────────────┼────────────────────────┼───────────────┤
│ dense_12 (Dense)                │ ?                      │   0 (unbuilt) │
└─────────────────────────────────┴────────────────────────┴───────────────┘

 Total params: 0 (0.00 B)

 Trainable params: 0 (0.00 B)

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



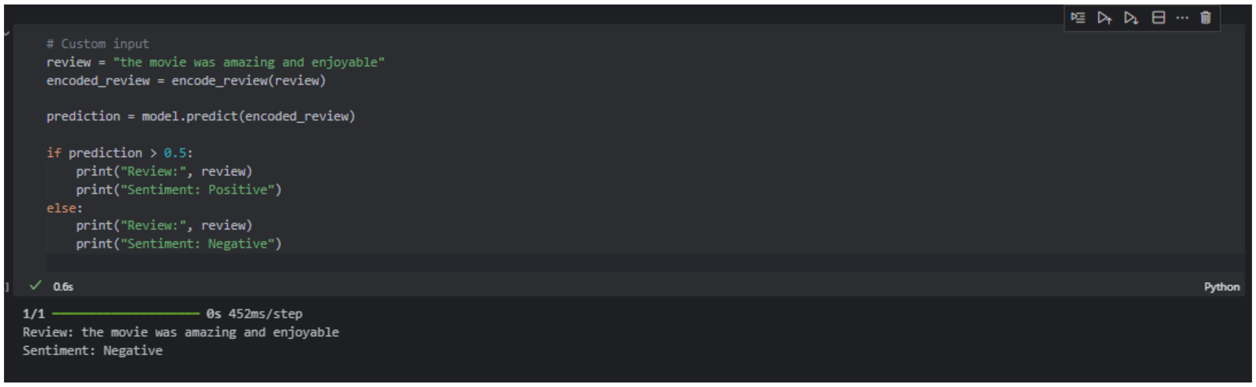
```
Trainable params: 0 (0.00 B)

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

```
model.fit(X_train, y_train)
```

```
460/782 ━━━━━━━━━━━━━━━━━━━━ 23s 74ms/step - accuracy: 0.5449 - loss: 0.6867
```

```
loss, accuracy = model.evaluate(X_test, y_test)
print("Test Accuracy:", accuracy)
# Load word index
word_index = imdb.get_word_index()

def encode_review(text):
    words = text.lower().split()
    encoded = [word_index.get(word, 2) for word in words]
    padded = pad_sequences([encoded], maxlen=max_len)
    return padded
```

```
782/782 ━━━━━━━━━━━━━━━━━━━━ 15s 18ms/step - accuracy: 0.8096 - loss: 0.4510
Test Accuracy: 0.8095999956130981
Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-datasets/imdb_word_index.json
1641221/1641221 ━━━━━━━━━━━━━━━━━━━━ 0s 0us/step
```



```
# Custom input
review = "the movie was amazing and enjoyable"
encoded_review = encode_review(review)

prediction = model.predict(encoded_review)

if prediction > 0.5:
    print("Review:", review)
    print("Sentiment: Positive")
else:
    print("Review:", review)
    print("Sentiment: Negative")
```

```
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 452ms/step
Review: the movie was amazing and enjoyable
Sentiment: Negative
```

LAB Task 4:

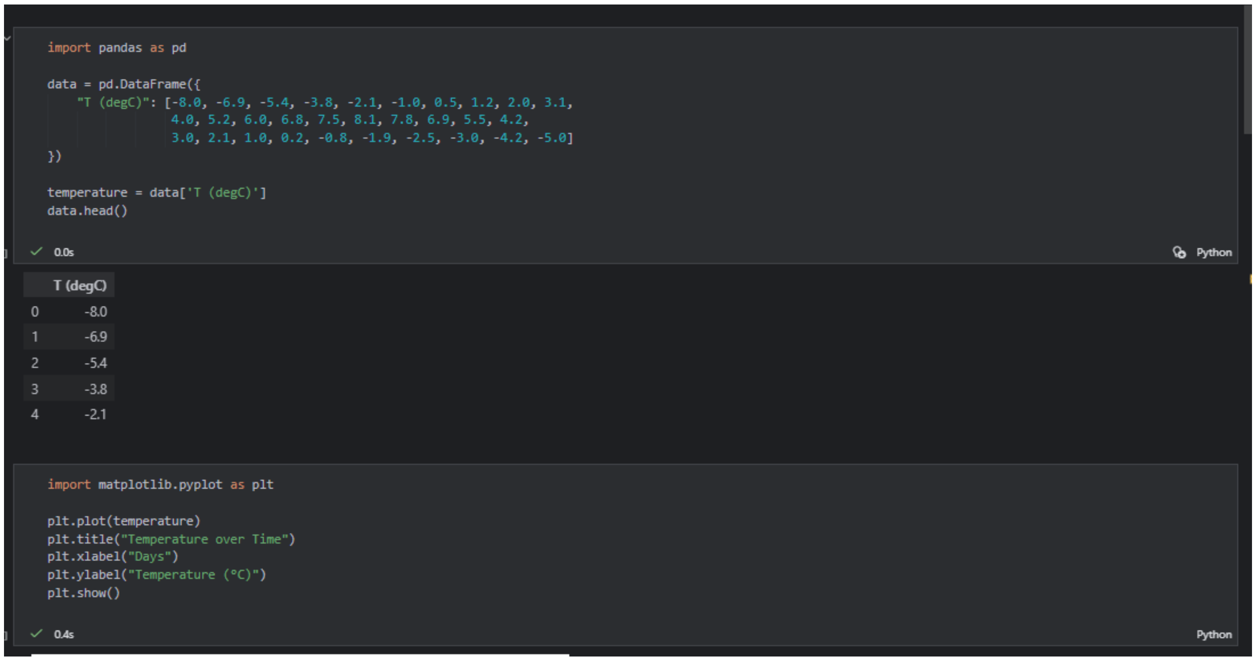
Weather Forecasting using RNN

Objective: Predict future temperature based on previous days' readings.
Dataset: *Daily temperature dataset* (e.g., "Jena Climate Dataset" from TensorFlow).
Tasks:

1. Load and visualize temperature over time.
2. Prepare input-output sequences for time series prediction.
3. Build an RNN to predict next day's temperature.
4. Plot actual vs predicted temperature.

Output:

Graph showing predicted vs actual temperature trends.



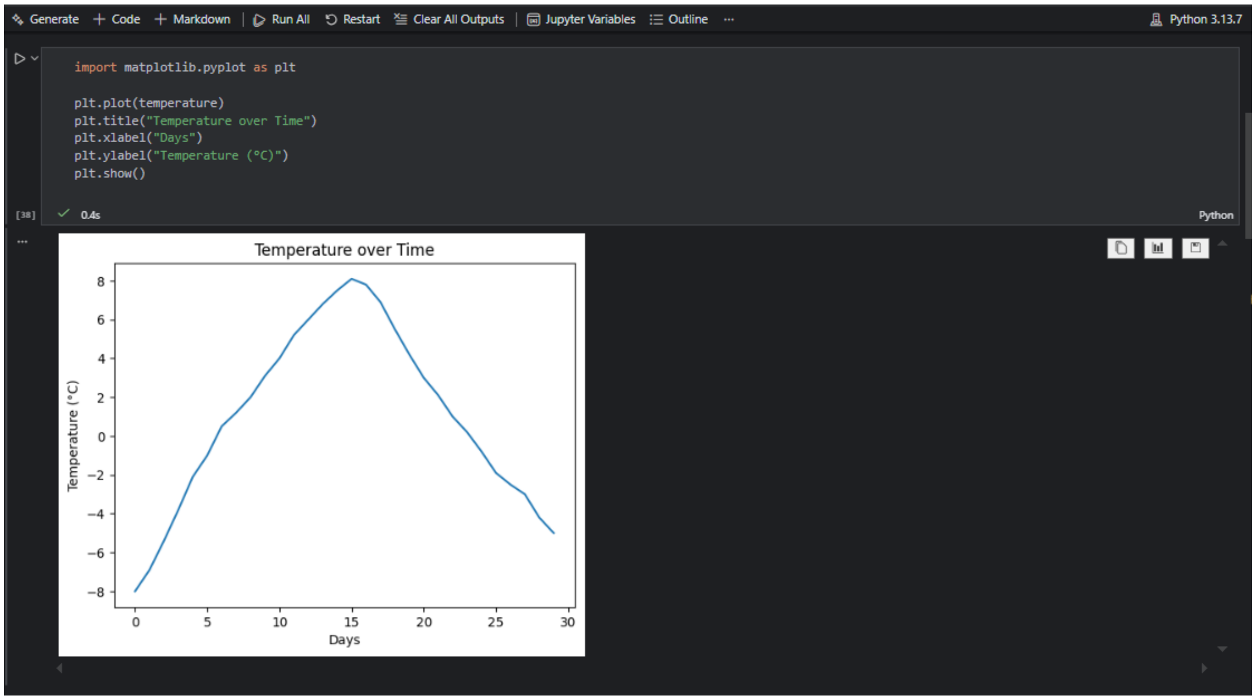
```
import pandas as pd

data = pd.DataFrame({
    "T (degC)": [-8.0, -6.9, -5.4, -3.8, -2.1, -1.0, 0.5, 1.2, 2.0, 3.1,
                 4.0, 5.2, 6.0, 6.8, 7.5, 8.1, 7.8, 6.9, 5.5, 4.2,
                 3.0, 2.1, 1.0, 0.2, -0.8, -1.9, -2.5, -3.0, -4.2, -5.0]
})

temperature = data['T (degC)']
data.head()
```

✓ 0.0s Python

	T (degC)
0	-8.0
1	-6.9
2	-5.4
3	-3.8
4	-2.1

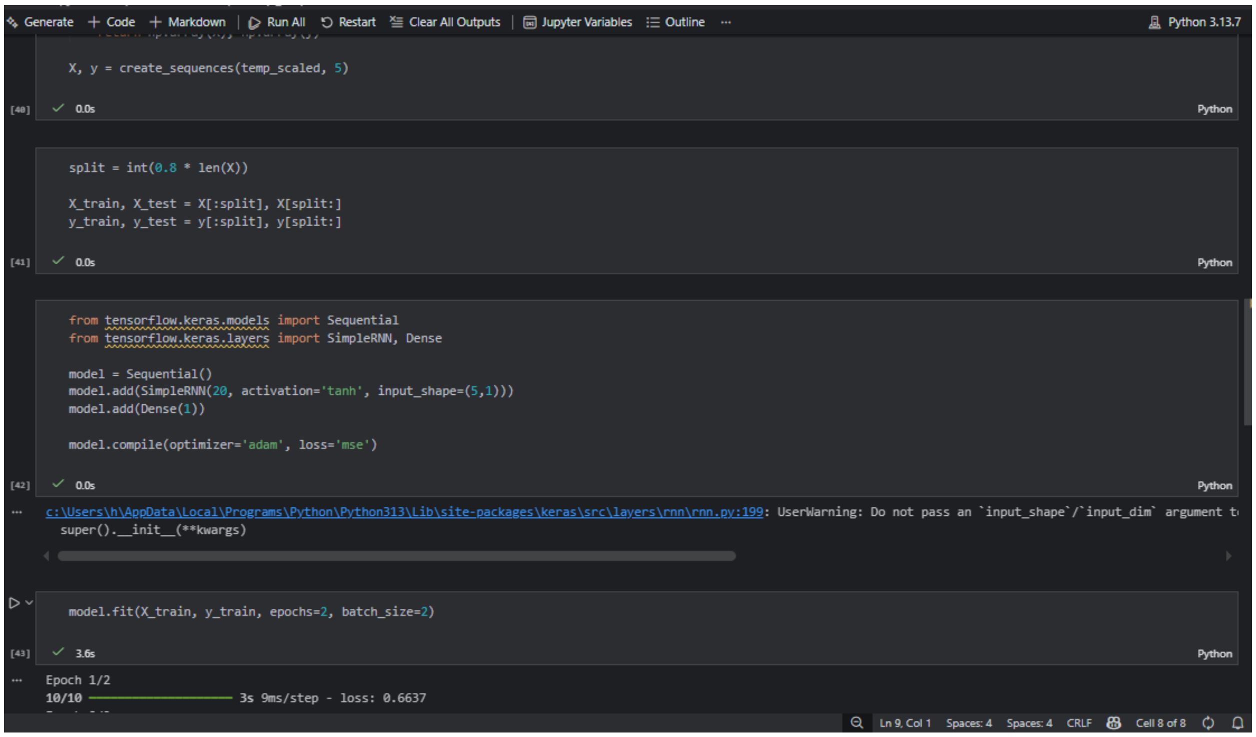
```
import matplotlib.pyplot as plt

plt.plot(temperature)
plt.title("Temperature over Time")
plt.xlabel("Days")
plt.ylabel("Temperature (°C)")
plt.show()
```

✓ 0.4s Python



```
import matplotlib.pyplot as plt

plt.plot(temperature)
plt.title("Temperature over Time")
plt.xlabel("Days")
plt.ylabel("Temperature (°C)")
plt.show()
```

[38] ✓ 0.4s Python

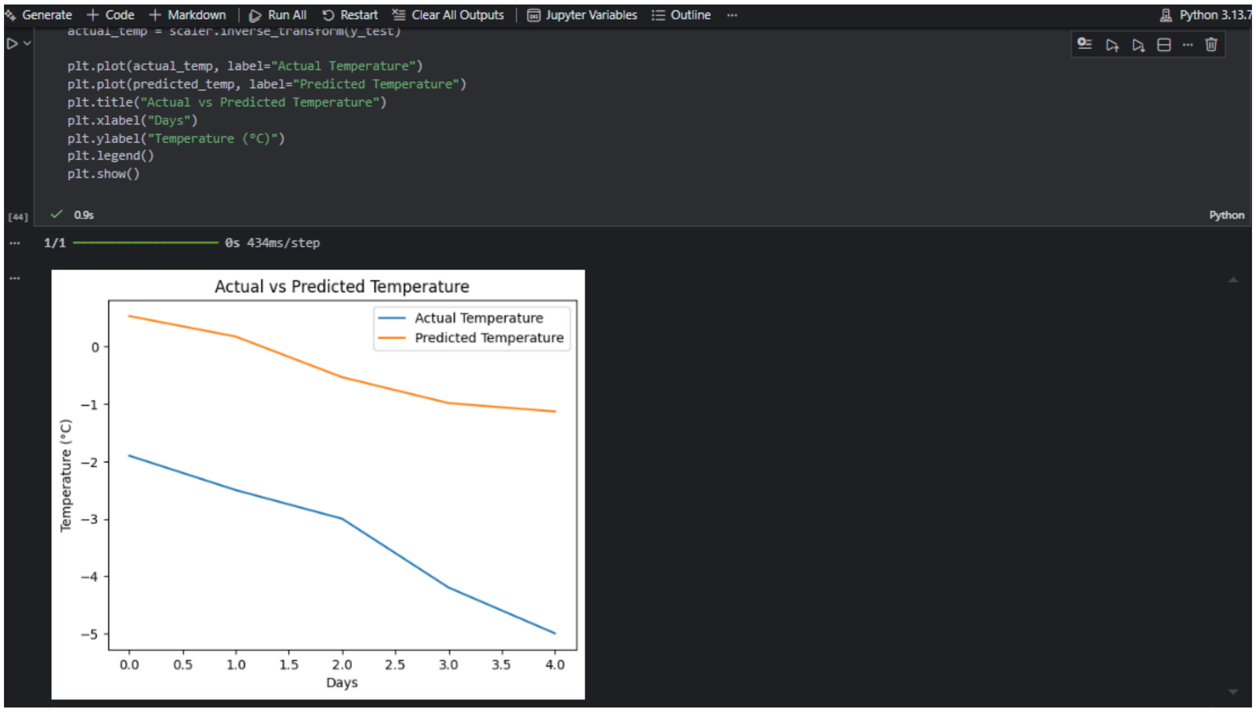


```
X, y = create_sequences(temp_scaled, 5)
```
```
[40] ✓ 0.0s
```

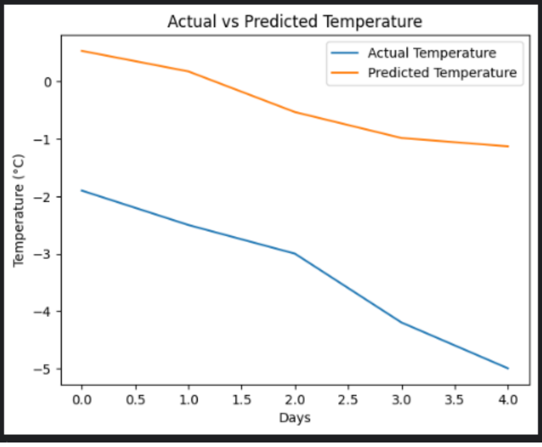
```
split = int(0.8 * len(X))

X_train, X_test = X[:split], X[split:]
y_train, y_test = y[:split], y[split:]
```
```
[41] ✓ 0.0s
```

```
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import SimpleRNN, Dense

model = Sequential()
model.add(SimpleRNN(20, activation='tanh', input_shape=(5,1)))
model.add(Dense(1))

model.compile(optimizer='adam', loss='mse')
```
```
[42] ✓ 0.0s
```
```
c:\Users\h\AppData\Local\Programs\Python\Python313\Lib\site-packages\keras\src\layers\rnn\rnn.py:199: UserWarning: Do not pass an `input_shape`/`input_dim` argument t
  super().__init__(**kwargs)
```

```
model.fit(X_train, y_train, epochs=2, batch_size=2)
```
```
[43] ✓ 3.6s
```
```
Epoch 1/2
10/10 ━━━━━━━━━━━━━━━━━━━━ 3s 9ms/step - loss: 0.6637
```



```
plt.plot(actual_temp, label="Actual Temperature")
plt.plot(predicted_temp, label="Predicted Temperature")
plt.title("Actual vs Predicted Temperature")
plt.xlabel("Days")
plt.ylabel("Temperature (°C)")
plt.legend()
plt.show()
```
```
[44] ✓ 0.9s
```
```
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 434ms/step
```



LAB Task 5:

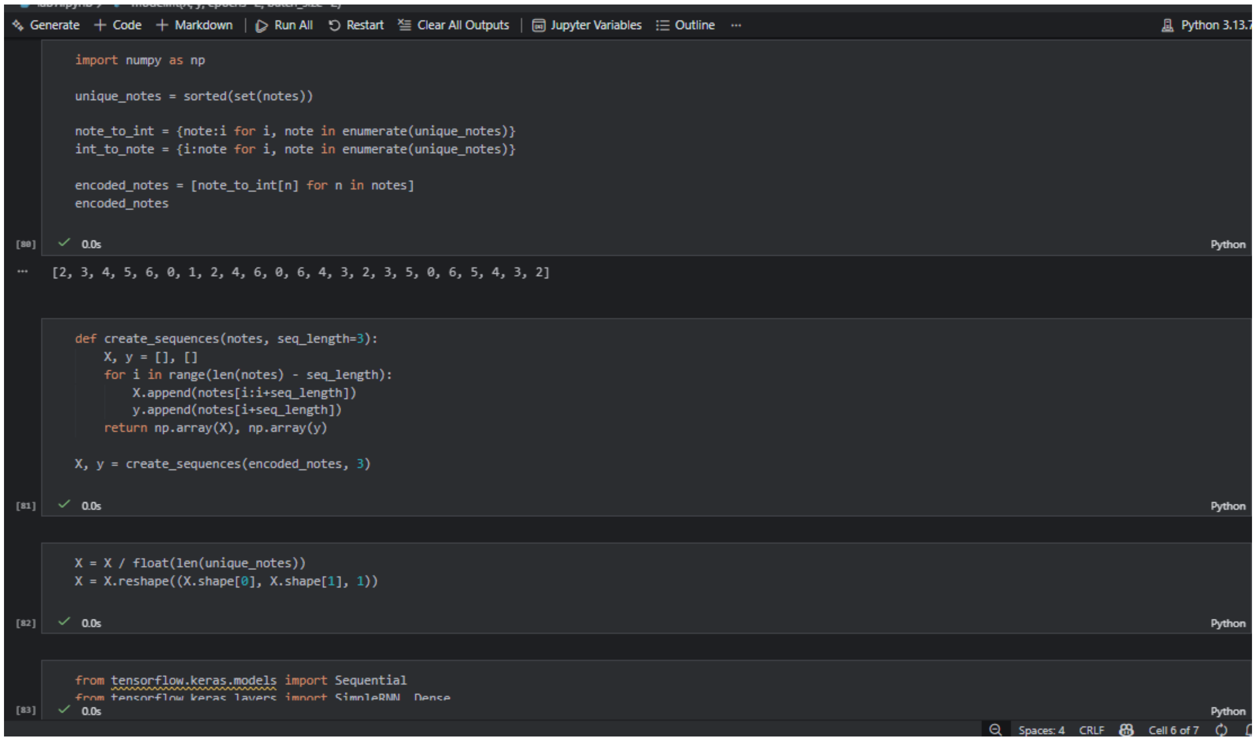
Music Note Generation using RNN

Objective: Generate new music sequences using RNN.
Dataset: *MIDI music dataset* (short sequences or melodies).
Tasks:

1. Convert MIDI data into integer-encoded notes.
2. Train an RNN on note sequences (input: previous notes → output: next note).
3. Generate a new sequence using the trained model.

Output:

A sequence of generated notes that can be converted to a playable MIDI file



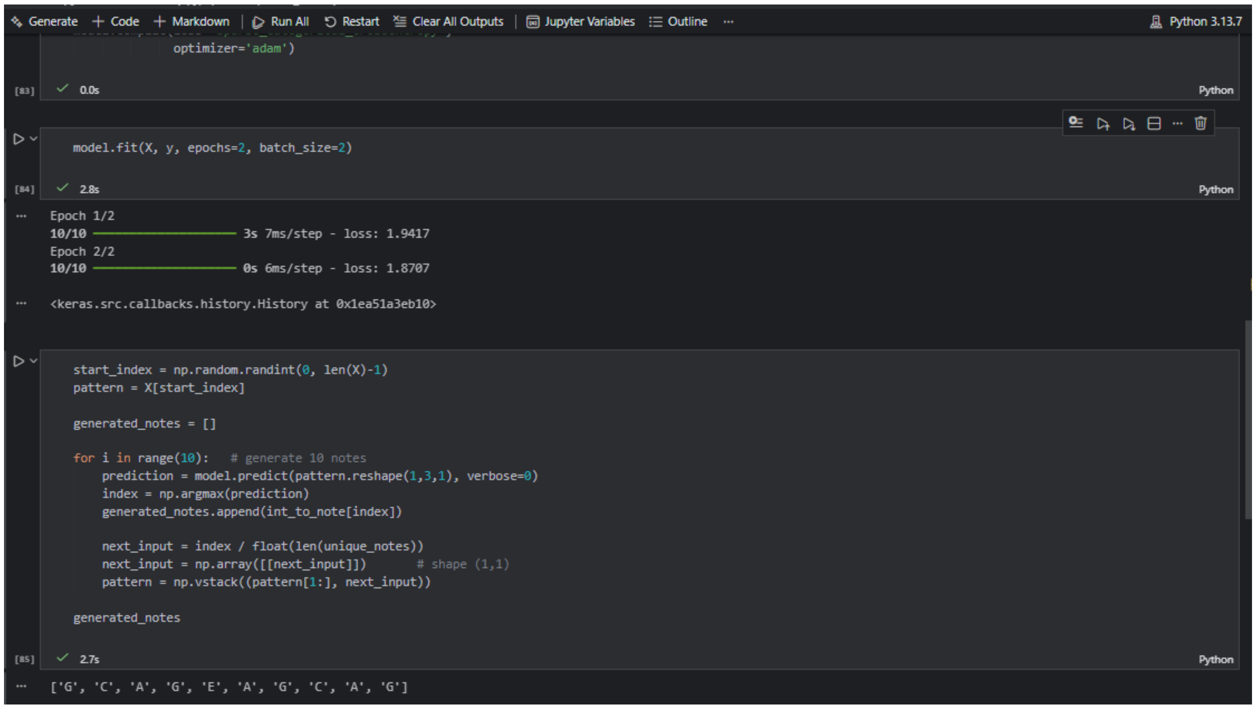
```
import numpy as np

unique_notes = sorted(set(notes))

note_to_int = {note:i for i, note in enumerate(unique_notes)}
int_to_note = {i:note for i, note in enumerate(unique_notes)}

encoded_notes = [note_to_int[n] for n in notes]
encoded_notes
```
[80] ✓ 0.0s Python

```
[2, 3, 4, 5, 6, 0, 1, 2, 4, 6, 0, 6, 4, 3, 2, 3, 5, 0, 6, 5, 4, 3, 2]
```

```
def create_sequences(notes, seq_length=3):
    X, y = [], []
    for i in range(len(notes) - seq_length):
        X.append(notes[i:i+seq_length])
        y.append(notes[i+seq_length])
    return np.array(X), np.array(y)

X, y = create_sequences(encoded_notes, 3)
```
[81] ✓ 0.0s Python

```
X = X / float(len(unique_notes))
X = X.reshape((X.shape[0], X.shape[1], 1))
```
[82] ✓ 0.0s Python

```
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import SimpleRNN, Dense
```
[83] ✓ 0.0s Python



```
                optimizer='adam')
```

[83] 0.0s Python

```
model.fit(X, y, epochs=2, batch_size=2)
```

[84] 2.8s Python

```
Epoch 1/2
10/10 ━━━━━━━━━━━━━━━━━━━━ 3s 7ms/step - loss: 1.9417
Epoch 2/2
10/10 ━━━━━━━━━━━━━━━━━━━━ 0s 6ms/step - loss: 1.8707

<keras.src.callbacks.history.History at 0x1ea51a3eb10>
```

```
start_index = np.random.randint(0, len(X)-1)
pattern = X[start_index]

generated_notes = []

for i in range(10):   # generate 10 notes
    prediction = model.predict(pattern.reshape(1,3,1), verbose=0)
    index = np.argmax(prediction)
    generated_notes.append(int_to_note[index])

    next_input = index / float(len(unique_notes))
    next_input = np.array([[next_input]])       # shape (1,1)
    pattern = np.vstack((pattern[1:], next_input))

generated_notes
```

[85] 2.7s Python

```
['G', 'C', 'A', 'G', 'E', 'A', 'G', 'C', 'A', 'G']
```