Using MATLAB with Python

Heather Gorr, PhD & Yann Debray
Top Questions Using MATLAB with Python

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Example: Build Air Quality App using MATLAB and Python
Follow along with the code 😊
API key was created successfully

You can generate as many API keys as needed for your subscription. We accumulate the total load from all of them.

<table>
<thead>
<tr>
<th>Key</th>
<th>Name</th>
<th>Create key</th>
</tr>
</thead>
<tbody>
<tr>
<td>515d6a97988df8f797bafe41700337d6</td>
<td>expo</td>
<td></td>
</tr>
</tbody>
</table>
Strategies

Data Access

Co-execution

Deployment

Call Python from MATLAB

Call MATLAB from Python
Data Access
Access Data from a Web Service

https://openweathermap.org/

OpenWeather global services

Weather forecasts, nowcasts and history in fast and elegant way

2 Billion Forecasts Per Day
2,500 new subscribers a day

2,600,000 customers
20+ weather APIs

Hourly forecast

<table>
<thead>
<tr>
<th>now</th>
<th>6pm</th>
<th>7pm</th>
<th>8pm</th>
<th>9pm</th>
<th>10pm</th>
<th>11pm</th>
<th>12am</th>
<th>1am</th>
</tr>
</thead>
<tbody>
<tr>
<td>27°C</td>
<td>27°C</td>
<td>26°C</td>
<td>24°C</td>
<td>23°C</td>
<td>22°C</td>
<td>21°C</td>
<td>20°C</td>
<td>19°C</td>
</tr>
</tbody>
</table>

8-day forecast

Wed, Sep 09
Thu, Sep 10
Fri, Sep 11
Sat, Sep 12
Sun, Sep 13
Mon, Sep 14
Tue, Sep 15
Wed, Sep 16

27 / 19°C clear sky
25 / 18°C broken clouds
28 / 17°C scattered clouds
25 / 16°C clear sky
26 / 15°C broken clouds
32 / 17°C scattered clouds
27 / 20°C moderate rain
21 / 17°C light rain
What type of data?
Numerical, Textual, Geolocalized, Timeseries, …

Called by:
geographical coordinates, zip codes, city name, city ID, number of cities (only in current and forecasted APIs)  
https://openweathermap.org/
Store & transfer tabular data between languages

Use Apache Parquet files for memory efficient data access

- Working with Parquet files in MATLAB
- MATLAB library for Apache Arrow on GitHub

```matlab
parquetwrite("temperatureFitting.parquet",T)
```

```python
# Use parquet file as alternative to exchange tables with MATLAB
df = pd.read_parquet("temperatureFitting.parquet")
df.head()
```
Co-execution
Given: Existing Python Code accessing & preparing weather data
Call Python from MATLAB

Co-Execution
- Call Python from MATLAB
- Call MATLAB from Python

Deployment
Call MATLAB from Python

Data Preparation

Modeling

Deployment

- Call Python from MATLAB
- Call MATLAB from Python

Weather Data

Sine fitting of weather forecast in Paris from 16-Jul-2020
Deploy:
MATLAB Analytics into Python

Data Access

Co-Execution
- Call Python from MATLAB
- Call MATLAB from Python

Deployment

Data preparation → Modeling → Deployment

Weather Data

Determine air quality conditions in your area.

Zip code: 02116

My Weather Page

www.myweather.com/stats.html

Site fitting of weather forecast in Paris from 16-Jul-2020

Temperature:

Time increment
Call Python from MATLAB
Why Call Python from MATLAB?

Already working in MATLAB, and:
- Want to reuse existing Python code
- Need functionality available in Python
- Want to collaborate with Python users
Calling Python libraries from MATLAB

Use the weather.py module to get the air quality for Paris. This is a user-defined Python module which includes functions to read and parse the current and forecasted weather data by location.

```python
jsonData = py.weather.get_current_weather("Paris","France",api_key.Key)
```

Parse the json data returned from the weather API.

The Python dictionary can be represented as a MATLAB struct.

```python
weatherData = py.weather.parse_json(jsondata);
struct(weatherData)
```

Use a function (prepData.m) to prepare data for machine learning (create a table with the expected variable names, preprocessing steps, etc).

```python
currentData = prepData(weatherData)
```

CurrentData = 1x12 Table

<table>
<thead>
<tr>
<th>DateLocal</th>
<th>city</th>
<th>StateName</th>
<th>T</th>
<th>P</th>
<th>DP</th>
<th>RH</th>
<th>WindDir</th>
<th>WindSpd</th>
</tr>
</thead>
</table>
First steps to connect to Python

Call Python from MATLAB

Check that MATLAB can recognize the Python installation. Use pyversion if you are using a MATLAB version prior to R2019b.

```
pyenv
```

```
ans =
    PythonEnvironment with properties:
        Version: "3.8"
        Executable: "C:\Python38\python.exe"
        Library: "C:\Python38\python38.dll"
        Home: "C:\Python38"
        Status: Loaded
        ExecutionMode: OutOfProcess
        ProcessID: "51824"
        ProcessName: "MATLABPyHost"
```

Test a simple function.

```
py.math.sqrt(42)
```

```
ans = 6.4807
```
Call the weather service with Python and import data into MATLAB

Handle timeseries with the weather forecast

Now let's get back to France, and look at the weather forecast for this weekend in Paris!

```python
jsonData = py.weather.get_forecast("Paris", apiKey.Key);
forecastData = py.weather.parse_forecast(jsonData);
forecast = struct(forecastData)
```

```plaintext
forecast - struct with fields:
  current_time: [1x40 py.array.array]
  temp: [1x1 py.array.array]
  deg: [1x1 py.array.array]
  speed: [1x1 py.array.array]
  humidity: [1x1 py.array.array]
  pressure: [1x1 py.array.array]
```

```plaintext
forecast.temp
```

```plaintext
ans =
  Python array:
Use details function to view the properties of the Python object.
Use single function to convert to a MATLAB array.
```

```plaintext
tempForecast = double(forecast.temp)
```

```plaintext
tempForecast = 1x40
```
Live Tasks

Data Access

Co-Execution
- Call Python from MATLAB
- Call MATLAB from Python

Deployment

TABLES AND TIMETABLES

- Join Tables
- Retime Timetable
- Stack Table Variables
- Synchronize Timetables
- Unstack Table Variables

Live Tasks Interface:

- Call Python from MATLAB
- Call MATLAB from Python

Retime Timetable

newTimetable = Retime forecast using interpolation

Select data
Input timetable: foreTemp

Specify new times
Selection method: Time step
1 Hours

Select method for adjusting data
General rule: Interpolate data
Linear

Exceptions: Add

Display results
Input timetable
Output timetable

% Retime timetable
newTimetable = retimetable(foreTemp, 'regular', 'linear', 'TimeStep', hours(1))

Output:

<table>
<thead>
<tr>
<th>time</th>
<th>Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 15-Oct-2022</td>
<td>10.500000152587</td>
</tr>
<tr>
<td>2 15-Oct-2022</td>
<td>11.073334223928</td>
</tr>
<tr>
<td>3 15-Oct-2022</td>
<td>11.556669092097</td>
</tr>
</tbody>
</table>
Live Tasks

Data Access

Co-Execution
- Call Python from MATLAB
- Call MATLAB from Python

Deployment

Remove Trends

detrendedData = Remove linear trend from tempForecast

Select data
Input data: tempForecast
X-axis: default

Specify trend parameters
Degree: Linear
Breakpoints: None

Display results
- Detrended data
- Input data
- Trend

% Remove trend from data
detrendedData = detrend(tempForecast);

% Display results
clf
plot(tempForecast,'Color',[109 185 226])
hold on
plot(detrendedData,'Color',[0 114 189],
'DisplayName','Detrended data')
plot(tempForecast-detrendedData,'Color',[106 90 205],
'DisplayName','Trend')
Train air quality prediction model in MATLAB

Data Access

Co-Execution
• Call Python from MATLAB
• Call MATLAB from Python

Deployment
Use air quality prediction model on Python data

Use the model to predict the air quality for the new weather data.

'airQualModel.mat' is a pre-trained Bagged Classification Tree/"Random Forest" classification network. The model was saved as a *.mat file for use in predicting air quality in this demonstration.

```matlab
load airQualModel
```

Use a function (prepData.m) to convert and prepare data for machine learning (create a table with the expected variable names, preprocessing steps, etc).

```matlab
apikey = readtable("accessKey.txt","TextType","string");
List = "Houston";
jsonData = py.weather.get_current_weather(List,"US",apiKey.Key);
weatherData = py.weather.parse_current_json(jsonData);
currentData = prepData(weatherData);
```

Data Access

Co-Execution
- Call Python from MATLAB
- Call MATLAB from Python

Deployment

Use air quality prediction model on Python data
Recap: Calling Python from MATLAB
Data are automatically converted where possible

*Otherwise convert explicitly*

### MATLAB to Python Data Type Mapping

When calling a Python© function, MATLAB® converts MATLAB data into types that best represent the data to the Python language.

#### Pass Scalar Values to Python

<table>
<thead>
<tr>
<th>MATLAB Input Argument Type — Scalar Values Only</th>
<th>Resulting Python <code>py</code> Type</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>double single</td>
<td>float</td>
<td>Use Python Numeric Variables in MATLAB</td>
</tr>
<tr>
<td>Complex single</td>
<td>complex</td>
<td></td>
</tr>
<tr>
<td>Complex double</td>
<td></td>
<td></td>
</tr>
<tr>
<td>int8</td>
<td>int</td>
<td></td>
</tr>
<tr>
<td>uint8</td>
<td>int</td>
<td></td>
</tr>
<tr>
<td>int16</td>
<td>int</td>
<td></td>
</tr>
<tr>
<td>uint16</td>
<td>int</td>
<td></td>
</tr>
<tr>
<td>int32</td>
<td>int</td>
<td></td>
</tr>
<tr>
<td>uint32</td>
<td>int (version 2.7 only)</td>
<td></td>
</tr>
<tr>
<td>int64</td>
<td>int</td>
<td></td>
</tr>
<tr>
<td>uint64</td>
<td>int</td>
<td></td>
</tr>
<tr>
<td>NaN</td>
<td>float(&quot;nan&quot;)</td>
<td></td>
</tr>
<tr>
<td>Inf</td>
<td>float(&quot;inf&quot;)</td>
<td></td>
</tr>
<tr>
<td>string scalar</td>
<td>str</td>
<td>Use Python str Variables in MATLAB</td>
</tr>
</tbody>
</table>

Note the syntax differences when calling Python from MATLAB

Python

```python
>>> import math
>>> math.sqrt(42)
```

MATLAB

```matlab
>> py.math.sqrt(42)
```

Python

```python
>>> print('hello','world',sep=' ', )
```

MATLAB

```matlab
>> py.print('hello','world',... pyargs('sep',' ', ))
```
Model Interoperability

Learn more about
Data Science with MATLAB

Data Science With MATLAB

Heather Gorr, PhD
Senior Product Manager, MATLAB
MathWorks

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Twitter: @HeatherGorr
Call MATLAB from Python
Why call MATLAB from Python?

Already working in Python, and:
- Want to reuse existing MATLAB code
- Need functionality available in MATLAB
- Want to collaborate with MATLAB users
Call MATLAB from Python
To perform advanced analytics

- Calling MATLAB from Python
  - via MATLAB Engine API

```bash
PS C:\\Program Files\\MATLAB\\R2021a\\extern\\engines\\python\\python setup.py install
```

```python
>>> import matlab.engine
>>> eng = matlab.engine.start_matlab()
>>> 
```
Call MATLAB from Python

To perform advanced analytics

- Calling MATLAB from Python
  - via MATLAB Engine API

```
>>> import matlab.engine
>>> eng = matlab.engine.start_matlab()
>>> eng.sqrt(42.0)
6.48074069840786

>>> z = eng.gcd(42.0, 8.0, nargout=1)
>>> print(z)
2.0
>>> z = eng.gcd(42.0, 8.0, nargout=3)
>>> print(z)
(2.0, 1.0, -5.0)
```
Call MATLAB from Python

To perform advanced analytics

- Calling MATLAB from Python
  - via MATLAB Engine API

```python
[1] import matlab.engine
    eng = matlab.engine.start_matlab()

Test a simple function

[2] x = eng.sqrt(float(43))
    print(x)

6.557438524302
```

- Call MATLAB function which returns multiple outputs.

```python
[3] y = eng.gcd(42.0, 8.0, nargout=1)
    print(y)

2.0
```

- More in Deployment:
  - via MATLAB Runtime
    (MATLAB Compiler SDK)
  - via MATLAB Production Server
Recap: Calling MATLAB from Python
Note the syntax differences when calling MATLAB from Python

MATLAB

```
>> [s,sidx] = sort(x)

>> foo(x)

>> C = A + B
```

Python

```
>>> s = eng.sort(x,nargout=2)

>>> eng.foo(x,nargout=0)

>>> C = eng.plus(A,B)
```
Data are automatically converted where possible

Deployment
Generate Python library from MATLAB functions

- Call Python from MATLAB
- Call MATLAB from Python

Deployment

- Generate Python library from MATLAB functions
Generate Python library from MATLAB functions

Data Access

Co-Execution
- Call Python from MATLAB
- Call MATLAB from Python

Deployment

- Generate COM Component
- Java Package
- .NET Assembly
- Python Package

NAMESPACE

Samples

Additional installer options

Files required for your library to run:
- AirQualModel.mat
- cities.mat
- prepData.m

Files installed for your end user:
- predictAirQual
- setup.py
Generate Python library from MATLAB functions

**Data Access**
- Call Python from MATLAB
- Call MATLAB from Python

**Co-Execution**
- Generate Python library from MATLAB functions
- Install library

**Deployment**
- Install library
Execute Python library from MATLAB functions

Predict Air Quality: Calling MATLAB from Python Using MATLAB Runtime

Import the weather data and use the MATLAB code to predict air quality.

Use the MATLAB Runtime to call the model and code, which does...
MATLAB Production Server
Access functions as web services

Calling our function:

{"nargout":1,"rhs":["input"]}

Getting the result:

{"lhs":{"mwdata":"output","mwsize":1,6,"mwtype":"char"}}
Execute Python library from MATLAB functions

Air Quality Conditions

Determine air quality conditions in your area.

Location: Seattle, WA

Submit

The air quality is **Good**.
The current temperature is **30.15 F**.
Share MATLAB App in the Web – Central Deployment

Data Access

Co-Execution
- Call Python from MATLAB
- Call MATLAB from Python

Deployment
MATLAB App Designer

App development for Non-Programmers

- Call Python from MATLAB
- Call MATLAB from Python

Deployment

App development for Non-Programmers with MATLAB App Designer.
Data Access

Co-Execution
- Call Python from MATLAB
- Call MATLAB from Python

Deployment

MATLAB Web App Server – Central Deployment

- R2019b
- R2020a

MATLAB Web App Server

Web App

OpenWeather

IQAir

47
Integrate your Production System in an IT ecosystem

Data Access
- Call Python from MATLAB
- Call MATLAB from Python

Co-Execution

Deployment

Data
- Streaming data
- Data stores
- Big Data
  - cloudera
  - databricks

Production System
- MATLAB Production Server
  - Worker processes
  - Request Broker

Analytics Development
- Compiler SDK
- MATLAB
- Package & Deploy
- Model

Business Decisions
- Tableau
- Spotfire
- PowerBI
- Qlik
- Web App
  - Dashboards
- Enterprise App
  - RESTful API
Use MATLAB Reference Architectures for easy cloud setup, Dockerfiles, and interfaces to OSS

- [https://github.com/mathworks-ref-arch/matlab-dockerfile](https://github.com/mathworks-ref-arch/matlab-dockerfile)

[Image of MATLAB Reference Architectures]

https://github.com/mathworks-ref-arch
MATLAB Integration for Jupyter

Data Access

Co-Execution
- Call Python from MATLAB
- Call MATLAB from Python

Deployment

MATLAB Integration for Jupyter (mathworks.com)
Data Access

Co-Execution
- Call Python from MATLAB
- Call MATLAB from Python

Deployment

Find out more: Cloud and IOT
Summary: Using MATLAB with Python

- **Access Data**
  - Weather App example

- **Interoperability**
  - Calling libraries written in Python from MATLAB
  - Calling MATLAB from Python

- **Deploy Apps & Algos**
  - Web App
  - Production API
Resources

- Cheatsheet
- Example on GitHub
- Blog post
- Videos
  - Calling Python from MATLAB
  - Calling MATLAB from Python
  - Using MATLAB with Python + Q&A (YouTube live stream recording)
- Documentation
  - Calling Python from MATLAB
  - Calling MATLAB from Python via:
    - MATLAB Engine API
    - MATLAB Compiler SDK
    - MATLAB Production Server
  - Data management:
    - Data type conversions
    - Working with Parquet files
    - MATLAB library for Apache Arrow on GitHub
  - Deep Learning (TensorFlow, PyTorch, etc)

MATLAB EXPO 2021

Thank you

MATLAB + Python