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White paper

Alternative approach to implementing HTTP webservices based on Matlab code

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1 Introduction

Webservices are very useful for a variety of computing tasks. In this article we investigate the possibility to add a HTTP(S) interface to Matlab based software.

The Mathworks offers several routes to create a webservice from Matlab code. In all cases you'll need the Matlab compiler SDK. Starting from there you have a few options:

- compile your Matlab code to a component that integrates with C++, Java or Python, and use one of these languages to implement a HTTP server;
- create a Docker® container-based microservice with a JSON interface;
- package Matlab functions for deployment on the MATLAB Production Server.

2 Limitations of the Matlab native approach

Although the suite of Mathworks products has its strong points, it also has its drawbacks.

From a cost perspective these solutions require the purchase of Matlab Compiler and Matlab Compiler SDK, and either require familiarity with an additional programming language (for example Python or Java) or the purchase and installation of MATLAB Production Server including at least 4 workers. Further scaling requires purchasing additional workers.

From a practical point of view it is worth noticing that server side code will only execute after compilation and subsequent deployment. This takes away part of the appeal of the original Matlab IDE, because you'll lose abilities like instant deployment, break point debugging, data inspection and execution of random code snippets from the command line.

From a functional perspective a disadvantage is that none of these methods make the HTTP request object available to the Matlab code. Access to this HTTP object helps with the proper integration of a webservice with a variety of client-side applications, for example by enabling control over response headers, return codes and authentication. Another limitation is that the starting and stopping of webservers is not controlled from within Matlab scripts but requires an external action.

Because of this type of considerations users might decide to migrate away from Matlab, even if this means re-implementing existing code in a different language.

3 Alternative approach: MEWT

The Modelit Embedded Webserver toolbox (MEWT) offers an alternative route for implementing Matlab based webservices. Contrary to the solutions discussed above, the MEWT makes it possible to use Matlab as a standalone HTTP(S) server with authentication and authorization. Supporting multiple webservices on different paths and ports. When invoked these webservices will invoke a Matlab callback with the complete HTTP request context. By default this callback is called with a com.sun.net.httpserver.HttpExchange object wrapped in a Matlab object as its only argument.

The HTTPExchange object is created by MEWT and has intuitive methods for retrieving the request data, headers, method, and setting the response headers, mime type, data, and the response code. The HttpExchange object support all HTTP methods such as GET, POST, OPTIONS. It can handle requests and responses in any format, e.g. JSON, XML or even serialized Matlab Objects. Besides this it also supports reading and setting the HTTP headers. For example, to solve CORS issues or implement User authentication and authorization.

Running this solution does not require additional software components. You can use Matlab as a webserver, run your own webservices or implement your own (restful) API’s in any active Matlab session, enabling easy debugging, or compile it with the Matlab compiler to an executable for stand-alone deployment. Once compiled, multiple instances of the service can be run without additional license costs or configuration of a license manager.

As compiled services require no additional components, packaging them in Docker containers is straightforward. If scaling is required the free NGINX load balancer can be used to run multiple workers in parallel, or the executable can be embedded in any other industry standard container orchestration tool such as Kubernetes.

Another use case is to extend a monolithic Matlab application with a HTTP(S) interface for integration with third party products. In this scenario it is convenient that webservices can be launched from within the application.

4 Example applications of MEWT

4.1 Web portal for accident analysis

Powering webportals is a major application of webservices. The figure below depicts the processes involved in the accident analysis webportal hotspots.modelit.nl. This portal helps the operator to identify candidates for speed enforcement by selecting road sections that combine high speed limit negation rates with high accident rates at any given time frame.

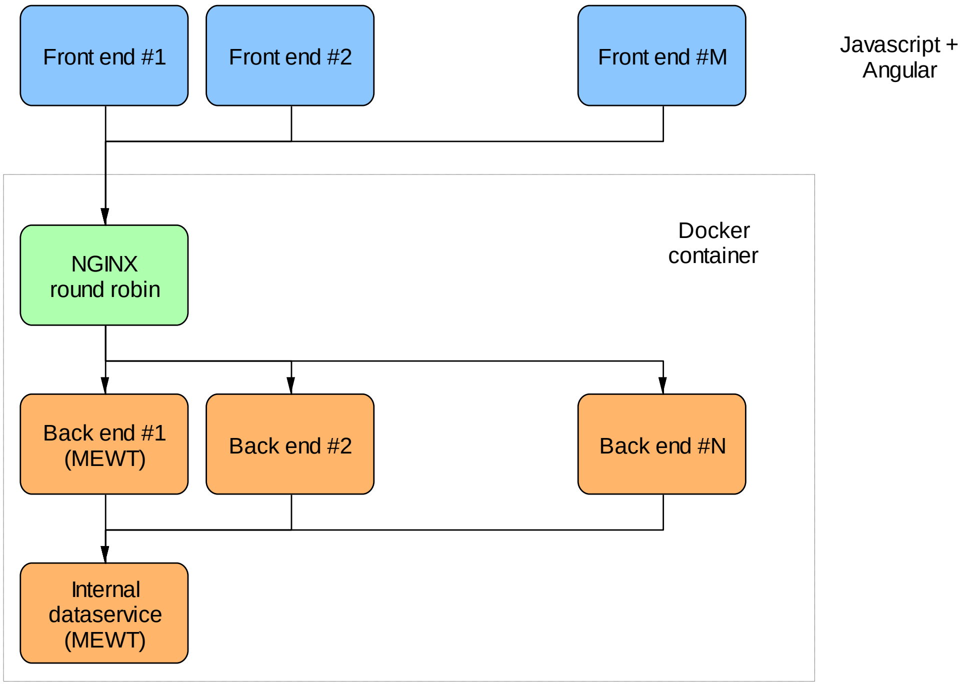
The portal is web based hence multiple users will be accessing it at the same time. The front end is implemented with the Angular framework.

Website data and graphics are supplied by a service called "Back-end". Typical tasks for this service are:

- creating png map tiles with dedicated graphics that are overlayed over a zoomable and interactive geographical map;
- Delivering content for tables that are displayed in the front-end;
- Creating chartJS HTML5 code that is displayed in the front-end.

This service is implemented in Matlab with a JSON interface using MEWT. To handle high loads, multiple instances of "Back-end" run in parallel using NGINX as a load balancer. The application relies on a large dataset containing up to 4 years worth of traffic speed and flow data at a 1 minute aggregation for over 11.6K cross sections. When changes are made in the query form in the front-end the selection of road sections is updated within seconds. This selection task is outsourced to the process "internal dataservice". This service keeps the entire dataset in memory so that it can be accessed instantly.

After several rounds of optimization this selection now only takes a few seconds. Therefore, the traditional form submit button could be removed from the front-end. The application now simply responds while the user is typing.



4.2 Calling Matlab functions remotely

Another compelling use case is where one calls a Matlab function that executes in another Matlab session, for example to access data that are only available at a remote location or to offload a computationally intensive task.

MEWT takes full advantage of the Matlab native methods to serialize data to establish compressed and lossless data exchange between client and server. It also uses the Matlab “anonymous function” construct to obtain an elegant notation that effectively hides complexity from the user.

The table below shows code snippets that can be used for remote function execution.

Server side	`%create an anonymous function that is a proper MEWT callback`
	`fp_server=remoteCallback('serverSideFunction');`
	
	`%launch a webservice that listens to PORT and processes`
	`%incoming requests:`
	`modelit.web.server.Server(<PORT>,fp_server).start;`

Client side	`%create an anonymous function that is interchangeable`
	`%with @serverSideFunction`
	`fp_client=remoteFunction(<URL:PORT>,@serverSideFunction)`
	
	`%execute serverSideFunction remotely.`
	`[a, b] = fp_client(c, d , e)`
	
	`%note that fp_client and serverSideFunction can be used`
	`interchangeably, even server side error messages are`
	`reproduced at the client side.`

MEWT contains additional utilities for executing asynchronous tasks as well.

4.3 Serving a javascript single page application (SPA)

As mentioned before, the MEWT is a fully functional server, able to serve any type of file, and it is thus possible to make a Single Page Application which is dynamically generated in Matlab.

For example, if the MEWT callback is set like this:

```
function Callback(event)
event.send(200,readBytesFromFile(helloworld.html'));
```

The (static) content of `helloworld.html` will be displayed in the browser. But “Callback” can be used to return anything, including HTML and javascript code that is generated on the fly. One can create a React or Angular app and let the MEWT serve these files. After loading, this app will again call MEWT for the necessary resources such as css and javascript and for the dynamic content that is generated with Matlab code.

An example of such an approach is shown at the permanent MEWT demo page: https://www.modelit.nl/demo_MEWT/temperatureconversion

The underlying Matlab code is shown at: https://www.modelit.nl/modelit/ToolboxModelit/embeddedmatlabserver/examples/html/TemperatureConversionCallback.html

The demo can be used as a template to create your own SPA.

5 MEWT availability and support

A free version of MEWT is shared on our website. This version is fully functional but contains no Matlab source code, except for the examples. A full source code version can be purchased from us at a rate of 1000 euro (excluding VAT). This version is also freely available if it will be solely used for teaching and university research purposes, or if you hire us for a project of 12 hours or more.

at Modelit we have over 15 years of experience with creating and running Matlab based websites and services. You can hire us for a variety of MEWT related consulting tasks such as:

- Setting up the toolbox and help you getting started;
- Convert your legacy Matlab code to a Matlab based webservice or develop a webservice from scratch for you particular application;
- Help you with deploying your webservice in the cloud or on your private server;
- Package your application in a Docker container;
- NGINX load balancing;
- Assist with related issues such as firewall and router setup;
- Assist with SSL setup;
- Creating a javascript SPA or a more elaborate web portal;

6 References

Hoogland, K.J. and Zijpp, N.J. van der (2023), Modelit Embedded Webserver Toolbox for Matlab (Version 20230622) [Software]. Available from www.modelit.nl

Mathworks (2020) MATLAB Production Server Guide. Planning, Deployment, Operations, and Application Development. Published online at: https://www.mathworks.com/content/dam/mathworks/guide-or-book/matlab-production-server-guide.pdf

Mathworks (2023) Product Requirements & Platform Availability for MATLAB Production Server - MATLAB (mathworks.com) [web page]