



**FACULTY
OF MATHEMATICS
AND PHYSICS**
Charles University

BACHELOR THESIS

Tomáš Husák

**Client-side execution of PHP
applications compiled to .NET**

Department of Software Engineering

Supervisor of the bachelor thesis: RNDr. Filip Zavoral, Ph.D.

Study programme: Computer Science (B1801)

Study branch: ISDI (1801R049)

Prague 2021

I declare that I carried out this bachelor thesis independently, and only with the cited sources, literature and other professional sources. It has not been used to obtain another or the same degree.

I understand that my work relates to the rights and obligations under the Act No. 121/2000 Sb., the Copyright Act, as amended, in particular the fact that the Charles University has the right to conclude a license agreement on the use of this work as a school work pursuant to Section 60 subsection 1 of the Copyright Act.

In date
Author's signature

Dedication.

Title: Client-side execution of PHP applications compiled to .NET

Author: Tomáš Husák

Department: Department of Software Engineering

Supervisor: RNDr. Filip Zavoral, Ph.D., Department of Software Engineering

Abstract: Blazor is a new technology enabling to run .NET applications directly in the browser using WebAssembly, a recently created binary instruction format adopted by major web browsers. Whilst PHP is the most popular language in the realm of web applications, it cannot run directly in the browser. The PeachPie compiler provides a way to compile projects written in PHP into Common Intermediate Language (CIL), enabling them to run on the .NET platform.

This thesis aims to design and implement a convenient interface between Blazor and compiled PHP, enabling developers to create client-side PHP applications. These applications would be able to utilize the specifics of the client-side paradigm, such as fast response times, the possibility to preserve the application state between the requests more efficiently and the direct access to the Document Object Model (DOM) of the page. To demonstrate the usability of the implementation and the specific benefits of the solution, a pilot interactive application will be created.

Keywords: PHP .NET Blazor Peachpie

Contents

Introduction	2
1 Existing technologies	3
1.1 WebAssembly	3
1.2 Mono	3
1.3 Blazor	4
1.3.1 Blazor WebAssembly App	4
1.4 Peachpie	6
1.5 PHP	7
2 Problem analysis	8
Conclusion	9
Bibliography	10
List of Figures	11
List of Tables	12
List of Abbreviations	13
A Attachments	14
A.1 First Attachment	14

Introduction

Nowadays, web applications are mostly dynamic in order to offer a convenient user interface. Dynamic features of a web application are achieved by a programming language JavaScript which is supported by all modern web browsers like Google Chrome, Safari, Opera, and Mozilla. Despite advantages that have JavaScript, like manipulation with DOM, WebAPI, and easy syntax, there are also several severe disadvantages.

The first of them is a slow execution and effectiveness compared with other languages like C++ and CSharp. It became crucial for 3D graphics and, another time expensive computations. Since December 2019, when the W3 Consortium has begun recommending WebAssembly, this problem is solved because WebAssembly is almost as fast as native code in modern browsers. Another advantage of WebAssembly is being a target of compilation-friendly low-level languages like C or C++ due to its memory model. Although there are exists ways, how to compile other high-level languages like CSharp or PHP. A concrete project relates to a PHP to WebAssembly compilation is Pib.

The second problem of Javascript relates to developing a whole web application in more than one single language even though there are Node.js and the project Pib which has some limitations. PHP is the most popular server-side language. Since developers have to understand two programming languages, there is more space for mistakes.

One of this thesis's goals is to design a comfortable way how developers can write a whole web application using only PHP. It can be considered to reinvent a gear, but there is another way how to achieve similar results as the mentioned project and even more to add a new feature.

This thesis aims to integrate Peachpie and Blazor, which results in an interesting connection between PHP world of libraries for server-side processing and Blazor world, which is another way how to create a dynamic web application without JavaScript. Peachpie is able to compile PHP into CIL, and Blazor runs CSharp code on a client-side. So this approach has the potential to offer a possibility to PHP and CSharp developers to collaborate with their programming languages using a minimum knowledge of the integration. Another interesting functionality of this approach is full CSharp, PHP, and JavaScript interop which offers more options for developers and future extensions.

The first chapter addresses existing technologies used in the integration, alongside the existing project, which uses direct compilation to WebAssembly. The second chapter describes the problem of running PHP on the client-side and other problems related to used technologies. The third gives a detailed problem's solution. There are examples that demonstrate how to use all aspects of the created solution in chapter 4. In chapter 5, you can see benchmarks that explore the limits of implementation and compare them with the already existing project. And the last chapter relates to a conclusion of this solution.

1. Existing technologies

In the beginning, I will introduce an existing solution of how to run PHP in a browser. The project Pib aims to use compiled PHP interpreter into WebAssembly, which allows evaluating a PHP code. The page has to import a specialized module `php-wasm`. A PHP code is evaluated by writing a specialized script block or manually by JavaScript and API. PHP can afterward interact with JavaScript using a specialized API. At first glance, that might be a good enough solution, but they are several parts that can be problematic due to PHP semantics. The solution doesn't solve globals. This is reasonable because this is the server's job, but you are not able to get information about a query part or handling forms without writing a JavaScript code. The next problem is navigating how a script can navigate to another script without an additional support code which has to be JavaScript. These problems can be solved by following technologies and their integration.

1.1 WebAssembly

Web [a] is a new code format that can be run in today's browsers. It has a compact byte format, and its performance is near to a native code. WebAssembly is designed to be a compiling target of popular low-level languages like C or C++ due to its memory model. It should be able to support languages with garbage collector in the future. The advantage of this format is a similarity with Javascript modules ES2015 after compilation into a machine code. This enables browsers to execute it by a JavaScript runtime. So its security is as good as a code written in Javascript. Because of the same runtime, WebAssembly can call Javascript and vice versa.

The support is currently discussed nowadays and appears to be realistic. After all, new versions of Google Chrome experiments with true multi-threading support despite of the chance of vulnerability. A replacement of multi-threading can be web workers referred in Web [b] article. The workers limitation is communication with UI thread only by messages.

Despite supporting to run WebAssembly in a browser, the browser cannot load it as a standard ES2015 module yet. WebAssembly JavaScript API was created in order to be able to load a WebAssembly to a browser using JavaScript.

1.2 Mono

Mono is a .NET runtime that aims to mobile platforms. Recently, they started to support com into WebAssembly. This support allows executing CIL inside browsers. The compilation has two modes. The first one is compilation Mono runtime with all using assemblies. The second only compile Mono runtime, which then can execute .dll files without further compilation of them into WebAssembly. A consequence of these compilations into WebAssembly is enabling to call Javascript and WebAPI from .NET.

1.3 Blazor

Blazor is a framework that provides a convenient way how to write dynamic web pages using CSharp. Blazor platform is divided into two Hos which have different approaches to creating web applications. The first one is referred to as Blazor Server App and has a similar methodology to a standard website written in PHP. An interesting innovation is SignalR which is a communication protocol between the server and a client. However, this thesis uses the second model, which Microsoft refers to as Blazor WebAssembly App enabling offline support after loading the app into a browser.

1.3.1 Blazor WebAssembly App

From now on, I will use Blazor App to refer Blazor WebAssembly App. Blazor App can be divided into two parts. The first part serves the main WebAssembly application and its additional resources, which can be requested during runtime. The second part is WebAssembly wrapped together with an additional user code. The division enables to choose of a place for the implementation of business logic. If there is a bad connection, we can move the majority of business logic to the client and use the server for connection to a database; otherwise, we can use the client only for rendering the page. It consists of the following components. Kestrel with ASP.NET libraries provides the server part of an application. Mono runtime compiled to WebAssembly runs CSharp code inside a browser. WebAssembly is essential for being able to interact with DOM and JavaScript using CSharp without an additional plugin, which was necessary for older technologies like Microsoft Silverlight. Blazor's libraries provide constructs for manipulation with DOM and WebAPI together with rendering the page and JavaScript interop. And there is a user's code that using the libraries for creating dynamic pages with CSharp. A better imagination, how the app is situated on the client-side, can be represented by the figure 1.1 copied from Gli.



Technical details of interoperating with a browser are one part of the Blazor App. The main part is the architecture of the libraries. A common approach how to create a page is using the markup language Razor. There already exists Razor in standard ASP.NET website where `.cshtml` extensions consist of this markup. Unfortunately, the markup used in BlazorApp has the same name. From now on, I will use Razor for the markup language, which is the content of `.razor` files in Blazor App. Because interleaving HTML with other languages turns out to be helpful, the Razor uses special characters to identify CSharp code in HTML and convert it to rich content pages. A significant purpose of Razor is for generating CSharp structures, which represent parts of a page, during compilation time. These structures have a complex interface for rendering a page, so the markup is there in order to free users using a complicated mechanism for putting a page together.

Blazor introduces a Component that can represent a whole page or the part of it. Components can be arbitrarily put together in order to form the desired page. They can have different purposes. For example, a Router takes care of routing the right page whenever the navigation is triggered. Alongside components, a dispatcher supplies additional services like logger to components when they are creating. The last item, which is not used transparently, is a WebAssemblyHost builder. The builder configures the application and prepares the renderer used by components to render their content.

Balzor presents its own virtual DOM to reduce changing a DOM directly in a browser to its demanding performance. A component works with `RenderTreeBuilder`, which provides an interface for adding content to the virtual DOM. The usage of `RenderTreeBuilder` is complex due to Blazor’s diff algorithm, which is used afterward. `RenderTreeBuilder` is just a superstructure over `Renderer`, which

is responsible for updating the page. The diff algorithm is used to minimize the browser's DOM update after all components used `RenderTreeBuilder` to render their content. This algorithm used sequence numbers for parts of HTML to identify modified sections. Sequence numbers respond to an order of `RenderTreeBuilder`'s instructions in the source code. A benefit of this information is detecting loops and conditional statements to generating smaller updates of DOM. It follows the browser's DOM update, which is executed by Blazor's JavaScript support code called through Mono runtime.

The process of bootstrapping the Blazor App to a browser follows these steps. Kestrel gets a request for a page that is contained in Blazor App. The server responses with the `index.html` page, which contains references to JavaScript support code (This code is referred to as `blazor.js` and `mono.js` in the figure 1.1) responsible for loading and running the runtime with the application part. The runtime runs the application using the `Main` method in Blazor App. The remaining interactions are maintained by event handling. I distinguish two types of events. The first type is navigation. The nav can be triggered by an anchor, form, or filling up the URL bar. The URL bar is handled separated by a browser. JavaScript can influence the remainings elements. Blazor App handles only an anchor by. After clicking on an anchor, predefined methods in `blazor.js` try to invoke navigation handler in Blazor App using a Mono WebAssembly gateway. A user can modify this handler, but a specialized component Router implements a default behavior. The Router finds out all components, which implements an `IComponent` interface, by a reflection and tries to render the page according to path matching `RouteAttribute` of a component. The navigation can be redirected to the server if there is no match. The second type is events invoked by UI like `onchange`. These event's callbacks call right CSharp callbacks thanks to `RenderTreeBuilder`, connecting CSharp callback with element's event.

1.4 Peachpie

Pea is a modern compiler based on Roslyn and Phalenger project. It allows to compile PHP into a .NET assembly, which can be executed alongside standard .NET libraries. Peachpie introduces several structures representing states, scripts, and variables of PHP written in Csharp. First of them is a context representing one request to PHP code. The context consists of super globals, global variables, declared functions, declared and included scripts. A possibility of saving the context and using it later is a major advantage used in the solution. The context can be also consider as a configuration of comming script's execution. Every information about a request can be arrange to mock every situation on server-side. The compiler offers dedicated type of assembly for PHP libraries. Using this assembly can add addition functions, which can provides a extra nonstandard functionality as an interaction with a browser. Another advantage of the compiler is a great interoperability between PHP and .NET. An option to work with Csharp objects, attributes and calling methods will become crutial for achieving advanced interaction between Blazor and PHP.

However there are limitations following from differences of the languages and the stage of development. Availability of PHP extensions depend on binding these function to CSharp code giving equivalent results, even more a time and

memory complexity together with supporting this code in Blazor can be tricky. The previous mentioned interoperability has limits as well. Csharp constructs like structs and asynchronous methods are undefined in PHP.

1.5 PHP

This section describes the language with a common practice for a website development. PHP was designed for generating a page on server-side. This purpose creates several features that make a website development easy. PHP has dynamic types in order to more concentrate on intuitive usage. The most of PHP application has the semantic of one way pass. A request incomes to server calls the script. The script generates a response and shutdowns. The intention of being a server-side language introduces special global variables representing an incoming request. These variables are dictionaries. Three variables are relevant for the thesis. The GET variable stores parsed query part of the URL. The POST variable stores a variables which are sent by post method. The FILES variable contains uploaded files. There is also a SESSION variable, which holds an user session. This variable will become needless because of the final solution. Global functions are the most popular characteristic of PHP despite of wide-spreaded object oriented programming. It is untypical to use asynchronous methods in PHP.

It is hard to follow trends in web applications due to fast changing technologies, but the following concepts are popular for a few years. The basic pattern is Front Controller. There is usually a main script which invokes other parts of the program, based on the request, to deal with it and sends the response back. A HTML interleaving has appeared to be useful method for data binding. The feature allows to insert a PHP code between HTML. These fragments does not have to form an individual indenpendent blocks of code closed in curly brackets. The only way how to add user's interaction with the page were forms before Javascript. So most of developers should be familiar with this concept.

2. Problem analysis

Conclusion

Bibliography

URL <https://daveaglick.com/posts/blazor-razor-webassembly-and-mono>.

Hosting models. URL <https://docs.microsoft.com/en-us/aspnet/core/blazor/hosting-models?view=aspnetcore-5.0>.

URL <https://docs.peachpie.io>.

The project pib. URL https://github.com/oraoto/pib?fbclid=IwAR3KZXWCC3tlgQf886PF3GT_Hc8pmfCMI1-43gdQEdE5wYgpv070bRwXqI.

URL <https://developers.google.com/web/updates/2018/10/wasm-threads>.

Webassembly, a. URL <https://developer.mozilla.org/en-US/docs/WebAssembly/Concepts>.

b. URL https://developer.mozilla.org/en-US/docs/Web/API/Web_Workers_API/Using_web_workers.

compilation. URL <https://www.mono-project.com/news/2017/08/09/hello-webassembly/>.

URL <https://chrissainty.com/an-in-depth-look-at-routing-in-blazor/>.

List of Figures

1.1	Running a Blazor WebAssembly App on client-side.	5
-----	--	---

List of Tables

List of Abbreviations

A. Attachments

A.1 First Attachment