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YESWEB: A CONCISE WEB DEVELOPMENT FRAMEWORK BASED ON HASKELL

[1]XIAO LIU, [2]YEONEO KIM, [3]SUGWOO BYUN, [4]GYUN WOO,

[1,2]Dept. of Electrical and Computer Engineering, Pusan National University, Busan 46241, South Korea

[3]Department of Computer Engineering, Kyungsung University, Busan 48434, South Korea

[4]Smart Control Center of LG Electronics, Busan 46241, South Korea

E-mail: [1,2,4]{liuxiao, yeoneo, woogyun}@pusan.ac.kr, [3]swbyun@ks.ac.kr

ABSTRACT

This paper presents YesWeb, an improved framework of Yesod. Yesod is a well-known web-development framework written in Haskell. However, the syntax of it is somewhat verbose and not familiar to those who are not accustomed in functional programming. In contrast with Yesod, YesWeb allows the user to create a web system in a more concise way with a familiar programming syntax. Further, YesWeb takes the full advantage of the many-core architectures to get high performance of parallel computing. Still, YesWeb does not lose the advantages of valuable Haskell features including the type-safety, the modularity, and the parallelism and concurrency. To demonstrate the effectiveness of YesWeb, we have developed a blog application using YesWeb. The result shows that the performance of YesWeb is proportional to the number of cores until the workload saturated.

Keywords: *Haskell, web development framework, parallel computing, many-core architecture*

1. INTRODUCTION

In this paper, we present YesWeb, a compatible extension of Yesod, both of which are web development frameworks written in pure functional programming language Haskell. Though Haskell provides Yesod with a versatile features including the type-safety and the modularity, the unfamiliar syntax of it hinders programmers from using it for implementing realistic web systems. Further, the implicit concurrency of Haskell is not fully utilized in Yesod even though Haskell supports parallel constructs.

YesWeb is a concise and efficient web development framework based on Haskell. Though it is derived from Yesod, it supports a natural syntax similar to imperative and object-oriented counterparts. Further the resulting syntax is concise. This conciseness implies that the developers can express their intension in a relatively short code, which makes the final code be less error-prone.

The concise syntax of YesWeb is provided in addition to the full functional one. Actually, the concise syntax is supported as a mode, namely "the concise syntax mode," in addition the normal functional syntax mode. The concise syntax mode is quite intuitive for the imperative and the object-oriented developers to understand.

In fact, developing web applications using existing frameworks is still not simple. To implement a working web application, the developers are required to have a good understanding on the design of the web front-end, the underlying logic of the implementation, the data management, and the request processing [1]. There are numbers of web application frameworks, such as ASP.NET, Zend Framework, Django, and Ruby on Rails, which can help web developers to build many kinds of web applications [2].

Using those web application frameworks, several different programming languages are required such as C#, PHP, Python, and Ruby. Additionally, basic web programming languages such as HTML, CSS, and Javascript are also needed for the front-end of the web design [3]. There are also several different web application servers such as IIS, Apache, Nginx, lighttpd, and Node.js, which can provide a powerful platform for running web applications [4].

Further, according to different servers, the different server side programming languages are also

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be required. In addition, the SQL is usually required, too, if the web application is supposed to manage data. Following up all these languages and frameworks required to the front-end and the back-end of web applications can be quite time-consuming for web application developers.

On the other hand, how to handle the large-scale of requests processing is becoming a hot issue in the web development fields [5]. As illustrated in Figure 1, the number of Internet users has increased more than three times in a recent decade, reaching up to more than 3.2 billion, and is still increasing [6].

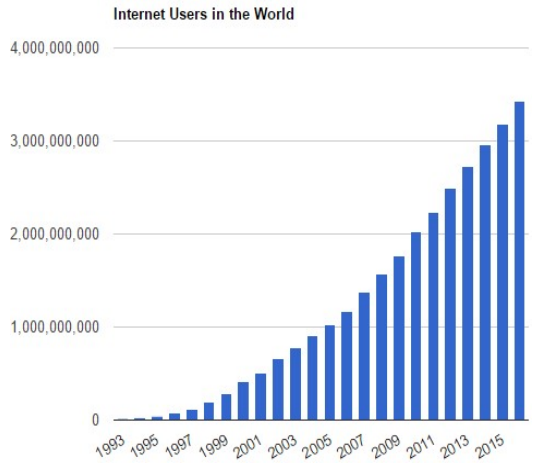

Figure 1: The increment of the number of Internet users during the past decades. The number of Internet users has increased more than three times in a recent decade.

A natural but brilliant approach to make the web applications process a large quantity of requests from users is adopting the parallelism and concurrency [7]. The existing web applications mentioned above such as Apache can achieve parallel processing and concurrency with the aid of a framework so called Camel [8]. The ISS server also provides parallelism functions for parallel processing [9]. Nginx further supports load balancing on top of the parallelism and concurrency [10]. Other servers including Lighttpd also support parallel computing as well [11]. And Node.js supports a package named node-parallel to implement parallel processing, too [12].

Yesod includes most features of web components such as website template design, web page routing, the data storage, the sessions, and the authentication. YesWeb, as an improved model of Yesod, provides more convenient programming environment than Yesod so that users can create a web system using a more concise programming syntax. All elements of the web application can be developed in only one Haskell source file that can simplify the file structure.

YesWeb also supports the high performance of parallel computing in many-core architecture that can process a large amount of data stream. This is a striking advantage obtained for free owing to Haskell, which has an inherent parallelism and provides several parallel constructs. Both of the front-end and the back-end of a web application can be developed through YesWeb.

YesWeb and Yesod take advantage of most features of Haskell properties such as the static type system, both pure and monadic computations, the parallelism with lightweight threads, the data-stream processing based on lazy evaluation, etc. [13]. Most of all, the type safety guarantees that a web application runs in a type-safe manner once it is verified though the compilation, which saves a lot of test cost and effort.

This paper is organized as follows. Section 2 introduces related works such as the features and issues in existing web frameworks, features of Haskell, Yesod framework and its web server named Warp. Section 3 presents the architecture and features of YesWeb framework. Section 4 demonstrates an implemented web application that developed based on YesWeb framework named YesWeb-Blog. Section 5 presents the parallelism and concurrency of YesWeb-Blog to verify the feasibility, the practicability, and the functionality of YesWeb framework. Section 6 concludes this work. Section 7 addresses some limitations and future directions of the proposed work.

2. RELATED WORK

2.1 Existing web frameworks

With growth and evolution of the Internet, there are many of web application development frameworks such as ASP.NET, Zend Framework, Django, and Ruby on Rails, and many of web servers, such as IIS, Apache, Nginx, and Lighttpd, are introduced for running web applications [14]. These frameworks and servers are wildly used. For example, the BBC website is developed using Zend Framework and Apache server; the Bitbuket is built

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on top of the Django framework. Each of these frameworks and servers has its own features and problems.

ASP.NET is a web application framework developed by Microsoft and ASP stands for Active Server Page [15]. ASP.NET inherits the concept of MVC (Model-View-Controller) which provides an abstractive architecture for data protection and the independent components resulting a great help for programmers to focus more on their own development part [16]. Using ASP.NET framework with the powerful IDE, the Microsoft Visual Studio, the programmers can develop a functional web application with functionalities including the web contents presentations, request processing, responding, data management, and the security protection [17].

However, this famous web application framework, ASP.NET still has several weaknesses and problems. Firstly, ASP.NET only supports Microsoft Windows operating system well since it is based on .NET framework. The programmers can only use the maximal performance of ASP.NET on the Windows operating system and Microsoft Visual Studio [18]. Secondary, since the mechanism of ASP.NET is on the compile-and-run basis implying that it has to compile and run the ASP program over and over to send the HTML file to client's web browser for every time the client send request to server [19], it consumes lots of time and resources. Last one is the compatibility problem of web pages on different web browsers. Many of built-in web components in ASP.NET framework are only runnable on the Internet Explorer browser which is also developed by Microsoft, other browsers such like Firefox and Chrome might not be able to execute those components.

Zend Framework is another famous web application framework implemented in PHP 5 [20]. All the components of Zend Framework are fully object-oriented, and the loosely coupled use-at-will architecture can make the partial modification on web applications more convenient and easy [21]. Zend Framework also supports multiple databases including MariaDB, Mysql, Oracle, Microsoft SQL server, and SQLite [22]. The wonderful compatibility and portability of PHP makes Zend Framework operate on different operation systems, implying that the programmers do not have to be bound on a specified development environment [23].

However, this framework has its own problems, too. Because the complicated components and objects should be loaded every time once there is a script to be executed [24], Zend Framework seems too slow to run a web application which based on it. Some of disadvantages inherited from the PHP itself is the vulnerability; the external additional files may mess up the file structure of the web application; the errors will only appear when the scripts are executed.

Django is a web application framework which written in Python [25]. Different with ASP.NET and Zend Framework, Django has a built-in but standalone lightweight web server to let programmers test and debug their web applications [26]. Django also provides a useful data transition system that can easily and conveniently translate data between the HTML forms and the databases [27]. Not only that, the middleware classes and internal dispatcher system of Django can help programmers develop their web applications more quickly. This framework can also interact with XML and JSON [28].

However, according to Dauzon's book [29], the server hosts are not allowed to be changed in Django. A security vulnerability is also discovered in Django framework, which allows hostile attack on web applications [30]. The disadvantages of Python also influence the performance of Django, resulting the lower computing performance [31] and the memory management problems due to the overhead of Python [32].

Ruby on Rails is a web application framework written in Ruby and it follows several valuable software engineering principles such as DRY (Don't Repeat Yourself) and CoC (Convention over Configuration) [33]. Since Ruby on Rails is one of the famous projects in GitHub, there are lots of developers working on the improvement of the performance of it [34].

However, there are also several technical issues about Ruby on Rails. Alex Payne, a developer of Twitter, criticized the scalability problem of Ruby on Rails [35]. Also, a vulnerability problem on the security of the Ruby on Rails has also been reported, that may reveal cookie information without authentication [36].

IIS (Internet Information Services) is a web server developed by Microsoft and supports many of Internet protocols such like HTTP, HTTPS, FTP, FTPS, SMTP, and NNTP [37]. There are several features of IIS such as SNI (Server Name Indica-

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tion), dynamic IP address restrictions, and CPU throttling that are very helpful for developers or for administrators to deploy and to manage web applications quite comfortably [38].

However, like ASP.NET, IIS only supports Microsoft Windows operation systems or servers well. The compatibility problem reduces the portability of IIS and the web application runs on it.

Apache is a HTTP server and served as one of most popular servers [39]. The URL rewriter module and the virtual hosting function can help programmers to develop and to run multiple web applications without worrying the server distribution. A framework named Camel helps Apache to achieve parallel processing, which can improve the request processing performance.

However, there are many of complicated configurations on Apache when programmers want the Apache to fit their web applications. Besides, Apache does not provide a friendly user interface to help developers to configure it.

Nginx is a web application server which supports the concurrency with low memory usage [40]. The reason for Nginx to be able to process more requests in a unit time with low resource utilization is the distributed processing. It has a main process to distribute jobs to multiple worker processes [41]. Different to Apache, the architecture of Nginx supports the asynchronous event-driven mechanism that affords to show a certain performance under high loads [42].

However, Nginx also has its own problems. The ability of Nginx to processing dynamic requests is not quite useful, compared with Apache, Nginx cannot report the problem immediately after a re-configuration if the configuration file has any problem including a simple typo. [43].

Lighttpd is a lightweight web application server that has high security and flexibility; it also supports chroot, servlet, and Cache Meta Language [44]. However, Lighttpd has lots of restrictions which can make the development process complicated [45].

2.2 Parallelism in Haskell

Haskell is quite suitable for parallel programming due to its purity of functional programming. As it uses no mutable variables, i.e. no assignment statements, every expression has a unique value independently in the order of evaluation. From this point of view, one can say Haskell has the property of natural parallelism.

Recent versions of GHC, a Haskell compiler, support several constructs for parallel computation. Its virtual machine manages its own threads independently from OS threads, lightweight thread fork, thread scheduling, and profiling. Using the tool ThreadScope, one can analyze graphically the statistics produced from executing programs and debug the parallel performance [46].

It is convenient to build parallel programs using the parallel constructs such as par, pseq in source code [47]. The '–threaded' option to tell the compiler that program is proposed to run concurrently when compiling Haskell code and using '+RTS –N' option with the number of cores specifying the maximum number of threads for processing and executing the program. The overhead of GHC threads is extremely low so that GHC is quite powerful in a large amount of event processing. This feature is beneficial in the efficiency of web applications.

2.3 Yesod

For web development, Haskell also provides a powerful and convenient web application framework named Yesod. As a web application framework, Yesod includes almost all of necessary web development tools and technologies such as layout design, function development, and system deploying.

Yesod does not require programmers to write all the HTML, CSS, and Javascript code to print the layout of the web page. This framework has a template named Shakespearean family to generate all the source code [48]. Specifically, Yesod supports templating languages: Hamlet for generating HTML code, Lucius and Cassius for generating CSS code, and Julius for generating Javascript code. All of these template languages are quite easy to use, and the type safety of Haskell ensures that all of the generated code are correct.

Warp is an outstanding Haskell web server used not only for Yesod application but also for other Haskell web applications. Especially the seamless integration of Yesod with Warp makes the best of performance. Only a little configuration is required for deploying and running a web application on Warp, and this convenient approach can reduce lots of time and work.

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3. ARCHITECTURE AND FEATURES OF YESWEB

As we mentioned, YesWeb can support its web application run on a many-core machine to provide parallelism and concurrency for handling a large amount of accessing. The YesWeb framework with Warp server and GHC compiler can work together to generate web applications. The requests and responses between the client and the web application can be handled after compiling from source code and running the web application on the server at the back-end.

Figure 2 illustrates the three-tier architecture of YesWeb. The infrastructure layer provides the hardware environment that is a sever consisting of a database storage device and many-core processors; the application layer contains YesWeb framework and GHC for creating a web application to be run on the Warp server; the client layer allows clients to access web application and to use it.

YesWeb also provides a concise programming syntax mode for the developers who are not familiar with Haskell. The concise syntax is able to generate Haskell code through a code generator.

Table 1 presents a comparison among YesWeb and other frameworks we mentioned in subsection 2.1 and Yesod framework we introduced in subsection 2.3. The comparison result shows that YesWeb is advantageous at all facets such as WORA (Write Once, Run Anywhere), loading speed, security, and the conciseness of the syntax.

We introduce an example of using the concise syntax mode of YesWeb in the next Section

4. USABILITY TEST OF YESWEB: IMPLEMENTING YESWEB-BLOG

As a usability test of the YesWeb framework, we created a web application named YesWeb-Blog, an online blog application, using YesWeb framework. YesWeb-Blog has the functions such as user authentication, posting articles and comments. As we mentioned, the source code of YesWeb-Blog is developed in only one .hs file that is easy to migrate and maintain, rather than developing web application through other approaches to create various of files including .html, .js, .css, .php (or other back-end scripting source code files).

```
$doctype 5
yesweb-blog.url = pl.pusan.ac.kr:5111
yesweb-blog.pages.Auth.Manager = YesWeb.Auth("pllab@pusan.ac.kr");
yesweb-blog.pages.Post = YesWeb.SendInfo(title, content);
```

Figure 3: Concise syntax mode of YesWeb, which provides familiar syntax to imperative and object-oriented developers.

```
instance Yesod YesBlog where
    approot = ApprootStatic "http://pl.pusan.ac.kr:5110"

isManager visitor = visitorMailAddr visitor == "pllab@pnu.ac.kr"
postListR :: Handler Html
postListR = do
    ((res, articleWidget), enctype) <- runFormPost articleF
    case res of
        FormSuccess article -> do
            articleId <- runDB $ insert article
            setMessageI $ MsgEntryCreated $ articleHeading article
            redirect $ ListEntryR articleId
        _ -> defaultLayout $ do
            setTitleI MsgPleaseCorrectEntry
```

Figure 4: Complex syntax mode of YesWeb, which is similar to Yesod adopting a full-fledged functional syntax.

We also test the syntax mode of YesWeb in our web application. Figure 3 and Figure 4 demonstrate the comparison of the concise syntax mode in YesWeb and the Yesod programming syntax. Figure 3 shows the concise syntax code supported in YesWeb. The first line decides the document type as HTML 5; the second line is for setting the URL of YesWeb-Blog; the third line configures the manager ID of YesWeb-Blog that only the authenticated user can manage the contents of our web application; the fourth line adds two variables added by the manager for posted articles: article's title (title) and the content of article (article). If the developer is familiar with Haskell syntax, then the Haskell-liked syntax mode shown in Figure 4 which is based on Yesod is also available for build the same functions in Figure 3. Comparing the two modes in Figure 3 and 4, the YesWeb supports more concise syntax than Yesod, which can help developers to build their web application faster.

Figure 5 demonstrates how YesWeb-Blog looks like on a web browser. Once a user clicks the link (a) shown in Figure 5(1), YesWeb-Blog will

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bring the user to the sign in web page shown in (b) of Figure 5(1), which is called from a third-party system named Persona. After the authentication progress, YesWeb-Blog will show a web page similar to (c) in Figure 5(1). Figure 5(2) shows the test result for posting an article with a comment from a guest.

```
<html>
▶<head>…</head>
▼<body background="http://164.125.34.198:5110/static/background.png?
etag=LIfYDas_">
   <p>There are no articles in the blog</p>
 ▼<form method="post" enctype="application/x-www-form-urlencoded">
    <input type="hidden" name="_token" value="oK332zTXsw">
   ▼<div class="required ">
      <label for="hident2">Article Title</label>
      <input id="hident2" name="f1" type="text" required value>
    </div>
   ▼<div class="required ">
      <label for="hident3">Article Content</label>
     ▶<div unselectable="on" style="width: 600px;">…</div>
     ▶<div style="width: 600px; border-width: 0px 1px 1px; border-top-
      style: initial; border-right-style: solid; border-bottom-style:
      solid; border-left-style: solid; border-top-color: initial; border-
      right-color: rgb(204, 204, 204); border-bottom-color: rgb(204, 204,
      204); border-left-color: rgb(204, 204, 204); border-image: initial;
      overflow-y: auto; overflow-x: hidden;">…</div>
      <textarea class="html" id="hident3" name="f2" style="display:
      none;"></textarea>
    </div>
   ▼<div>
      <input type="submit" value="Publish to blog">
    </div>
  </form>
  <script src="http://js.nicedit.com/nicEdit-latest.js"></script>
  <script>
  (function(){new nicEditor({fullPanel:true}).panelInstance("hident3")})
  ();
  </script>
 </body>
</html>
```

Figure 6: HTML code generated by YesWeb-Blog for rendering the corresponding web page on web browsers.

The entire HTML code for rendering web pages in Figure 5 is presented in Figure 6, which is generated through only one Haskell source code file named YesWeb-Blog.hs. The HTML code is generated on a web browser when a user accessing our web application. Therefore, to migrate the web application to another machine, the only thing we have to do is move the YesWeb-Blog.hs file to another place then compile and execute it.

5. PERFORMANCE OF YESWEB-BLOG

Figure 7 presents the benchmark result, the variation of the throughput of YesWeb-Blog with increasing the number of cores. We measured the number of concurrent hitting times on YesWeb-Blog in 60 seconds as the number of cores is increasing.

With this measurement, we can verify the performance of parallelism and scalability for handling a large amount of accesses on YesWeb-Blog.

The graph in Figure 7 shows two cases: 500 and 1,000 concurrent users. YesWeb-Blog processed a similar number of accesses from 500 users no matter how many cores are processing.

However, when there were 1000 users, YesWeb-Blog only was able to process requests on more than six cores. The numbers of successfully handled accesses are also growing from 6 cores to 10 cores. This result shows that YesWeb is adaptable and scalable on many core environments.

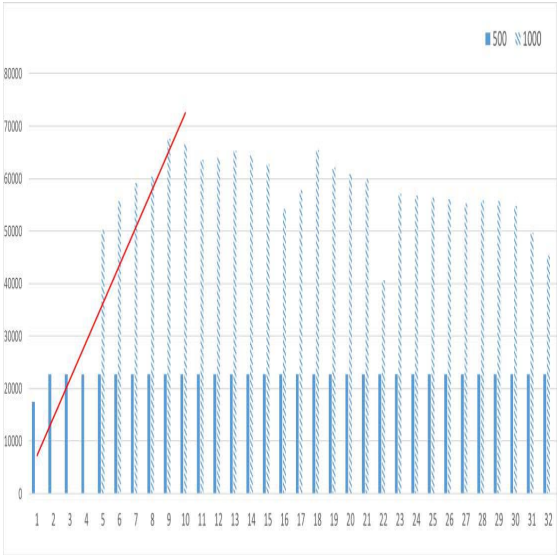

Figure 7: Performance benchmark evaluated by an HTTP load testing utility named Siege. Two cases are shown in this experiment: 500 concurrent users and 1000 concurrent users. Each of the cases are tested 32 times from a single core to 32 cores for handling accesses in 60 seconds.

6. CONCLUSION

In this paper, we proposed a new web application development framework named YesWeb. Developers can use YesWeb in the overall process of a web application development including the front-end design, data handling, and requests processing.

We compared YesWeb with existing web development frameworks. Most of web application frameworks and web servers have issues on their

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efficiency and compatibility. According to the comparison result, YesWeb can be a viable alternative to existing frameworks.

YesWeb is a compatible extension of Yesod framework to provide more concise programming syntax and to archive parallelism and concurrency. The concise programming syntax of YesWeb is much productive. To test the effectiveness of YesWeb, we created an implementation of YesWeb named YesWeb-Blog, an online web blog application, which is written only in 220 lines of Haskell code.

To summarize, the contributions of this work are two folds:

- YesWeb provides a concise and familiar syntax understandable for imperative and object-oriented developers, yet not losing the valuable features of Haskell
- YesWeb supports the parallelism to provide the high performance by utilizing the full advantage of parallel machines including many-core architectures.

7. LIMITATIONS AND FUTURE WORK

Though the performance of YesWeb-Blog is also satisfactory up to 21 cores of the many-core architecture, it needs improvement for more cores. Particularly, the performance of parallel data processing is not growing after more than 10 processor cores. The main reason for this can be the overhead of the run-time system of Haskell.

Improving the scalability of parallel data processing of YesWeb can be the most urgent future work. Though the scalability problem cannot be solved by modifying a single part of the system, we can try other parallel processing models such as message passing models to break the bottle neck of the non-increasing scalability on many-core architectures for YesWeb.

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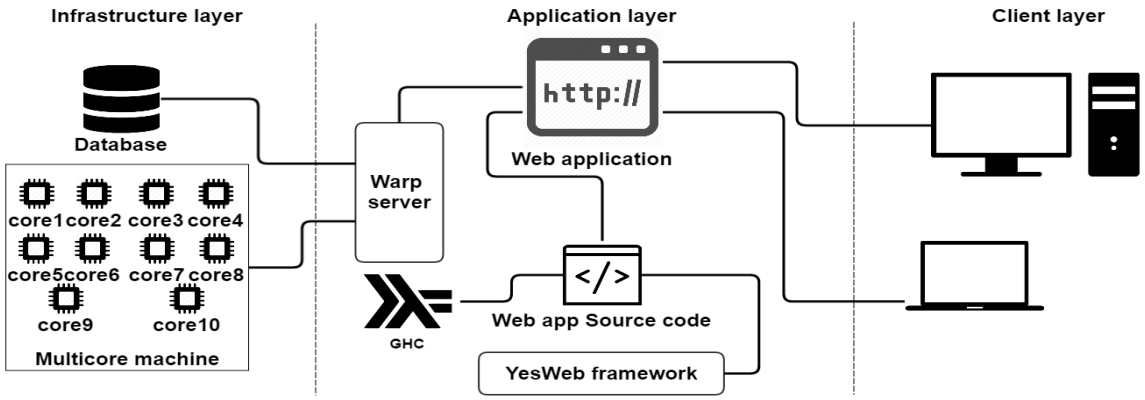

Figure 2: A three-tier architecture of YesWeb. The infrastructure layer provides a hardware environment, application layer contains YesWeb framework and system components, and client layer is for the user to access generated web application.

Table 1: A Comparison among YesWeb and other existing frameworks. Four typical criteria are used in this comparison including WORA (Write Once, Run Anywhere), loading speed, security, and syntax complexity.

Framework	WORA	Fast loading	High security	Concise Syntax
ASP.NET	No	No	Yes	No
Zend	Yes	No	No	No
Django	No	No	No	No
Ruby on Rails	Yes	No	No	No
Yesod	Yes	Yes	Yes	No
YesWeb	Yes	Yes	Yes	Yes