Large Scale Web Page Optimization of Virtual Labs

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***Abstract*—We propose web page optimization as necessary step in web application development. In context of virtual labs, several online experiments were designed by domain experts from various disciplines and thousands of web pages were developed. But domain expert did not know best practices for web development, therefore webpages had lot of performance issues on client side. So end user suffered slow rendering of pages on the client side. Performance of an web application largely depends upon the content of the web page because rendering takes place on client side. And client machine may have limited resources at his side. Therefore web page optimization seems necessary step to improve user experience. In contrast to existing work on this field, here we focus on large scale web performance analysis through data visualization. Based on this large scale visualization, we present a utility of existing web optimization tool by experimentation on a MHRD web project "virtual labs".**

I. Introduction

After onset of world wide web, performance of web implied optimizing the server side but nowadays optimization on the client side has become bottle neck because of complex web application. Now days, front-end developers use a lot of resources like javascipt, CSS and images to make a good user interface but this all adds overhead during page rendering which means lesser user experience. Success of a web application is judged based user's experience which also includes fast response time. Optimized web pages not only renders a web page faster but also saves network bandwidth. Along with making a good responsive web page, web developers should also focus on using a optimal number of critical resources and its size should also be minified. Critical rendering path is the chain of necessary events that occurs to render webpage on browser. The main critical resources on a web pages are CSS, javascript and images. For each critical resource on a webpage, browser makes a new request to server. CSS and javascript are the two critical resources that blocks the rendering of a webpage. Therefore, correct order of http requests can reduce the perceived page load time which means page load time will not reduce in reality but critical resources needed to render webpage are fetched first and remaining resources are fetched in background. Therefore, while optimizing web page for speed we should focus on

1) Minifying size of critical resources
2) Minifying number of critical resources
3) Minifying critical rendering path.

The goals of our experimentation, performed in collaboration with VLEAD lab, IIIT-Hyderabad were :

- To analyze performance of thousands of web pages hosted at virtual labs.
- To evaluate the utility of the Pagespeed with respect to optimizing web pages of virtual labs.
- Comparison between the web performance of virtual labs web pages with and without a web optimization like Google PageSpeed tool inoder

II. Background

Initially when world wide web started most of the web pages where plain hyper text documents. Slowly people started sharing media content like images and audio on web and in past decade web pages got transformed into web application with depends upon on critical resources like CSS, javascript and media content like images, audio, video etc. Now rendering of webpages depends upon following three major criteria's. Firstly order in which critical resources are fetched, secondly on number of critical sources and lastly on size of critical resources. Web gaints like Yahoo and Google have listed best practices for web developers to improve performance of web pages. So now we briefly explain some of the best practices in order to appreciate significance of web performance optimization.

- **Minimize http requests :** Number of http requests to render any web page is directly proportional to number of critical resources. For each critical resource in the page, browser have to make a new http request to server and then its get loaded. So, almost 80% of the response time is consumed in downloading all the resources. So to reduce number of http requests, one can combine multiple CSS into one, also multiple javascipt files can be combined into one. Other ways include image spriting, etc.
- **Use a Content Delievery Networks :** Nearest geographical server is selected for delivering the content which reduces load time.
- **Add Cache Control Header :** For static components, setting far future expires header will reduce number of http request so that browser can load from cache when request to same webpage is made again. For dynamic components, use an appropriate Cache control header to help browser with conditional requests. This reduces unnecessary http requests.
- **Gzip components :** Compression reduces response time by reducing the size of http response. Gzip is most popular and effective compression method at this time.It reduces response time by 70%.If a web client indicates for support for compression in the http request header,server sends a compressed components.
- **Stylesheets at the Top:** Problem with putting style sheets not in the head tag is that it blocks progessive rendering and till the sytlesheets are not fetched users sees nothing on screen.

- **Put Scripts at Bottom :** Putting scripts at the top,blocks parallel downloading of resources per hostname.
- **Make Inline Small CSS and javascript files :** If file size is to small, then it should be made inline as it will reduce number of http requests.
- **Make large css and javascript file external :** CSS and javscript files are cached by browser. So we avoid downloading it every time make request. First time it will take time to download but after caching http request.
- **Minify javascript and css :** Unnecessary characters from code should be reduced which includes removing comments, duplicacy and removing white spaces.
- **Avoid Redirects :** Connecting an old page to new one takes time and increases page load time.It should be avoided.
- **Configure ETags :** Entity tags is a way that browser and server use to determine whether the component in cache is same as that on server.
- **Flush the buffer early :** It allows to send partially ready response to browser.It should be written as early as possible in the code, preferably in the head section. In php there is function flush() to flush the buffer.
- **No 404 error :** Http requests made and getting a response like 404 Not found is totally useless and it increases response time.
- **Make favicon small and cacheable :** Favicon stays in the core of server and it is necessary as if its not there , browser will still request for it and getting 404 error will increase response time.

Yahoo **Yslow** and **Google Pagespeed** are well known tools that are capable of evaluating webpages performance and providing suggestions to optimize webpages based on performance best practices listed above. But the pagespeed is more than a performance analysis tool and is also capable of optimizing webpages without changing semantic of webpage.

Yahoo yslow.js is javascript API which runs on phantomjs. PhantomJS is a headless browser with JavaScript API. We used Yslow as performance measuring tool because it not only analyzes a webpage but gives suggestions on how to improve it. It works on three process:

- It crawls the DOM to find each component.
- Collects information for each component and analyzes each component.
- It generates scores out of 100 for each rule which produces the overall score for page.

The grades for individual rules are computed differently depending on the rule. For example, for Rule 1, three external scripts are allowed. For each script above that, four points are deducted from the grade. The code for grading each rule is found in rules.js. The overall grade is a weighted average of the individual grades for each rule, calculated in controller.js The rules are approximately in order of importance, most important first. The specific weights are in the ruleset objects in rules.js. Score computation is shown in the following table no 1 in Appendix section.

Mod_pagespeed is an automated web page optimization tool developed by Google for post optimization of web pages. It not only analyzes a web page but also optimizes it .Based on best practices, it has certain set of filters which optimizes web page during run time. As the server gets request for the webpage, it dynamically rewrites the page using its filters and sends an highly optimized page. Note that rewriting happens only when the first request for web page is made and for all later request web page is served from the cache at server side. There are total of 40+ filters which supports optimization. These filters can be turned on or off based on requirements.

Score	Grade
95-100	A+
90-94	A-
85-89	B+
80-84	B-
75-79	C+
70-74	C-
65-69	D+
60-64	D-
55-59	E+
50-54	E-
Below 50	F

III. Approach

Our work is broadly divided into four major phases namely Data Collection, Data Visualization, Analysis of Data and optimizing web pages based on analysis. During data collection phase we first collected all the urls of virtual labs hosted at IIIT-Hyderabad. Then we collected Yslow reports for each web page using an automated script and phantomJS. After collecting all the reports we extracted scores for each rule from reports and stored it in a csv file. During visualization phase all data is visualized using an automated script indicating performance for each rule and also overall performance of web pages. Later we did analysis for optimized pages of virtuals labs.

A. URls and Report Collection

As first step to visualize the performance of all the webpages, we collected urls of all the webpages at following domain deploy.virtuals-labs.ac.in hosted at IIIT-Hyderabed. Since we have access to server, to get all the urls, we wrote an automated bash script to extract all the html and php pages links from the server and stored it into the text file. To test the performance of vlab.co.in, we also collected the 5000 urls for this website. This time since we do not have the access of server ,we used an online sitemap generator to get the urls. We wrote an automated script to generate the reports for each web page using yslow.js and phantomJS. This automated script read an url from a file containing all the urls and generate report for each web page. In this script, we are making ten phantomjs call as background process for ten different webpages. For urls which are inactive, failed reports will be generated and we are pushing that url into the failed urls file and deleting the failed reports. These reports serves as input to CSV file generation.

B. CSV File Generation

CSV file is generated using a bash script. This CSV file will contain the overall score and scores corresponding to each rule. Script will extract all the scores for corresponding rule and will dump into the CSV file line by line. The content in the CSV file will be used for visualization.

C. Visualization

Visualization is done using python matplotlib. Soumya has written an automated scripts to generate all the graphs at one shot. Scripts takes csv file as input.

IV. Experimentation

A. www.vlab.co.in

We started our experiment with collecting Yslow reports for vlabs. We collected 5000 urls of www.vlab.co.in. and generated Yslow reports corresponding webpages and generated CSV file for the scores. Finally, we plotted data accumulated in csv files and analyzed the current status of webpages by looking at bar graphs.

B. deploy.virtual-labs.ac.in without pagespeed

This is the virtual lab website hosted at IIIT-Hyderabad. To analyze performance of webpages, we collected all the urls located at deploy.virtual-labs.ac.in by using our bash script. Total of 8786 urls were collected, reports were generated for web page located at each url and scores were accumulated in csv file. Later we visualized scores to analyze the current status of web pages.

C. Optimization of deploy.virtual-labs.ac.in using mod_pagespeed

We made a replica of deploy.virtual-labs.ac.in server on a container. We installed Google mod_pagespeed on the container to what extent pagespeed optimizes. Then, we collected reports for all the web pages and generated CSV file. After generating bar graphs we compared results with deploy.virtual-labs.ac.in without pagespeed to observe how much optimization was done by pagespeed.

V. Analysis

In this section we analyze web page performance of virtual-las.ac.in in two different settings on data set containing 9000 web pages. One when page speed module is installed on our system and other one without page speed. We also analyze web page performance of vlab.co.in on data containing 5000 web pages.

A. Analysis of vlabs.co.in

Out of 5000 urls we collected statistics for 4945 web pages.

- From the figure 1, we can observe that only 1 web page is having good performance. Rest of the web pages does not get good grades and need to be optimized to improve performacne. Out of rest 687 i.e 13% webpages are in above average conditions, 1038 webpages are performing average and rest 3220 webpages are not in good condition. Therefore, statistics are shows that these pages are not following performance best practices and performace of webpages can be improved.

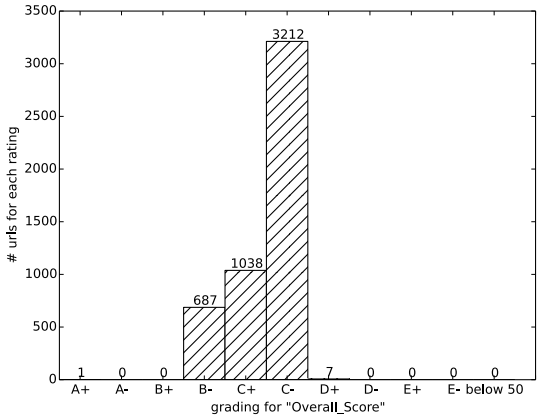

Fig. 1: Number of urls versus Overscore

- From the graph below, we can observe that all the webpages are having their CSS files inside the head tag else they block the progressive rendering.
- From the graph below, we can observe that all the webpages are having their script files at the bottom else they block parallel downloading.
- From the graph below, we can observe there is no usage of Content Delivery Networks. Actually it should have been used for such large website so that page rendering speed is high.
- From the graph below, we can observe that there is no use of Expires Headers in the wepages. This practice is not followed in the pages and it has to fetch each static critical resources everytime page is requested as it is not set expire far future.
- From the graph below, we can observe that only 89 webpages out of 4945 pages are in compressed form and rest are in uncompressed form. This will lead to large payload size and thus will increase network traffic and will slow page rendering.
- From the graph below, we can observe that this website does ot use entity tags. Due to this it has download critical resoures everytime request for page is made.
- From the graph, we can see that all pages vlabs are having favicon for it.
- from the graph, we can see that number of critical resources on the pages are more than required. Only 1 web page is getting A+ grade.Around 4500 webpages have scores between 65 to 75 means they are loaded with multiple css, javascript and images.For each resource, browser have to make a request to server and most of the time is wasted downloading the

resources.This resources number should be reduced for fast rendering.

B. Optmization using Pagespeed.

As we have generated statistics for 8986 webpages under deploy.vitual-labs.ac.in and for replica of deploy server on which pagespeed has been installed. Here we observed how much pagespeed optimizes the webpages.

- From the graphs, we can see that for deploy.virtual-labs.ac.in 4299 are in A+ grades for **overall score** while with pagespeed this rises to 6051. It shows pagespeed is imroving the performance of web pages by optimizing it. Also we can see see without pagespeed only 1226 wepages are in A- grade but with pagespeed it increased to 1667. From the graphs we can analyze that overall number of webpages is going to low to high grades.
- From the graphs, we can observe that without pagespeed mostly only 3214 webpages are in B+ and have **added expires headers** followed and around 45% are not follwing it. But with pagespeed, 4729 webpages were in B+ grade and there was shift of number from low grades to high grades.
- From the graphs, we can observe that most webpages are **compressed using Gzip** and 8257 urls falls under A+ grades while with pagespeed this number rises to 8761.
- From the graphs,we can see that w.r.t **Etags** without pagespeed 3535 pages have A+ grade,831 have B+ grade,384 have C+ grade, 3704 have score less than 50 but with pagespeed this number shifted to more higher grades. We can see now 6441 pages in A+ in comparison with 3534. But major difference is seen at below 50 score pages, now this have reduced to 633 in comparison to previous 3704.
- From th graphs we can see that w.r.t **make fewer http requests**, without pagespeed only 7791 webpages were in grade A+ and 461 pages were in A- but with pagespeed 8202 pages were in A+ grades. Major shift was from A- grade to A+ grade. Rest pages shows no observable changes.
- From the graphs, we can see that w.r.t **minified JavaScript and CSS** without pagespeed 7059 webpages were in grade A+,1395 pages in A- ,then 254 in B- and 20 were below F but with pagespeed this pages shifted to higher grades. After optimizing with pagespeed 8639 pages were in grade A+ ,94 in A- and only 3 below F w.r.t to previous 20 below F.

VI. Conclusion

This paper is concerned about Web Page Optimization of virtual labs which means fast rendering and less network bandwidth. This lead us to think us how to decrease the number and size of resource and also how to decrease the perceived load time. This webpages consists of critical resources like CSS, JavaScript and images. This optimization can be achieved by minimizing the number of critical resources, minimizing the size of critical resources and minimizing the critical path length. There are several best practices which are suggested to use in your webpages.

Our framework is mainly to visualize website performance on a large scale and it can be used to suggest lab developers to work on these best practices. Also it gives the list of inactive urls. Google Pagespeed is the automated web optimization tool that comes as a saviour for optimizing webpages of already existing web applications. It has 40+ filters which optimizes page and can be used according to our requirement. Also, it is open source and available for free. It should be used for huge websites like virtual labs application developers comes various domains and backgrounds.

VII. Future Work

This framework can be modified to give the list of urls of web pages that perform badly. Generating report takes atleast 24 hrs to process 5000 urls but by making phantomjs clusters on framework like Hadoop we can parallelized. Also functionality of pagespeed can be improved by adding more filters. For example, there is no filter to give default favicon for a webpage.

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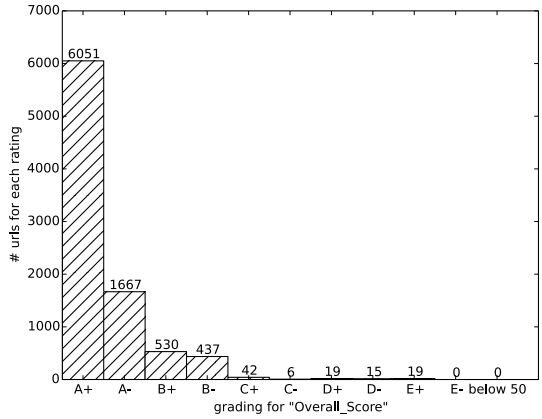
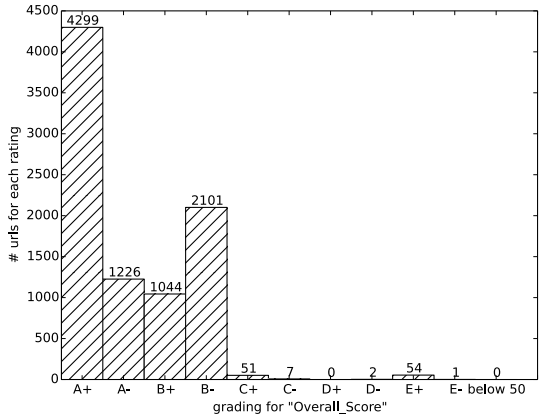
Appendix A
Figures

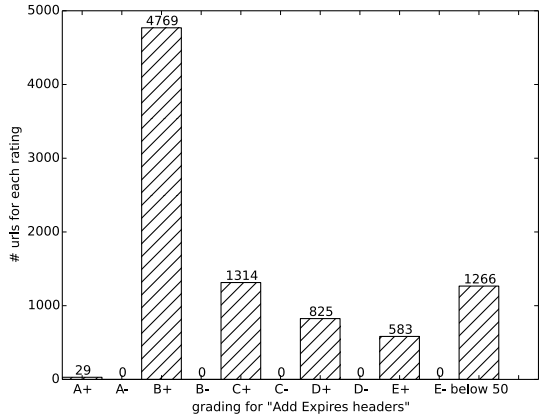


(a) Overall Score With PageSpeed

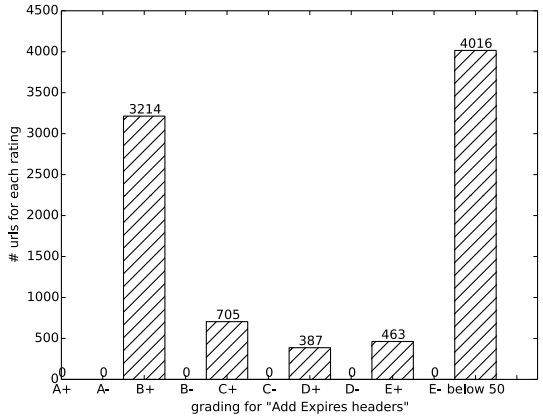


(b) Overall Score without PageSpeed

Fig. 2: Comparing Overall Scores

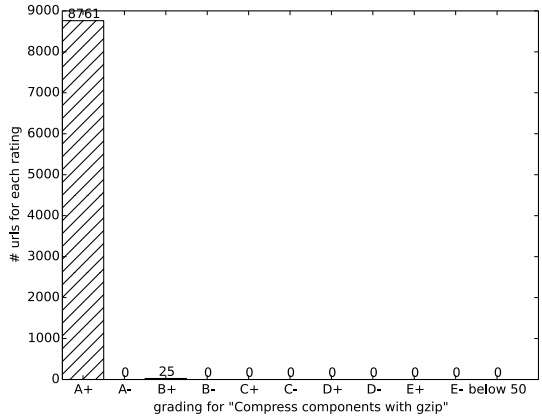


(a) 'Add Expires Header' Rule with PageSpeed

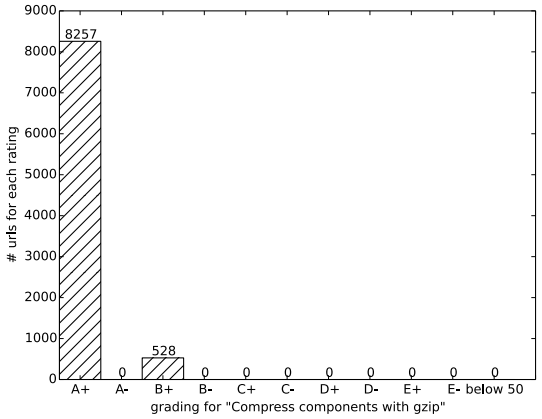


(b) 'Add Expires Header' Rule without PageSpeed

Fig. 3: Comparing 'Add Expire Header' rule

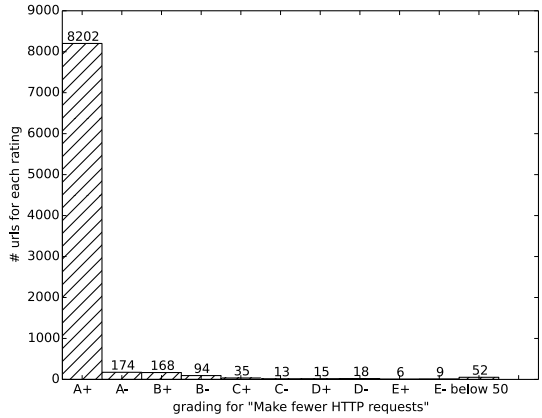


(a) 'Compress Components with gzip' rule with PageSpeed

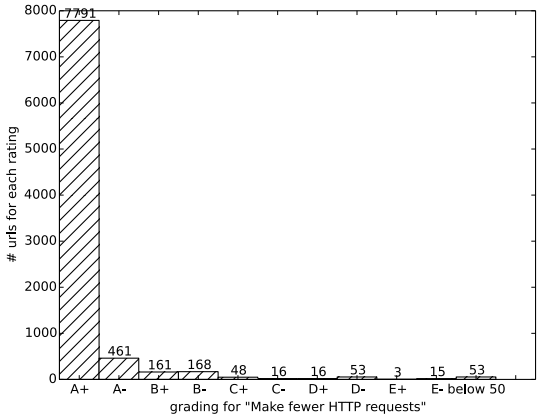


(b) 'Compress Components with gzip' rule without PageSpeed

Fig. 4: Comparing 'Components with gzip' rule

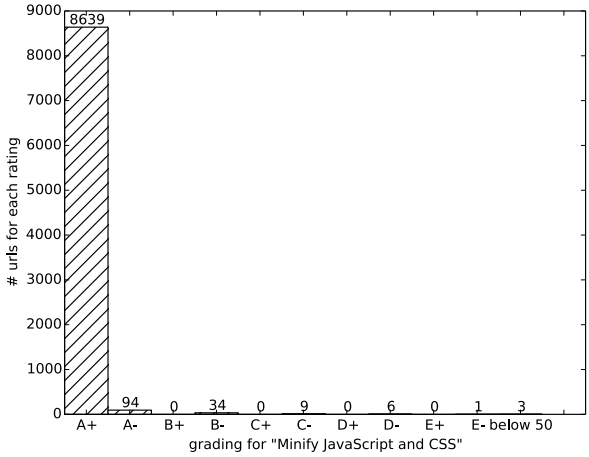


(a) Caption A

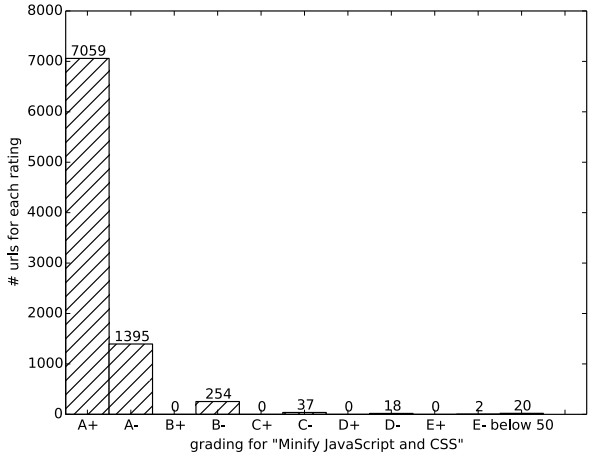


(b) Caption B

Fig. 6: ROC curve of failure detection;



(a) Caption A



(b) Caption B

Fig. 7: ROC curve of failure detection;

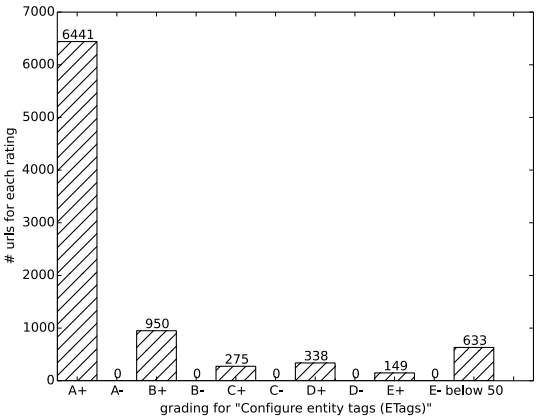


Fig. 5: Number of urls versus Configure entity tags (ETags) on container