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Master's Thesis

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A distributed system is one where the failure of some
computer I've never heard of can keep me from getting my work done.
– *Leslie Lamport*

Contents

1 Introduction

- Explain structure and main goal of this thesis
- Introduction Chapter: Describe shortly all sections from this chapter and what the reader can expect
- Give short outlook to following chapter

1.1 E-Commerce

1.1.1 The Internet

In the last 50 years, a new technology emerged, spread over the entire world and influenced many aspect of most peoples life. Within the turmoil of the cold war, the United State's Advanced Research Projects Agency (ARPA) established in 1957 a communication network to bring together universities and their researches all around the country in order to be able compete against the USSR ([CA11]). What started as a tool for scientific collaboration evolved a half century later into the internet, a global network and phenomenon, to which every user with a dedicated device has access and can contribute to. The internet is an integral part, if not the backbone of today's everyday life. Users of the internet use it for everything, that is sending emails, watching television, chatting with friends, order lunch, checking the weather for the next day or renting motorized scooters.

In 2021, the internet has 4.66 billion users, which is around 60% of the world population.[1] Compared to 2020, the number of internet users increased by 7.3%. In Europe, more than 90% of the population are also internet users. For a developed country like Germany, the numbers are even more impressing: 94% of the German population are using the internet with an average daily time of over 5h.

Those numbers demonstrate impressive that the internet is an integral part of our daily life. Along the rise of internet users, transactions and processes falling under the term of e-commerce rise. Before discussing the term "e-commerce" and take a grasp at its history and types, some statistics are presented to demonstrate the importance of e-commerce.

[1] Following statistics are taken from `https://datareportal.com/reports/digital-2021-germany` [14.05.2021]

1.1.2 E-Commerce

Introduction

From the global data report, we can see that over 90% of the world population visited an online retail site. Over 76% of the world population purchased a product online. For most categories growth is over 15%. Again, for a western country like Germany, the numbers are higher: 92.5% of the german population visited an online retail site and over 80% purchased a product online. And the usage is growing: growth of amount spent in category food and personal care is 28.6%, and 17.6% for fashion and beauty.

Revenue in e-commerce is constantly growing over the last 20 years, topping to 57.8 billion in 2019.[2]

The COVID-19 pandemic with its implications had and still has an not negligible impact on the growth of e-commerce. Several measures were taken to stop the spread of the virus and the number of deaths, one of which was to minimize physical interaction between people. This leads consequently to a shift of human interactions to the internet. Along this, e-commerce benefits. Bhatti et al. ([BAB+20]) conclude that "e-commerce enhanced by COVID-19".

Short History

E-Commerce, or electronic commerce, is according to the *Encyclopædia Britannica* about "maintaining relationships and conducting business transactions that include selling information, services, and goods by means of computer telecommunications networks."[3] In short, e-commerce is about buying and selling products and services via the internet.

The success of e-commerce is tightly coupled to the vast advances of internet technology in the past years, like for example the development of the Electronic Data Interchange (EDI) starting from the 1960s, which standardised the communication between two machines.

Personal computers in 1980s and one of the first examples of online shopping is from CompuServe who introduced Electronic Mall in 1984.

Another milestone is Word Wide Web, introduced in 1990 by Tim Berners-Lee, made internet accessible to everyone. First browser by Tim.

Social media since 2000 again offeres new possibilities for businesses and consumers alike to participate in e-commerce, e.g. for marketing, selling channels

New devices such as smart phones and tablets again decreases the hurdle to participate in e-commerce. While in the time dimension e-commerce was already available all the time, with the new mobility its also available everywhere. More flexible. [Her19].

With the ongoing progress in technology, also e-commerce can expect a shining future with trends such as AI recommendation systems, outstanding UX thanks to Virtual

[2] https://einzelhandel.de/presse/zahlenfaktengrafiken/861-online-handel/1889-e-commerce-umsaetze [14.05.2021]

[3] https://www.britannica.com/technology/e-commerce [19.05.2021]

Reality, simple payment methods with crypto etc.[4]

Types

Multiple types in e-commerce are existing. They emerge from the possible combinations between the actors *business*, *consumer* and *government* ([SSMG17]).

- B2B: Business to Business
- B2C: Business to Consumer
- C2C: Consumer to Consumer
- G2C: Government to Consumer
- B2G: Business to Government
- G2G: Government to Government

B2C Business to Consumer in e-commerce describes basically online shopping, by means of a business offering its services and products to the consumer over the World Wide Web. The consumer can browse within an online shop through the presented products and services and order them directly via the website. A variety of payment and delivery options conclude the B2C type ([Hei20]).

For a aspiring business, multiple ready to use software solutions to install an online shop are existing, for example. Shopify, ePages, Magento or WooCommerce ([SBR+19]).

A famous example of a B2C company is Amazon. On the 16th of July in 1995, Amazon launched as a website and entered the stock market on the 15th of May 1997 ([SB19]). Amazon is successful, the stock started with a price of X, which is at the time of this writing at Y.[5] Today Amazon employs over 1 million employees[6] and serves the wishes of 200 million paying prime members.[7]

By taking a quick look at the pros and cons of maintaining an online shop, we can see that some of the advantages are that there is no need of a real house to present and sell the products, the virtual shop is available to the consumer at any time and has to closing hours; there is a high potential for the online shop as it is part of growing market; online business is scalable; due to tracking algorithms precise targeting as well as data analysis is possible; to start with an online business, not that much float is needed and there are in general lower costs; it is possible to provide a personalized customer experience;

[4] https://www.spiralytics.com/blog/past-present-future-ecommerce/ [19.05.2021]
[5] https://finance.yahoo.com/quote/AMZN?p=AMZN [19.05.2021]
[6] https://www.statista.com/statistics/234488/number-of-amazon-employees/ [19.05.2021]
[7] https://www.statista.com/statistics/829113/number-of-paying-amazon-prime-members/ [20.05.2021]

Some disadvantages are that the speed of market is rapid, competitors arise everyday everywhere, technology evolves quickly while consumers expectations go high ([Her19], [LO20]).

Another downside is that there is no direct or physical concat with the consumer. As described above, online shopping takes place in the World Wide Web domain. Consequently, in person interaction between a buyer and a seller is not possible and the shopping event takes place on a website. Deriving from this fact, the overall virtual user experience needs to be outstanding in order to stay ahead of competition. The performance of the online shop is one part of the user experience.

In the next section, I will describe the findings between the correlation between user satisfaction and the performance of the retailers web presence.

1.1.3 User Satisfaction and Performance

The aim of this thesis is not to deep dive into terms and concepts or the non-trivial problem of defining user satisfaction, usability or the like. Therefore the term user satisfaction is in this context loosely defined as how happy the user is with the website he or she interacts with.[8]

For this context, performance can be understood as the the speed of an online shop, e.g. how long it takes the page to load, how quickly the user can interact with the page, and how the user perceives the performance of the website. Later we will see that measuring performance is not that trivial and a lot of ideas and metrics are existing to measure it.

SpeedHub

A plethora of information and studies about the phenomenon of user satisfaction and web site performance is collected at *SpeedHub.org*, a portal by *Baqend* in cooperation with *Google* which provides "the largest systematic study of Mobile Site Speed and the Impact on E-Commerce."[9] On the hub, not only studies and reports are available, but also collections of videos and blog posts.

In his presentation at code talks 2019, Felix Gessert summarizes the findings and provides insights to the most relevant aspects and questions of the study:

The first observation when tackling the question regarding a correlation between the performance of a system and the user satisfaction, is that the users have to be distinguished which leads to the concept of a *User Profile*: Regarding gender, young woman are the most demanding consumers and buy less on slow pages. Generally, people between 18 and 24 have higher expectations regarding site speed than their older counterparts.

There are also differences between nations and regions, for example people from Japan have the highest expectations, which for a certainty coheres with the technological progress in this country. Not only the expectations themselves differ geographically, but also how

[8] For a discussion cf. "User satisfaction measurement" in
[9] `https://www.speedhub.org/` [21.05.2021]

speed influences the users, for example "speed influences New Yorkers more than Californians."

What all users have in common is their human psychology. With respect to performance, researchers generally suggest to keep waiting times under 1000 ms in order to keep the users attention.

After considering the user itself, the next step is to investigate the influence of the device in use: Studies show that mobile users are more likely to buy products and services than their colleagues using a desktop computer, where iOS users have generally more expectations regarding site speed.

Last but not least is the context and the users condition important, where naturally relaxed and calm users perceive sites faster than stressed users or people that are in a hurry. Also when on the move, users experience sites slower.

There are many real world examples and studies existing which prove and demonstrate the importance of site speed with respect to user satisfaction and eventually revenue: *Amazon* fount out that a decrease of 100 ms in page loading leads to -1% conversion rates. If the site loads 100 ms faster, *Walmart* observed that the revenue increases by 1%. For *Zalando*, increasing site speed by 100 ms leads to an uplift of 0.7% revenue per session.

Search Engine Optimization is heavily impacted by load speed: For *Google*, 500 ms slower sites lead to a decrease of 20% in traffic. *GQs* traffic increased by 80% after the page load went down from 7 s to 2 s. And for *Pinterest*, 40% faster loads led to 15% more SEO traffic.

Also the user engagement and satisfaction rely heavily on load times: *Forrester* noted an increase of 60% for the session length while brining down the load time by 80%. *Akamai* monitored that the bounce rate climbed up incredible 103% when the load time increased by 2 seconds. And for the *AberdeedGroup*, the customer satisfaction dropped by 16% at one more second delay in response times.

To summarize, many studies and real world examples prove and demonstrate that faster web sites and online shops cause a better user experience and typically lead to happier customers. Concluding in commercial terms, one can say with a certainty that page speed equals money.

In order to properly test the impact of performance on the users, a scientific method is needed. A/B testing as a controlled experiment is one of them and will be explained in the next section. After a discussion of A/B Testing, I will move on to the examination of *Web Analytics*, a term which subsumes methods, tools and instruments for businesses to better understand their business and customers.

A/B Testing

Controlled experiments such as A/B Testing are not a new tool for scientists and researchers and have been used already in the 1920s. With the rise of the internet in the

1990s, the concept has been adopted to the online domain and is as of today widely used by big companies such as Amazon, Facebook or Google to directly test ideas and hypothesises on a live system. Controlled experiments such as A/B Testing are utilised to support decision making and to deliver "causal relationship with high probability". They enable a data driven and quantitative validation of the hypothesis.

Controlled experiments help to test hypothesis and questions of the form: "If I change feature X, will it help to improve the key performance indicator Y?"

To answer this question, two systems are needed: Version A, the control variant or default version, and a slightly different version B, called the treatment. If more than two versions or one treatment should be evaluated at the same time, an A/B/n split test has to be implemented. For an univariable setup, only one variable differs between the systems, where in a multivariable structure, more than one variables are changed at the same time.

Usually, the users of the system are randomly split into two groups and testing is directly performed with real users on a production system. Beneficial, also when comparing with other experimental setups, is, that the users and participants are not aware that they are part of an experiment, which leads to less bias and side effects. In order to measure the differences and the user behaviour, web analytics has to be integrated within the system.

A short and general discussion about controlled experiments in computer science is in chapter X.

To resume with the question of performance and user satisfaction, A/B testing enables to serve two different versions of the same site to two groups, one site being slow, the other one fast, at the same time without the users knowing. With web analytics implemented, it is possible to measure how the different systems and user groups behave.

What web analytics exactly is, what tools are available and how a web analytics process looks like, will be discussed in the next section.

1.2 Web Analytics

First some definitions, then quickly summarize the history, and then technical aspects of collecting data.

1.2.1 Introduction

What is Web Analytics? Going through the literature, makes it clear that multiple definitions are existing:

Nakatani et al. state that "Web analytics is used to understand online customers and their behaviors, design actions influential to them, and ultimately foster behaviors beneficial to the business and achieve the organization's goal." According to this definition, web analytics is about getting insights of the users using the system, not only who or

what they are, but also how they interact with the system. Additionally, the definition stressed that the underlying motivation of web analytics is are the achievement business goals.

Singal et al provide a more technical definition by pointing out that "Web Analytics is the objective tracking, collection, measurement, reporting and analysis of quantitative internet data to optimize websites and web marketing initiatives." Again, the ultimate target is to drive business forward, but backed up with data science methods and instruments such as tracking, collecting and analysis of vast amount of data.

Bekavac et al provide a similar definition by pointing out that web analytics is "the analysis of qualitative and quantitative data on the website in order to continuously improve the online experience of visitors, which leads to more efficient and effective realization of the company's planned goals."

- 4 usages: - Improving website/application design and user experience - Optimizing e-Commerce and improving e-CRM on customer orientation, acquisition and retention - Tracking and measuring success of actions and programs such as commercial campaigns - Identifying problems and improving performance of web applications

Summarizing above definitions, we can see that web analytics is composed of two important aspects: A data driven, information focused and technical aspect of collecting and analysis data about the users, and a commercial perspective, which provides the main motivation of collecting the data beforehand, by setting business goals.

- 2 categories: on-site and offsite

1.2.2 Short History

TODO check out Wolles dissertation!

- Logfiles, 1996 ELF - GetStats, one of the first tools to present log files nicely to user - Only interesting for IT in the beginning - With 1.5 billion internet users in 2009, also interesting for marketing - Focus shifted to visitor, so that his behaviour can be linked e.g. with purchase. Cookies helped with this - Segmentation as crucial step - First web analytics companies tracked log files, which needs it heavy infrastructure - Generally the shift was from technical aspects (such as where are 404 on the server requests) to marketing in order to get more insights about users of website

- 3 important changes for this shift from IT to marketing: - 1. JS enables to bypass IT and track data directy without the need to gather log files. 1996: Urchin released service called Quantified - 2. With Googles ad system, shift to information about success of campaign and referrer sites - 3. New cost model for analytics service: pay for traffic you measure. Analytics as percentage of web revenues

- Cookies to identify unique users - Page tagging: not only track technical data but also business context, e.g. analyst can say if user buys shoes he also buys jackets - "Today, web analytics is a marketing discipline used to measure the effectiveness of communications strategies" p.83 - p. 84 visual history of web analytics - More data: performance data,

visitor opinion, usability data

- 1990 birth of WWW - Hit: when visitor requests html file. is in log file - WebTrends 1993 - 1995: Analog. First free log file analysis software - 1996: WebCounter: hit counter service - JS page tagging - 2003: Foundation of Web Analytics Association WAA by Edwards, Eisenberg and Sterne. - 2006 In-Page analytics - 2012 WAA renamed to Digital Analytics Association as all digital users are inlcuded in web analytics - Image: Genesis of Web Analytics (nice graphic) with WAA, DAA

- Ever growing since start of WWW - From http traffic logging to use data tracking, analysis and reporting - Log file analysis - First browser Mosaic 1993 - WebTrends 1993 - 1995 Analog - 1996 WebSideStory - Page tagging - Trends: - mobile analytics, - application specific analytics - from web to digital analytics: understand entire digital footprint of users (see name change of WAA)

- all 500 imortant companies run websites - Rise in the volume of data and internet users -

1.2.3 Web Analytics Process

Data Sources: Log Analysis versus Page tagging - Page tagging illustration p. 82

1.2.4 Web Performance

TODO move this to end of web analytics chapter? like again focus on performance...

- What is web performance? Why it matters
- Overview of factors that impact performance, bottlenecks
- Overview of measurement methods, techniques and metrics

1.2.5 Tools

- Some short overview about existing tools
- Conclude that I use WPT for synthetic performance testing and GA for RUM

1.3 Research Question

- Difficulty of defining scope
- Measuring performance of a web site impacts its performance or other effects take place / Observer effect
- Why the research question is relevant

What is the research question of this thesis? What is the goal?

2 Terms and Definitions

- Last chapter...
- This chapter: Describe shortly all sections from this chapter
- In the next chapter...
- This chapter should cover all relevant terms and definitions within web performance measurement
- How terms can be structured / taxonomy
- Ambiguity of definitions

2.1 Metrics

2.1.1 Introduction

- Metrics jungle, difficulty of taxonomy
- Performance vs UX

2.1.2 "Non-Performance" metrics

- User engagement: session length, bounce rate, etc.
- Business KPIs: Cart size, conversion rate, etc.
- QA metadata: Page views, JS errors, etc.
- Hit
- Click-Through
- Page View
- Visit
- Visitor / Unique Visitor
- Referrer
- Conversion Rate

- Abandonment Rate
- Attrition
- Loyalty, Frequency and Recency
- Measuring Reach: ...
- Measuring Acquisition: ...
- Measuring Conversion: ...
- Measuring Retention: ...
- Basic metrics (see table): basic metrics are meaningless
- Advanced metrics: Customer lifecycle analysis, customer behaviour analysis
- Types: Counts, Rations, KPIs
- Definitions for all terms, like Page view, unique visitor, etc.
- Importance of setting goals
- Conversion Rate
- Kennzahlen für Websites nach Typ: ROI-Ebene, Online-Shop, ...
- Conversion Rates, pages that visitors abandon most
- Click throughs
- UGC (User generated content)
- Subscriptions, Signups
- Referring URL
- Visitor Motivaton, VOC: Voice of the Customer
- Ad and campaign effectiveness
- Findability and Search Effectiveness
- Trouble Ticketing and Escalation
- Loyalty: Ratio of new to returning visitors; average time between visits; time since last login; rate of attrition or disengagement

p.15 "whether your business benefited in some way from their visits."

The percentage of visitors that your site converts to contributors, buyers, or users is the most important metric you can track -> Conversion Rate

p. 74 Page View, first useful web analytics metric

- 4 categories: site usage, referrers, site content analysis, quality assurance
- 8 fundamental metrics
- Site usage:
  - Demographics and System Statistics
  - Internal Search Information
  - Visit Length
  - Visitor Type
- Referrers:
  - Referrering URL and Keyword Analysis
- Site content analysis:
  - Top Pages
  - Visitor Path
- Quality assurance:
  - Errors
- Erfolg messen und bewerten
- Traffic:
  - Page Impression / Page View
  - Visit
  - Visitor / Unique visitor
- Bounce rate
- Conversion rate
- CTR: Click-through-rate
- Session length
- Good metrics should be: Uncomplex, Relevant, Timely, Instantly Useful
- Basic metrics: Visits, bounce rate, page views, pages/visits, avg time, % new visits
- Guidance Performance Indicator (GPI) metric
- Visit count: page view, visit, unique visitor
- Visit duration: time on page, time on site.

- Bounce rate and exit rate.
- Besucheranalyse: Wie viele Besucher?, Anzahl Besucher mit Mobilgerät, Demographische Daten (Geschlecht, Altersgruppe)
- Seitenanalyse: Was machen die Besucher im Shop?, Zielseite / Startseite: Erste Seite, die ein Besucher angeschaut hat, Ausstiegseite
- E-Commerce-Analyse: Transkations-daten aus Shop, Funnel-Analyse
- Types: Anzahl, Relations, Werte
- Content: Where, Who, How, What
- Hits
- Page Views
- Visits / Sessions
- Visitor / Unique Visitor

2.1.3 Performance Metrics

- Introduction to the Web Performance Working Group
- Overview of Browser APIs and the data they expose: High Resolution Time API, Navigation Timing API, etc.
- If possible make one deep dive into one API: What exactly gets measured? Maybe check out html standard, v8 or chromium implementation, etc.

Standards and APIs, Browser metrics, standards

- Web Performance Working Group
- User Timing API
- Navigation Timing API: Level 1 (performance.timing), Level 2 (PerformanceNavigationTiming) ?
- Network Information API
- Resource Timing API
- Paint Timing API
- High Resolution Time API
- Performance Timeline API

- Performance Observer API
- Long Tasks API
- Element Timing API
- Event Timing API
- Server Timing API

Navigation Timing API

- Show image of navigation timings
- Explain one or two events directly with specification: navigationStart, domInteractive, etc.

Google metrics? User-centric / UX / visual

Web Vitals

- Key questions: Is is usable, is it delightful, ...
- Types of metrics
- important metrics
- custom metrics
- Core Web Vitals: First Input Delay, Cumulative Layout Shift, Largest Contentful Paint
- First Paint, First Contentful Paint: Is it happening? PerformanceObserver
- First Meaningful Paint, Hero Element: Is it useful?
- Time To Interactive: Is it usable? Use Polyfill
- Long Tasks: Is it delightful? PerformanceObserver
- Total Blocking Time
- Time To First Byte

Core Web Vitals

- Most important metrics, Apply to all websites, Measures real user experience, Measurement support for Lab and Field, Concise and clear
- LCP: Progressive loading. FCP may become a core web vital
- FID: Interactivity during load
- CLS: Visual stability
- Future goals: Better support for Single Page Apps, Input responsiveness, Scrolling and animations
- Areas of user experience beyond performance: Security, Privacy, Accessibility
- Introduction, what is it
- How to measure
- How to improve
- Introduction, what is it
- How to measure
- How to improve
- Introduction, what is it
- How to measure
- How to improve

Others

- Visually complete ?

Speed Index

2.1.4 WebPageTest Metrics

- Metrics Categories:
  - High Level Metrics:
    * Document Complete
    * Fully Loaded
    * Load Time

    - First Byte
    - Start Render
    - Requests
    - Bytes In (Page Size)
- Page-level Metrics:
    - Technical Page Metrics:
        - -> APIs, GA Site Speed Metrics
        - TTFB
        - loadTime
        - docTime
        - ...
    - Visual Metrics:
        - SpeedIndex
        - firstPaint
        - firstContentfulPaint
        - firstMeaningfulPaint
        - ...
    - Javascript and CPU timings
    - Page Information
    - Browser State
    - Lighthouse Summary Metrics
    - Optimization Checks/Grades
    - Instrumented Metrics
    - Test Information
    - Misc
- Request-level metrics:
    - Request Details
    - Request Timings
    - Request Stats
    - Headers
    - Protocol Information
    - Javascript/CPU details

        * Optimization Checks
        * Misc

- Optimization Grades:
  - Keep-alive Enabled
  - Compress Text
  - Compress Images
  - Cache Static Content
  - Use of CDN
- First View and Repeat View

Name	Description
Successful Tests	Amount of tests who completed successfully
Document Complete	The time from the initial request until the browser fires load event. Also known as the document complete time. This is the time at which the Document Object Model (DOM) has been created and all images have been downloaded and displayed. For most traditional web pages, the load time is a suitable metric for representing how long a user must wait until the page becomes usable. This is the default performance metric on WebPageTest. Also known as Load Time (?). Around this time, the page's script is hard at work in the load-event handler firing off more requests for secondary content. The incomplete nature of this metric is why Fully Loaded was added to the table of metrics from the previous section. window.onload (?). The point where the browser onLoad event fires. The equivalent Navigation Timing event is loadEventStart. Document Complete Time: Amount of time that has elapsed from the initial page request until the browser fires the load event. This is the time at which the Document Object Model (DOM) has been created and all images have been downloaded and displayed.

Fully Loaded	The time from the initial request until WebPageTest determines that the page has finished loading content. The page might have waited for the load event to defer loading secondary content. The time it takes to load the secondary content is accounted for in the Fully Loaded Time. The time (in ms) the page took to be fully loaded — e.g., 2 seconds of no network activity after Document Complete. This will usually include any activity that is triggered by javascript after the main page loads. The point after onLoad where network activity has stopped for 2 seconds. Specific to WebPageTest and not provided by Performance API. Fully loaded waits for 2 seconds of no network activity (and no outstanding requests) after onLoad and then calls it done (only measures to the last activity, doesn't include the 2 seconds of silence in the measurement). Fully Loaded is a measure based on the network activity and is the point after onload when there was no activity for 2 seconds.
First Byte	Time until the server responds with the first byte of the response.
Start Render	Time until the browser paints content to the screen. The time for the browser to display the first pixel of content (paint) on the screen. Time until the browser paints content to the screen. WebPageTest's own metric, determined by programmatically watching for visual changes to the page. Same as First Render?
Bytes In (Doc)	Total size of the Document Complete Requests' response bodies in bytes.
Requests (Doc)	Number of HTTP requests before the load event, not including the initial request.
Load Event Start	Time in ms since navigation started until window.onload event was triggered (from W3C Navigation Timing).
Speed Index	See Speed Index
Last Visual Change	Time in ms until the last visual changed occured. Last change is a completely visual measurement and is the last point in the test when something visually changed on the screen. It could be something as simple as an animated gif or ad even that didn't really cause much CPU work but changed some pixels on the screen. It is only captured when video is recorded because it depends on the video capture to measure it.
Visually Complete	Time in ms when page was visually completed. Is measured from a video capture of the viewport loading and is the point when the visible part of the page first reached 100% "completeness" compared to the end state of the test.

Table 2.1: Your caption here

2.1.5 Google Analytics Site Speed Metrics

Show with analytics.js that it is indeed those navigation timing api calculations.

Ec = function (a)...

GA does not really provide any UX metrics! The site speed metrics are all from navigation timing api which are measurements from the browser.

GA Site Speed Metrics (description from `https://support.google.com/analytics/answer/2383341?hl=en&ref_topic=1282106`)

`https://stackoverflow.com/questions/18972615/how-do-the-metrics-of-google-anal`

Name	Description
Page Load Sample	The number of pageviews that were sampled to calculate the average page-load time.
Speed Metrics Sample	The sample set (or count) of pageviews used to calculate the averages of site speed metrics. This metric is used in all site speed average calculations, including avgDomainLookupTime, avgPageDownloadTime, avgRedirectionTime, avgServerConnectionTime, and avgServerResponseTime.
DOM Latency Metrics Sample	Sample set (or count) of pageviews used to calculate the averages for site speed DOM metrics. This metric is used to calculate ga:avgDomContentLoadedTime and ga:avgDomInteractiveTime.
Page Load Time (sec)	The average amount of time (in seconds) it takes that page to load, from initiation of the pageview (e.g., click on a page link) to load completion in the browser.
Domain Lookup Time (sec)	The average amount of time spent in DNS lookup for the page.
Page Download Time (sec)	The time to download your page.
Redirection Time (sec)	The time spent in redirection before fetching the page. If there are no redirects, the value for this metric is expected to be 0.
Server Connection Time (sec)	The time needed for the user to connect to your server.
Server Response Time (sec)	The time for your server to respond to a user request, including the network time from the user's location to your server.
Document Interactive Time (sec)	The average time (in seconds) that the browser takes to parse the document (DOMInteractive), including the network time from the user's location to your server. At this time, the user can interact with the Document Object Model even though it is not fully loaded.
Document Content Loaded Time (sec)	The average time (in seconds) that the browser takes to parse the document and execute deferred and parser-inserted scripts (DOMContentLoaded), including the network time from the user's location to your server. Parsing of the document is finished, the Document Object Model is ready, but referenced style sheets, images, and subframes may not be finished loading. This event is often the starting point for javascript framework execution, e.g., JQuery's onready() callback, etc.

2.1.6 Comparison

- We can show this with experiments
- Load test page on a specific day only once and save timings exposed by perfor-

Navigation Timing API	WPT	GA
loadEventStart - navigationStart	Document Complete, Load Event Start	pageLoadTime
domainLookupEnd - domainLookupStart	DNS lookup, dns_ms	domainLookupTime
connectEnd - connectStart	connect_ms	serverConnectionTime
responseStart - requestStart	..	serverResponseTime
responseEnd - responseStart	..	pageDownloadTime
fetchStart - navigationStart	..	redirectionTime
domInteractive - navigationStart	..	domInteractiveTime
domContentLoadedEventStart - navigationStart	domContentLoadedEventStart	domContentLoadedTime

mance.timing object (from console)

- Calculate differences corresponding to the table
- Get GA data for that day and save it
-

2.2 Measuring Methods

- Explanation and comparison of synthetic and real-user monitoring with concrete examples
- Short overview of other measuring methods such as log analysis or surveys

2.2.1 Synthetic Monitoring

- What is it
- How does it work
- Application, real life scenario
- Examples:
  - WebPageTest
  - Google Lighthouse
  - Other solutions

2.2.2 Real-User Monitoring

- What is it
- How does it work
- Application, real life scenario
- Examples:
  - Google Analyitcs
  - CrUX
  - SpeedKit
  - Other solutions

3 Related Work

- Last chapter...
- This chapter: Describe shortly all sections from this chapter
- In the next chapter...
- This chapter should list research which covers and explores questions relevant for this thesis, such as:
  - Metrics: New metrics, meaning of metrics, difficulties of defining metrics, etc.
  - Overview, evaluation and comparison of measurement tools and methods
  - If available: Impact of RUM on performance

3.1 WebPageTest

- Overview
- Configuration
- Private Instances

3.1.1 Overview

- What is it
- Why to use it, Who uses it, how to use it
- Waterfall and Grades
- See in performance tab for details about grades and optimization techniques

3.1.2 Configuration

- Caching, repeat view
- Traffic shaping
- e.g. capture devtools timeline

3.1.3 Private Instances

- Architecture
- AWS
- Docker localhost
- Bulk tests

3.2 Google Analytics

- Custom metrics with Google Web Vitals as example
- Show how to include GA script (analytics.js, gtag, Tag Manager, etc.)
- Show some real life examples how script code is included into page, e.g. from Amazon, Otto etc

3.2.1 The Tracking Script

- Show code example
- Explain whats going on: script tag, create script element etc.
- Maybe also show Hotjar example to see that they are similar

3.3 Research

- Research exists about topics like: ....
- Here i will provide a list of in my eyes relevant papers, summaries them and discuss why this is important for my research

3.3.1 some title for first category

2014 Singal I. - Describes history of web analytics and tools - Provides definitions and taxonomy for metrics - Describes log file vs page tagging - Describes KPIs

II. - Lit. overview for KPIs and Web Metrics - Lit. overview for "Trust" - Lit. overview for "Fuzzy" -> What are does categories?

III. - Some other literature worth mentioning

IV. - Describes 8 open challenges for researchers

2015 Bekavac - Two parts: - 1: Some general overview of web analytics, tools and metrics, KPIs etc - 2: Empirical study about employees satisfaction of used web analytics tools

1: - 9 web business models and 5 common goals - Hypothesis: Web analytics tools track and improve a user's satisfaction with web-based business models. - Web anayltics defintion. Log files vs Site Tagging - Web Analytics process - Tools: 5 categories, Process of selecting tool, Table with features of different tools - Web metrics categories, Table with business models and their KPIs

2: - Which tools are used for which purpose / Activity - Users satisfaction

3.3.2 Research about Tools

Kaushik 2007 - Provides 3 questions which help to choose web analytics tools

2011 Nakatani - Gives some arguments why web analytics is important for business - Provides different categorizations for web analytics tools - Gives pros and cons of log file analysis and page tagging - Provides tool selection method based on AHP (Analytic Hierarchy Process)

2016 Kaur

3.3.3 Research about Metrics

- Dont know:

4 Approach

- Last chapter...
- This chapter: Describe shortly all sections from this chapter
- In the next chapter...
- In this chapter the practical work should be documented and explained
- Elaboration of how the practical work could help answer the research question
- Discussion of real-life setup and how experiments approach it

4.1 Empirical Research Methods

- Overview of methods
- reproduceability etc.
- validity
- Justification why following approaches are conducted as controlled experiments
- Change something: Delete this item again

4.1.1 Controlled Experiment

- Short overview about controlled experiments in computer science
- Design: Show test setup image: Independent and dependent variables
- Hypothesis testing

4.1.2 Test Setup

- What is test object (website)
- What are dependent variables: Performance metrics
- What are independent variables: Specific changes in test object (see next chapter)
- Kohavi 2016: Sample size, collect right metrics, track right users, randomization unit

Variable	Values
Position	top-head, bottom-head, bottom-body
Attribute	no attribute, async, defer
Other Script	false, true

Measure effects: Dependent Variables

- Performance metrics from Lab and Field, see terms and definitions
- But also quality of RUM data. Because we could have a nice performance but RUM will be of bad quality.

Test object / HTML Template

- Depending on different approaches / Ideas (see next chapter), template looks different
- But general structure stays the same and independent variables can be defined
- Here we show different independent variables and variants

Lab and Field

- I want to collect Lab and field data for dependent variables for comparison
- This setup is a special case because lab bots (e.g. WPT) simulate at the same time real users for RUM data

4.1.3 Independent Variables within template

- IV 1 POSITION: Position of included analyitcs script. Values: top-head, bottom-head, bottom-body
- IV 2 ATTRIBUTE: Attribute of included analyitcs script: no-attribute, async, defer
- IV 3 OTHER SCRIPT: Other tracking script included
- Other IVs not included but worth mentioning

I will compare the values from one independent variable only. Therefore, when comparing the values of one independent variable, i need to set a default value for the other independent variables. The default values are:

Position: top-head Attribute: no attribute Other Script: false

Other IVs not included but worth mentioning

- More or less infinite number of independent variables
- Again the big and important fact that each website is different

Listing 4.1: Position 1

```
<!DOCTYPE html>
<html>
    <head>
        <!-- Google Analytics -->
        <script></script>
        <!-- End Google Analytics -->

        <title>
        <meta>
        <link>
        <script>
    </head>

    <body>
        ...
    </body>
</html>
```

Listing 4.2: Position 2

```
<!DOCTYPE html>
<html>
    <head>
        <title>
        <meta>
        <link>
        <script>

        <!-- Google Analytics -->
        <script></script>
        <!-- End Google Analytics -->
    </head>

    <body>
        ...
    </body>
</html>
```

Listing 4.3: Position 3

```
<!DOCTYPE html>
<html>
    <head>
        <title>
        <meta>
        <link>
        <script>

    </head>

    <body>
        ...
        <!-- Google Analytics -->
        <script></script>
        <!-- End Google Analytics -->
    </body>
</html>
```

Listing 4.4: Attribute 1

```
<!DOCTYPE html>
<html>
    <head>
        <!-- Google Analytics -->
        <script></script>
        <!-- End Google Analytics -->

        <title>
        <meta>
        <link>
        <script>
    </head>

    <body>
        ...
    </body>
</html>
```

Listing 4.5: Attribute 2

```
<!DOCTYPE html>
<html>
    <head>
        <!-- Google Analytics -->
        <script async></script>
        <!-- End Google Analytics -->

        <title>
        <meta>
        <link>
        <script>
    </head>

    <body>
        ...
    </body>
</html>
```

Listing 4.6: Attribute 3

```
<!DOCTYPE html>
<html>
    <head>
        <!-- Google Analytics -->
        <script defer></script>
        <!-- End Google Analytics -->

        <title>
        <meta>
        <link>
        <script>
    </head>

    <body>
        ...
    </body>
</html>
```

Listing 4.7: Other Script 1

```
<!DOCTYPE html>
<html>
    <head>
        <!-- Google Analytics -->
        <script></script>
        <!-- End Google Analytics -->









        <title>
        <meta>
        <link>
        <script>
    </head>

    <body>
        ...
    </body>
</html>
```

Listing 4.8: Other Script 2

```
<!DOCTYPE html>
<html>
    <head>
        <!-- Google Analytics -->
        <script></script>
        <!-- End Google Analytics -->

        <!-- Other Script-->
        <script></script>
        <!-- End Other Script -->

        <title>
        <meta>
        <link>
        <script>
    </head>

    <body>
        ...
    </body>
</html>
```

4.2 Test Object: HTML Template / Test website ideas

- Several ideas are proposed
- Each idea has pro and contra: each idea should be discussed of its usefulness, advantages and disadvantages

4.2.1 WordPress

- Show usage of WordPress with some statistics: Why is it so verbreitet
- Explain Plugin system
- Explain Setup on localhost with wocommerce and GA plugin
- Elaborate why this idea was not used

4.2.2 Plain / Skeletal Website

- Idea: Lab environment to have control over all and see effects of changing independent variables
- Problem: Too far away from reality
- Use this as the simplest test possible, not even POC (POC is http archive site)

4.2.3 HTTP Archive inspired website

- Idea: Get correct page weight
- POC: Show that changing independent variables X affect result

4.2.4 Mirroring a complete e-commerce website

- Which website / shop to clone? Show some statistics about biggest e-commerce websites in germany

Otto Re-write this to otto start page clone chapter

Manual adjustments: - Move everything to test folder because top domain is /otto

What did not work (mostly 404s): - user-set-consent-id-cookie: Cookie with name consentId is not set, user-set-consent-id-cookie returns therefore 404 - subscribeToNewsletterSnippetContent: Change path did not work... - amount.json: Not found, also wl_miniWishlistAmount in local storage does not created - a_info: Mock a_info response json does not work...

- footer - userTiming

WPT RV is returning empty csv when 404s are encountered. Therefore i mock the missing ressources so that WPT can run bulk tests successfully.

- mock image sprite_all_1ba408b2.png
- create empty file called user-set-consent-id-cookie
- change path for subscribeToNewsletterSnippetContent: This will remove the cookie banner... but then WPT works

- Idea: Close to reality as possible
- Problems when mirroring a website
- Elaborate why this idea of mirroring complete website was not used
- I used mock of start page of otto, which works fine
- Compare original otto website with mock

Comparison to original webpage

- Remove GA again from mock, so that mock and original are as similar as possible
- Run the same lab test on both pages: WPT and mabye lighthouse
- Compare both results and explain differences

- Setup: Run WPT on mock and on original website - WPT config: - Browser: Chrome - Number of test runs: 3 - FV and RV - Capture Video - Capture DevTools Timeline - Bulk testing: 100x

Diagrams with FV and RV for both cases:
Technical: - First Byte - Bytes In (Doc) - Requests (Doc)
VIsual: - Document Complete - Speed Index

Problem with Repeat View - Problem with RV, Caching: Otto sets request headers to cache-control: no-cache which means that RV basically downloads all resources again. The mock is hosted on Github, where the cache-control header is set to ... It is not possible to change the github request headers. We can modify the http request headers via html, but this is not a clean solution. Therefore I use a different e-commerce website which does not shut down caching so that the RV results are more similar.

Ideally I would host the mock website on a similar infrastructure as the original site with the same webserver configuration. This is for a masters thesis not feasible.

Zalando Idea: It looks like zalando page does not has that many cache-control headers, therefore it may be easier to clone so that RVs are more similar.

Comparison Diagrams with fixed traffic shaping:

4.3 Test Runs

- This section covers all conducted test runs
- Explain test configuration: how many runs, dependent and independent variables, etc.

4.3.1 WPT Configurations

General Settings

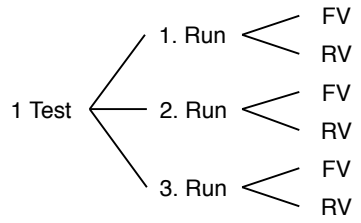
Table 4.1: Test Runs [Sch99]

Configuration Setting	Options	GA
Test Location	Test Location	.
Browser	Firefox, Chrome	.
Connection	LAN	.
Number of Tests to Run	1 to 9	..
Repeat View	First View and Repeat View, First View Only	.
Capture Video	True or False	..
Keep Test Private	True or False	...
Label	Any String	...
Advanced Tab	...	...
Chromium Tab	...	...
Auth, Script, Block, SPOF, Custom Tabs	...	...
Bulk Testing Tab	List of URLs	...

Explanations First View: "First View refers to the cold cache setup in which nothing is served locally" Repeat View: "Repeat View refers to the warm cache containing everything instantiated by the first view" (2016 Using WPT p. 62)

Capture Video: ...

Figure 4.1: Number of tests to run: 3, First View and Repeat View



For one test, we have actually six times that the website gets loaded and tested. For e.g. 500 URLs in the bulk test list, we have a total of $500 \times 6 = 3000$ page hits.

Configuration 1

Table 4.2: Configuration 1

Configuration Setting	Option
Test Location	Test Location
Browser	Chrome
Connection	LAN
Desktop Browser Dimensions	default (1366x768)
Number of Tests to Run	1
Repeat View	First View and Repeat View
Capture Video	True
Keep Test Private	False
Label	none
Advanced Tab	Nothing selected
Chromium Tab	Capture Dev Tools Timeline selected
Auth, Script, Block, SPOF, Custom Tabs	Nothing
Bulk Testing Tab	Test URL x times according to test plan

Configuration 2 Emulate Mobile Browser

Traffic Shaping

- Important to have stable and realistic network condition
- Chromes tool is not the best for this
- Private WPT Instance docker on mac does not allow traffic shaping functionality from WPT
- I use Network Link Conditioner from Apple to slow down the whole machine. See in same blogpost that Patrick highly recommends this
- WPT also slows down their whole machines
- IN general internet connection is very unstable. If i run network link conditionier with e.g. DSL each speedtest gives different results. And other test platforms such as fast.com gives also different result.
- as long as internet connection is stable along all tests, it should not make a big difference because i compare the different variants. Therefore internet connection will fall out of the equation
- i will use the durchschnitt in germany which seems to be 40 mbit per second. or actually i use LTE profile from network conditioner which is 50 mbit per second

4.3.2 Test Object (Website) Variations

as described before, i will compare the values within one independent variable. This is needed in order to compare the impact of the different values within one IV. For example,

i want to measure if there is a difference in performance between the different script attributes. To measure this, i set the default values for the other IVs and vary the values for the IV attribute

Positions: 1: Top of head element 2: just before closing head element 3: just before closing body element

Variants

Variant	Position	Attribute	Other Scripts
Variant P1	top-head	none	no
Variant P2	bottom-head	none	no
Variant P3	bottom-body	none	no
Variant A1	top-head	none	no
Variant A2	top-head	async	no
Variant A3	top-head	defer	no
Variant OS1	top-head	none	no
Variant OS2	top-head	none	yes

Table 4.3: Your caption here

I will not compare variants which are not from the same subgroup, e.g. Variant A2 will not be compared to Variant OS2. Because the first row of the variants table also includes the default values for Attribute and Other Scripts, VP1 is equal to VA1 and VO1.

With the defined IVs and variants, I can create the test objects, that is the index.html files with the corresponding setup. Because its easier to differentiate i will create for the three equal variants nevertheless own index files.

For each test variant, I will create a concrete test artefact, which is a modified index.html. This index.html needs to be uploaded to the webserver before starting with the tests.

All variants will have the same name which is index.html. This is the default file which will be delivered by the webserver when accessing root path of webpage.

Variants to measure: ————————

- Original website - Mock without GA - Position 1 - Position 2 - Position 3 - Attribute 1 - Attribute 2 - Attribute 3 - Other Script True - Other Script False

4.3.3 Test Plan. Generate the data

The Google Analytics code is more or less fixed and there are no configurations. It would be possible to change config of script, e.g. change sample rate, track other metrics etc. But it is not possible to change default tracking behaviour (?)

How the script is included into the file should reflected withing Website Variations

I will use only one WPT Configuration for all tests. Other WPT config can be used in future work, e.g. emulate mobile device.

Table 4.4: Test Runs [Sch99]

Variant	Traffic Shaping	Runs	Date
V-P1	DSL	500	2021-05-07
V-P2	DSL	500	2021-05-07
V-P3	DSL	500	2021-05-07
V-A1	DSL	500	2021-05-07
V-A2	DSL	500	2021-05-07
V-A3	DSL	500	2021-05-07
V-OS1	DSL	500	2021-05-07
V-OS1	DSL	500	2021-05-07

Pre-step: Compare Mock website with and without GA included The comparison between mock and original is part of chapter Test Object

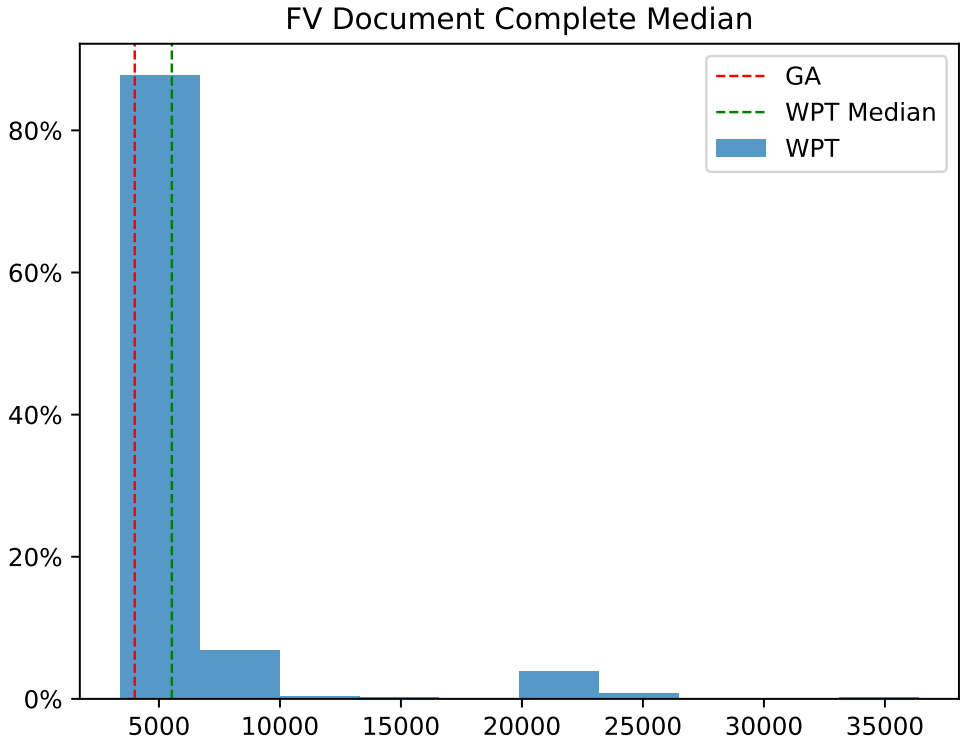
4.3.4 Test Protocol

- Deploy variant of index.html by pushing to GitHub
- Start Network Link Conditioner with specified config on local machine
- Test internet speed with speedtest-cli
- Start local WPT server and agent
- Configure WPT according to specified setup and add list of urls to bulk test interface
- Run test
- When finished, download summary csv file
- On GA helper site, fetch and download data for the current day

4.3.5 Tool support for diagrams and data analysis

- python
- Matplotlib
- seaborn library

5 Evaluation



- Last chapter...
- This chapter: Describe shortly all sections from this chapter
- In the next chapter...

5.1 Test Results

5.1.1 Metrics for Evaluation

Page Weight: Measured by WPT: - bytes - bytes uncompressed - Requests

Technical Timings / API: Measured by WPT and GA: - page load time - domain lookup time - page download time - redirection time - server connection time - server response time - Dom interactive time - Dom content loaded time

Visual Metrics / Web Vitals: Measured by WPT TODO Measure also with GA / own script ??: - CLS - FCP - FMP - LCP - SI

- Visually complete ? - Time to Interactive ? Is this the same as DOM interactive time ? Core Web Vital FID ?? -> Can not be measured without real users... From WPT bulk section. Also include this somewhere for comparison ?: - Filmstrips ? - Waterfall ? - Visual Progress ? - Layout Shifts ?

5.1.2 Original vs Mock Plain

5.1.3 Mock Plain vs Position 1 (which is default position of GA: Check this again!)

TODO rename this like with GA true false ?

5.1.4 Position 1 vs 2 vs 3

5.1.5 Attribute 1 vs 2 vs 3

5.1.6 Other script True vs False

5.2 General

- For each attempt, describe: Threats to validity, generalizability

generalizability: meine Daten zeige nur für Chrome, MacBook, diese Geschwindigkeit etc. Und auch nur für diese Test-Website Die Schwierigkeit der Generalisierbarkeit ist eines der grössten Probleme bei dieser Fragestellung

5.3 Plain / Skeletal Website

- Information gained from this experiment
- Limitations and questions which can not be answered with this approach

5.4 Mirroring

5.5 HTTP Archive inspired website

- Information gained from this experiment
- Meaning and interpretation of the collected data
- Limitations and questions which can not be answered with this approach

5.6 WebPageTest Bulk Tests

- Bulk testing is a feature for private instances only
- Misuse this feature to test the same website X times

5.6.1 Bulk Test Overview: Description of test result page

- Each test has Test ID: YYMMDD_random_random
- Test results after bulk test available under `http://localhost:4000/result/{testID}/`
- For each test run, following data is available:
  - Link to test results: Test result page as same as for single test run
  - Median load time (First view)
  - Median load time (Repeat view)
  - Median Speed Index (First View)
  - Raw page data (file: [TestID_summary.csv]
  - Raw object data (file: [TestID_details.csv])
  - Http archive (.har) (file: json)
- Average First View Load Time
- Average Repeat View Load Time
- Combined Raw: Page Data (file: [TestID_summary.csv])
- Combined Raw: Object Data (file: [TestID_details.csv]). For 100 test runs, this file is appr. 20 MB, 24432 rows, 76 columns.
- Aggregate Statistics (file: [TestID_aggregate.csv])

5.6.2 Summary File for one Test

- Contains 6 rows: 3 test runs: for each test runs 1x first view and 1x repeat view
- Rows 1, 3, 5 contain FV, rows 2, 4, 6 contain data for RV

5.6.3 Aggregate Statistics File

- Contains aggregated data from bulk test
- One row for each test run: For 100 URLs in bulk test will be 100 rows in csv
- Each metric is available with Median, Average, Standard Deviation, Min, Max

- Metrics are available once from FV and once for Repeat View
- Metrics:
  - Successful Tests
  - Document Complete
  - Fully Loaded
  - First Byte
  - Start Render
  - Bytes In (Doc)
  - Requests (Doc)
  - Load Event Start
  - Speed Index
  - Last Visual Change
  - Visually Complete
- => For metric details, see Terms and Definitions

5.6.4 Compare Section

WPT has a feature to compare multiple tests. Accessible under compare URL: `http://localhost:4000/video/compare.php?tests={TestID},{TestID},...`

The compare page contains:

- Film strip
- Waterfall diagram
- Visual Progress diagram
- Timings diagram:
  - Visually Complete (First View Visually Complete Median)
  - Last Visual Change
  - Load Time (onload)
  - ...
- Cumulative Layout Shift diagram
- Requests diagram
- Bytes diagram
- Visually complete

- Last Visual Change
- Load Time (onload)
- Load Time (Fully Loaded)
- DOM Content Loaded
- Speed Index
- Time to First Byte
- Time to Title
- Time to Start Render
- CPU Busy Time
- 85% Visually Complete
- 90% Visually Complete
- 95% Visually Complete
- 99% Visually Complete
- First Contentful Paint
- First Meaningful Paint
- Largest Contenful Paint
- Cumulative Layout Shift
- html Requests
- html Bytes
- js Requests
- js Bytes
- css Requests
- css Bytes
- image Requests
- image Bytes
- flash Requests
- flash Bytes

- font Requests
- font Bytes
- video Requests
- video Bytes
- other Requests
- other Bytes

5.7 Internal, external validity

- At this point, i have the data collected and can analyse it
- The quality and quantity of the data needs to be discussed
- Quality: There are chances that some data are malformed, e.g. because internet connection was bad, etc.
- Quantity: Is the amount of data sufficient to make the evaluation generalisable

6 Future Work

- Last chapter...
- This chapter: Describe shortly all sections from this chapter
- In the next chapter...

6.1 Limitations of this thesis

- Discussion of unobserved topics
- Discussion of possible next steps

6.2 Other measurement tools and metrics

- List of tools and metrics worth investigating

6.2.1 Google Analytics 4

6.3 Speed Kit

6.4 PWAs, AMPs, Service Workers, Caching, HTTP2 etc.

- Overview of other web technologies and how they could be relevant for further research

7 Conclusion

- Last chapter...
- This chapter: Describe shortly all sections from this chapter
- Scope and contribution of this thesis
- Short summary of each chapter:
  - Problem statement and why it is worth to examine research question
  - Terms and definitions
  - (Related work)
  - Approach and evaluation of practical work
  - Future work

- Several topics wurden bearbeitet in this thesis, such like mocking a website for testing purposes, literature review, metrics taxonomy, and the main part which is an experiment

8 Appendix

8.1 WebPageTest Bulk Tests

8.1.1 Single Test Raw page data

WPT Metrics from summary file

Name	Description
minify_total	Total bytes of minifiable text static assets.
responses_200	The number of responses with HTTP status code of 200, OK.
testStartOffset	...
bytesOut	The total bytes sent from the browser to other servers.
gzip_savings	Total bytes of compressed responses.
requestsFull	...
start_epoch	...
connections	The number of connections used.
base_page_cdn	The CDN provider for the base page.
bytesOutDoc	Same as bytesOut but only includes bytes until the Document Complete event. Usually when all the page content has loaded (window.onload).
result	Test result code.
final_base_page_request_id	...
basePageSSLTime	...
docTime	Same as loadTime.
domContentLoadedEventEnd	Time in ms since navigation started until document DOMContentLoaded event finished.
image_savings	Total bytes of compressed images.
requestsDoc	The number of requests until Document Complete event.
firstMeaningfulPaint	...
score_cookies	WebPageTest performance review score for not using cookies on static assets.
firstPaint	RUM First Paint Time, the time in ms when browser first painted something on screen. It's calculated on the client for browsers that implement this method.
score_cdn	WebPageTest performance review score for using CDN for all static assets.
optimization_checked	Whether or not optmizations were checked.

score_minify	WebPageTest performance review score for minifying text static assets.
gzip_total	Total bytes of compressible responses.
responses_404	The number of responses with HTTP status code of 404, not found.
loadTime	The total time taken to load the page (window.onload) in ms.
URL	The tested page URL.
score_combine	WebPageTest performance review score for bundling JavaScript and/or CSS assets.
firstContentfulPaint	...
image_total	Total bytes of images.
score_etags	WebPageTest performance review score for disabling *ETag*s.
loadEventStart	Time in ms since navigation started until window.onload event was triggered (from W3C Navigation Timing).
minify_savings	Total bytes of minified text static assets.
score_progressive_jpeg	WebPageTest performance review score for using progressive JPEG.
domInteractive	...
score_gzip	WebPageTest performance review score for using gzip compression for transferring compressable responses.
score_compress	WebPageTest performance review score for compressing images.
domContentLoadedEventStart	Time in ms since navigation started until document DOMContentLoaded event was triggered (from W3C Navigation Timing).
final_url	...
bytesInDoc	Same as bytestIn but only includes bytes until Document Complete event.
firstImagePaint	...
score_keep-alive	WebPageTest performance review score for using persistent connections.
loadEventEnd	Time in ms since navigation started until window.onload event finished.
cached	0 for first view or 1 for repeat view.
score_cache	WebPageTest performance review score for leveraging browser caching of static assets.
responses_other	The number of responses with HTTPS status code different from 200 or 404.
main_frame	...
fullyLoaded	The time (in ms) the page took to be fully loaded — e.g., 2 seconds of no network activity after Document Complete. This will usually include any activity that is triggered by javascript after the main page loads.
requests	List of details of all requests on tested page.

final_base_page_request	...
TTFB	Time to first byte, which is the duration in ms from when the user first made the HTTP request to the very first byte of the page being received by the browser.
bytesIn	The amount of data that browser had to download in order to load the page. It is also commonly referred to as the page size.
osPlatform	...
test_run_time_ms	...
tester	The ID of tester that performed the page test.
browser_version	The browser version.
document_origin	...
document_URL	...
date	Time and date (number of seconds since Epoch) when test was complete.
PerformancePaintTiming.first-paint	...
osVersion	...
domElements	The total number of DOM elements.
browserVersion	The browser version.
fullyLoadedCPUms	CPU busy time in ms until page was fully loaded.
browser_name	The browser name.
PerformancePaintTiming.first-contentful-paint	...
base_page_cname	...
eventName	...
os_version	...
base_page_dns_server	...
fullyLoadedCPUpct	Average CPU utilization up until page is fully loaded.
domComplete	...
base_page_ip_ptr	...
document_hostname	...
lastVisualChange	Time in ms until the last visual changed occured.
visualComplete	Time in ms when page was visually completed.
render	The first point in time (in ms) that something was displayed to the screen. Before that user was staring at a blank page. This does not necessarily mean the user saw the page content — it could just be something as simple as a background color — but it is the first indication of something happening for the user.
SpeedIndex	The SpeedIndex score.
visualComplete85	Time in ms when page was visually completed 85%.
visualComplete90	Time in ms when page was visually completed 90%.
visualComplete95	Time in ms when page was visually completed 95%.
visualComplete99	Time in ms when page was visually completed 99%.
LargestContentfulPaintType	...
LargestContentfulPaintNodeType	...

chromeUserTiming.navigationStart	...
chromeUserTiming.fetchStart	...
chromeUserTiming.responseEnd	...
chromeUserTiming.domLoading	...
chromeUserTiming.markAsMainFrame	...
chromeUserTiming.domInteractive	...
chromeUserTiming.domContentLoadedEventStart	...
chromeUserTiming.domContentLoadedEventEnd	...
chromeUserTiming.firstPaint	...
chromeUserTiming.firstContentfulPaint	...
chromeUserTiming.firstImagePaint	...
chromeUserTiming.firstMeaningfulPaint	...
chromeUserTiming.firstMeaningfulPaintCandidate	...
chromeUserTiming.domComplete	...
chromeUserTiming.loadEventStart	...
chromeUserTiming.loadEventEnd	...
chromeUserTiming.LargestContentfulPaint	...
chromeUserTiming.LargestTextPaint	...
chromeUserTiming.CumulativeLayoutShift	...
run	The run number.
step	...
effectiveBps	Bytes per seconds, i.e.: total of bytes in / total time to load the page.
effectiveBpsDoc	Same as effectiveBps but until Document Complete event.
domTime	The total time in ms until a given DOM element (specified via domelement parameter when running a test) was found on the page.
aft	Above the Fold Time (no longer supported). The time taken to load everything in the viewport above the fold.
titleTime	Total time in ms until page title was set on browser.
domLoading	...
server_rtt	...
smallImageCount	...
bigImageCount	...
maybeCaptcha	...
bytes.html	...
requests.html	...
bytesUncompressed.html	...
bytes.js	...
requests.js	...
bytesUncompressed.js	...
bytes.css	...
requests.css	...
bytesUncompressed.css	...
bytes.image	...
requests.image	...

bytesUncompressed.image	...
bytes.flash	...
requests.flash	...
bytesUncompressed.flash	...
bytes.font	...
requests.font	...
bytesUncompressed.font	...
bytes.video	...
requests.video	...
bytesUncompressed.video	...
bytes.other	...
requests.other	...
bytesUncompressed.other	...
id	...
chromeUserTiming.InteractiveTime	...

Table 8.1: Your caption here

8.1.2 Single Test Raw object data

8.1.3 Single Test Http archive (.har)

8.1.4 Combined Test Raw page data

8.1.5 Combined Test Raw object data

8.1.6 Combined Test Aggregate data

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