



WE ARE ALL GOOD WITH
BROWSERS MADE BY OTHERS



HOW MANY OF US HAVE NEVER SAID A #?!-*!!!?



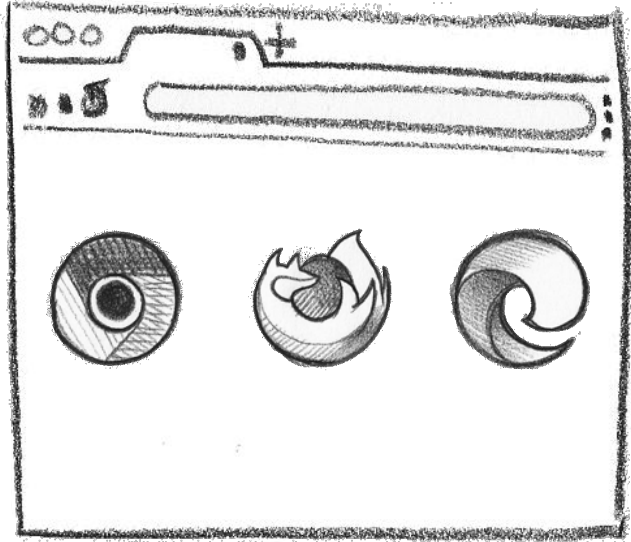


WHAT IS A BROWSER

EVERYONE USES IT. FEW KNOW IT.



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GOOGLE DEVELOPER EXPERT / MICROSOFT MVP / CODEMOTION DEVREL



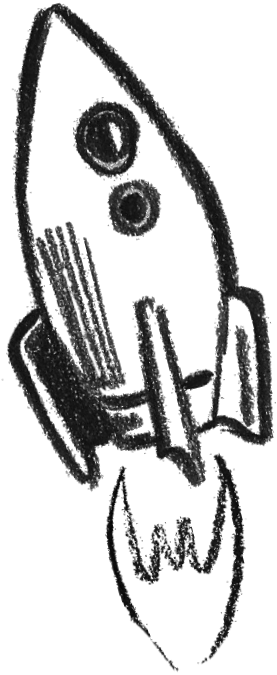
BROWSER

IT'S AN APPLICATION THAT REQUESTS DATA FROM WEB SERVERS, SENDS A NETWORK REQUEST TO THE URL, RETRIEVES RESOURCES, AND PRESENTS THEM INTERACTIVELY!

EASY, RIGHT?

- THE MOST WIDELY USED TYPE OF SOFTWARE BY FAR.
- MADE UP OF MILLIONS OF LINES OF C++ AND OTHER TOUGH STUFF
- CHANGED A LOT OVER TIME
- A POWERHOUSE OF TECHNOLOGY AND ALGORITHMS, EVEN MORE THAN THE BATMOBILE!

BUT THOSE WHO WRITE BROWSERS HAVE A LITTLE CHAOS TO MANAGE...



USERS LOVE TO SEE PIXELS ON THE SCREEN AS QUICKLY AS POSSIBLE, WHICH IS THE REASON WHY THE BROWSING EXPERIENCE IS ENJOYABLE!



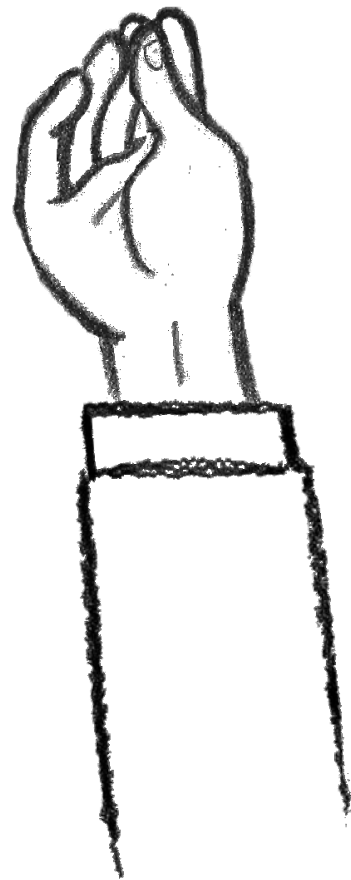
BUT YOU MIGHT BE THINKING...



WHY SHOULD I CARE?

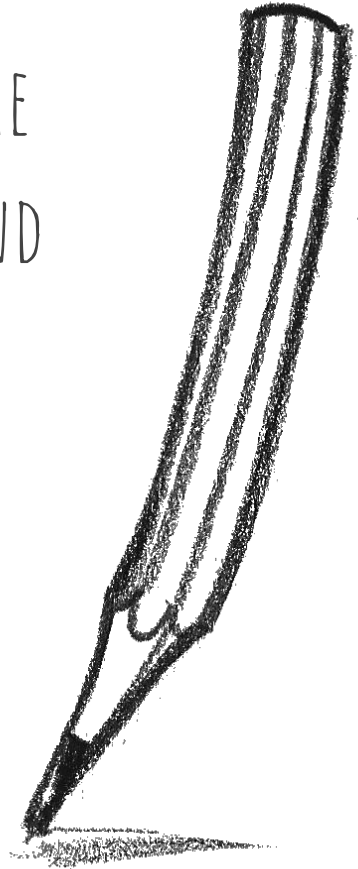
I'M NOT A BROWSER CODE DEVELOPER!

P.S. IF ANY OF YOU ARE ON THE CHROMIUM TEAM... PLEASE BE MERCIFUL!



AS WEB DEVELOPERS, WE MUST UNDERSTAND SOME OF THE
MECHANICS OF BROWSERS TO MAKE BETTER DECISIONS AND
MAKE SENSE OF SOME THINGS THAT SOMETIMES SEEM
ABSURD.

(QUOTE: CICCIO DA VAL DEMONE)



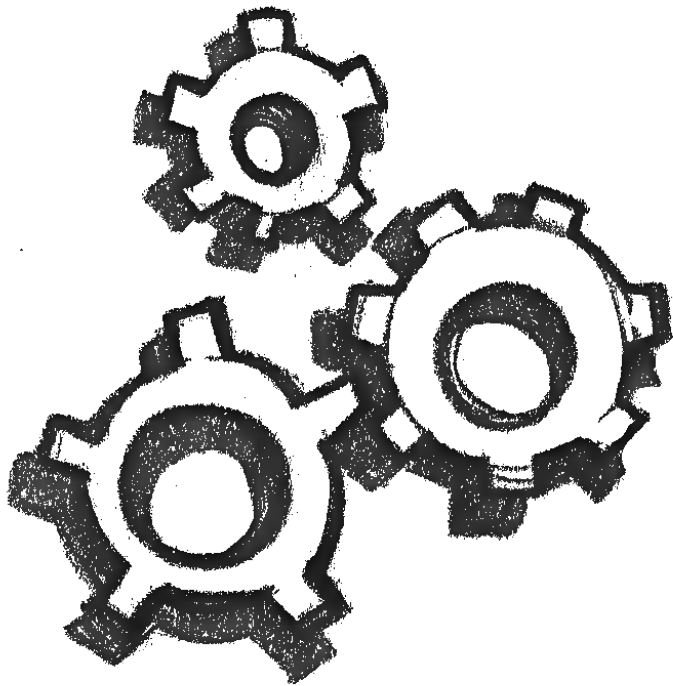


HOW IS IT MADE

WE'RE ALL EXCELLENT AT STEERING SOMEONE ELSE'S SHIP



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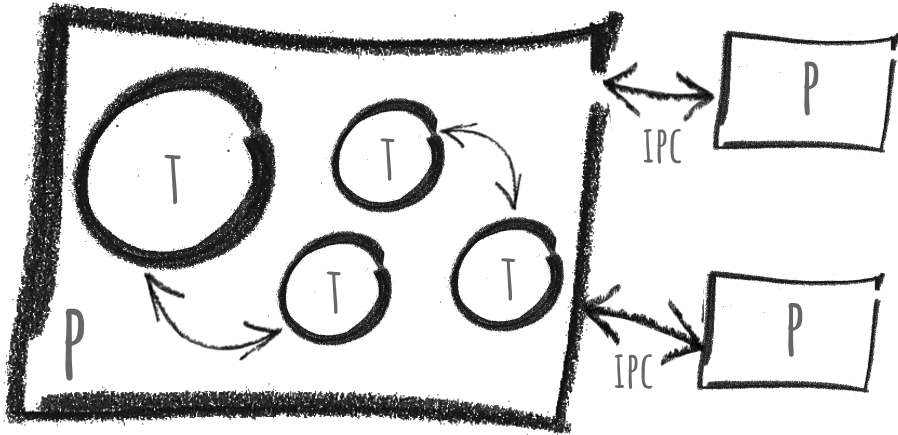


ARCHITECTURE

THERE ARE NO SPECIFIC STANDARDS ON HOW TO BUILD A WEB BROWSER. THE APPROACH CAN VARY SIGNIFICANTLY FROM ONE BROWSER TO ANOTHER.

- MULTI-PROCESS APPLICATIONS
- EACH PROCESS HANDLES SPECIFIC LOGIC
- EACH PROCESS HAS A MAIN THREAD AND POSSIBLE DEDICATED SPECIAL THREADS

PROCESSES & THREADS



- A **PROCESS** CAN BE DESCRIBED AS THE RUNNING PROGRAM OF AN APPLICATION.
- A **THREAD** LIVES WITHIN THE PROCESS AND EXECUTES ANY PART OF THE PROCESS TO WHICH IT BELONGS.

PROCESSES CAN COMMUNICATE WITH EACH OTHER THROUGH IPC (INTER PROCESS COMMUNICATION).

THREADS CAN ALSO COMMUNICATE WITH EACH OTHER WITHIN THE PROCESS THAT CONTAINS THEM, BUT NOT DIRECTLY WITH THREADS IN OTHER PROCESSES.

COMMUNICATION BETWEEN PROCESSES IS GENERALLY SLOWER THAN COMMUNICATION BETWEEN THREADS WITHIN A PROCESS.



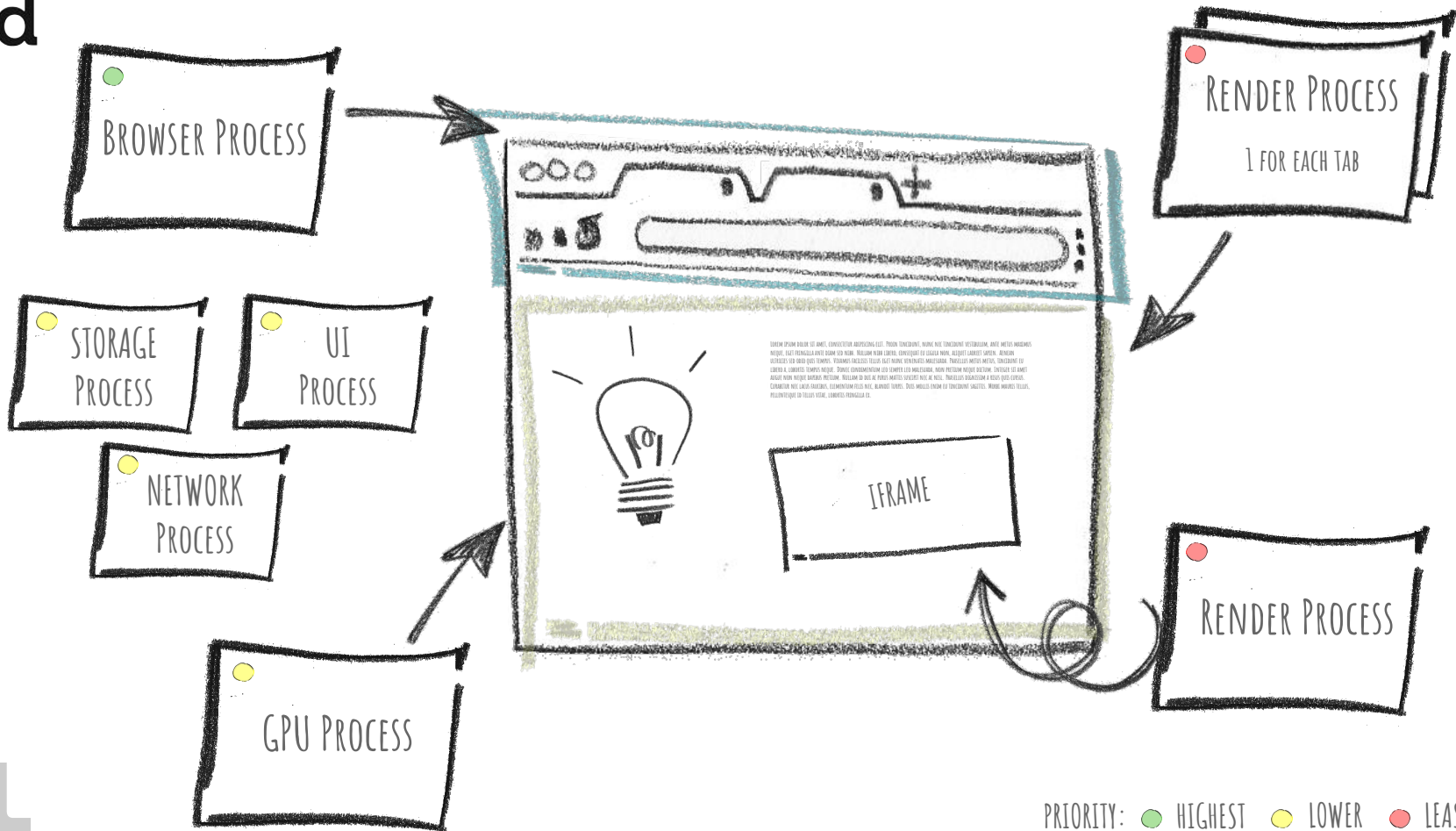
BROWSER PROCESSES

A PROCESS TO SEIZE THEM AND CHAIN THEM IN THE DARK



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PRIORITY: ● HIGHEST ● LOWER ● LEAST



MULTI-PROCESS ARCHITECTURES

PROS

- SAND-BOXING
- BLACK SHEEP DETECTION
- OPTIMAL MEMORY FOOTPRINT
- PRIVATE DATA
- SITE ISOLATION

CONS

- MEMORY OVERHEAD
- PROCESS CREATION OVERHEAD
- IPC OVERHEAD



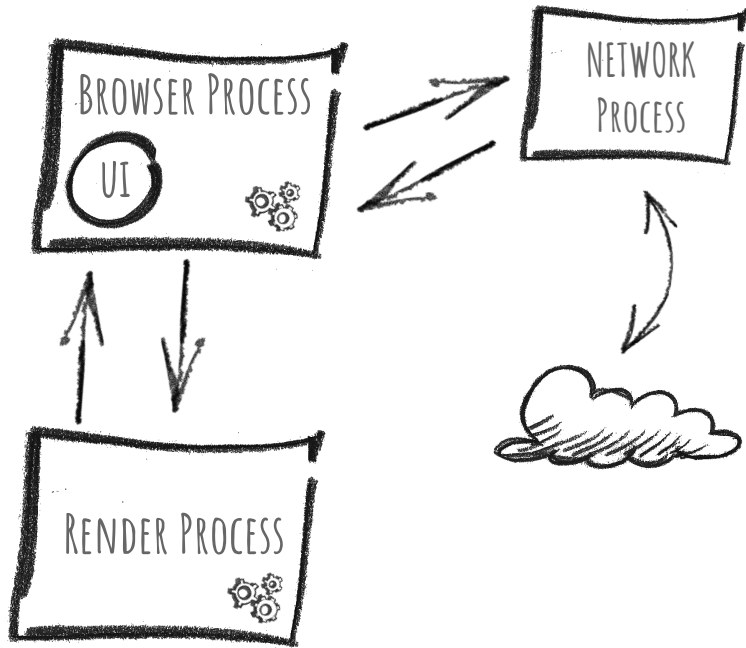
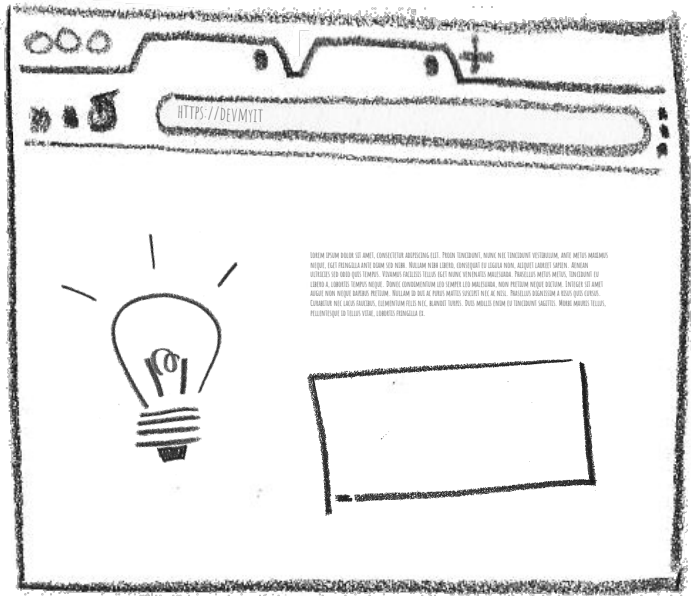
HOW DOES IT WORKS

SAILING SEEMS EASY, BUT STEERING THE TITANIC IS RISKY



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YOU WRITE IN THE ADDRESS BAR AND...



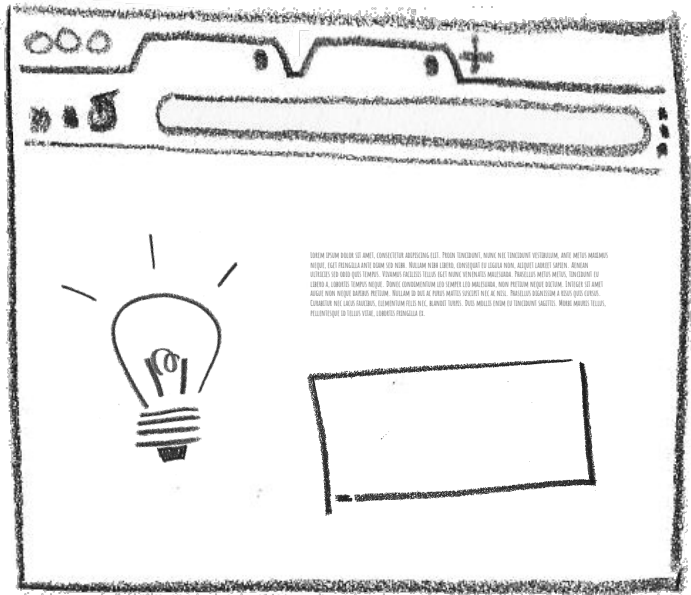


RENDERING

EASY, RIGHT?



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RENDER A PAGE

THE RENDERING PROCESS, WHICH THE EXCELLENT RENDERING PROCESS DEALS WITH, IS CERTAINLY THE MOST COMPLEX AND INTERESTING PART AND IS THE ONE IN WHICH WE HAVE TO FACE THE MUCH-FEARED **CRITICAL RENDERING PATH!**

A SINGLE PROCESS, MANY THREADS: MAIN THREAD, WORKER THREADS, COMPOSITOR THREAD, RASTER THREAD, ...

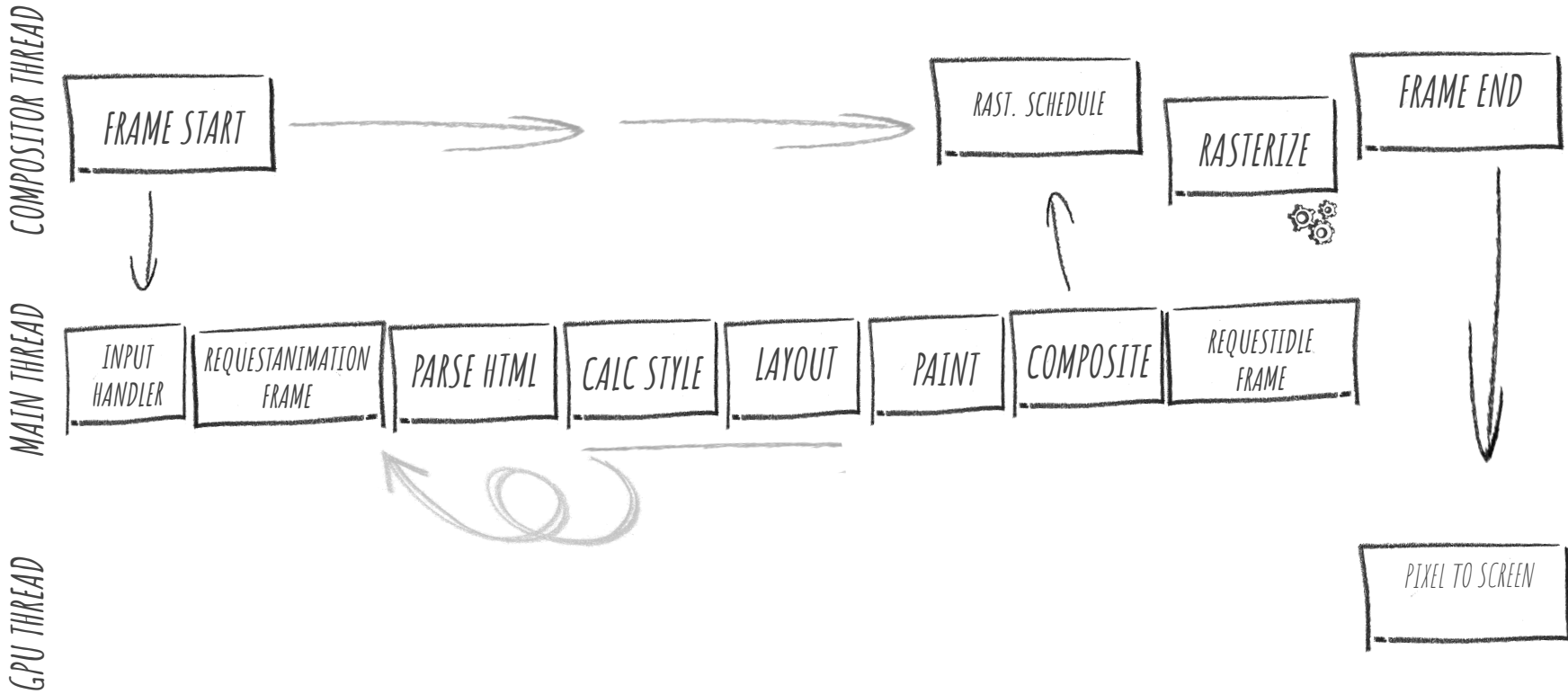
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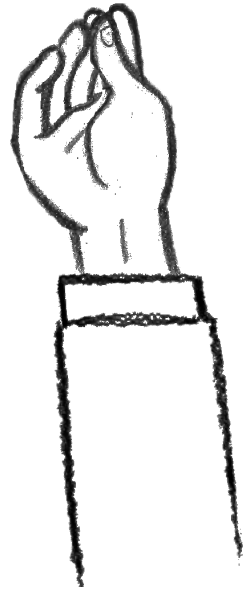


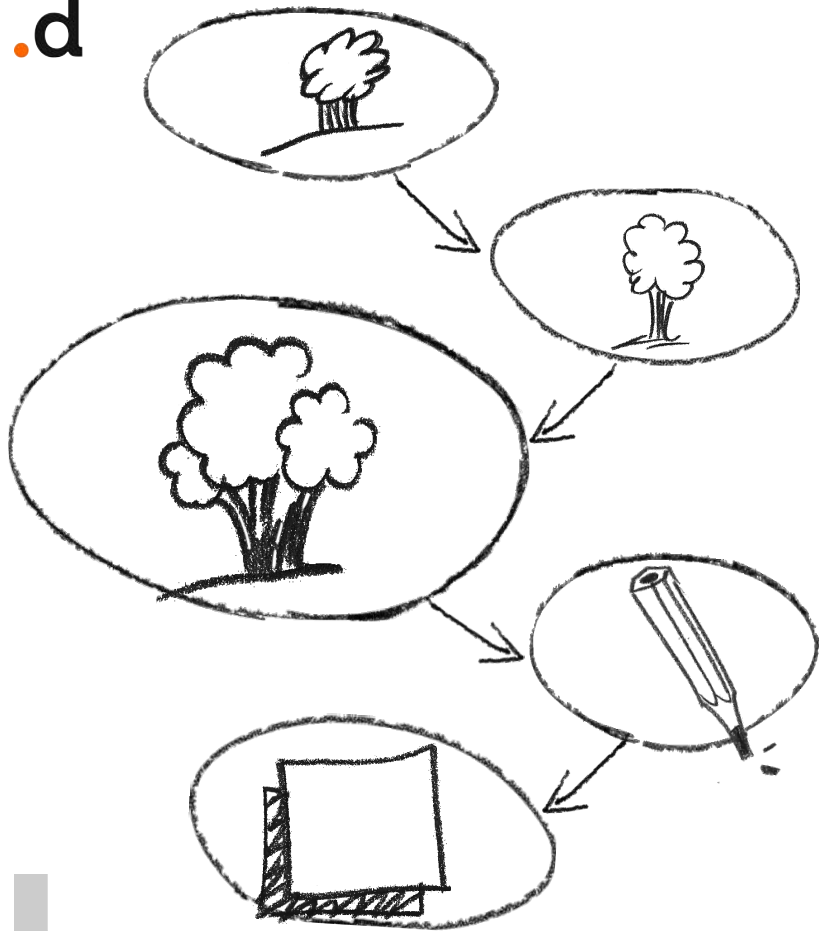
RENDER PROCESS

GPU PROCESS



SCARED, HUH?





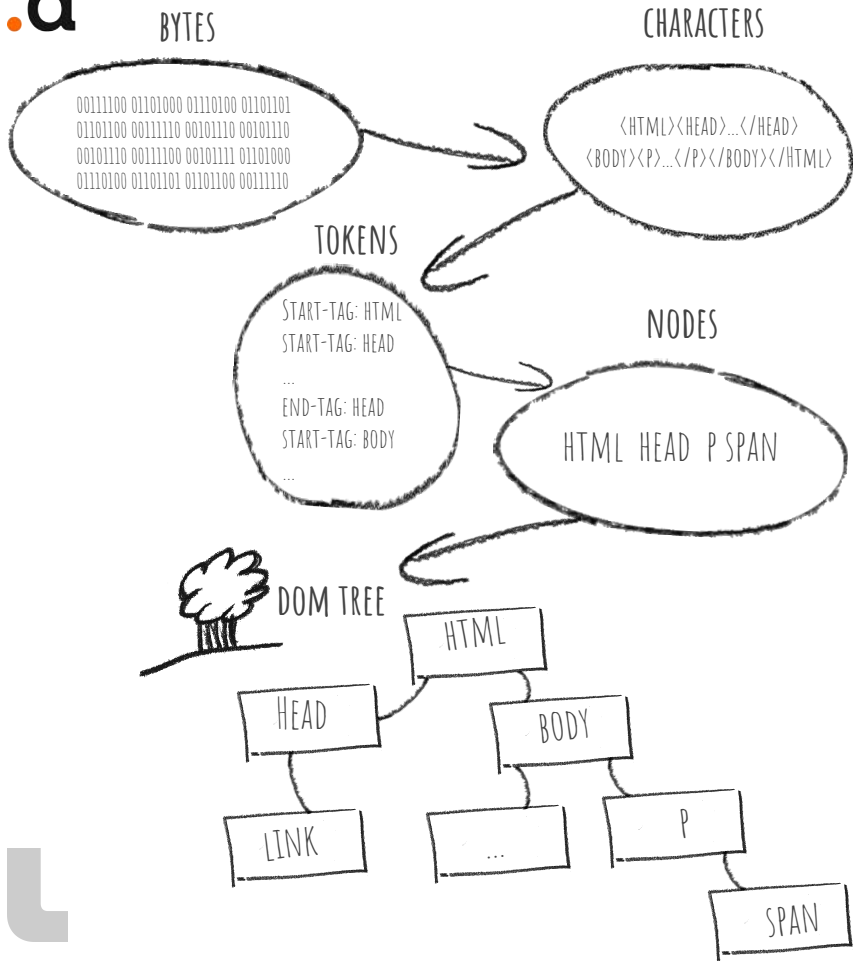
RENDER A PAGE

THE RENDERING PROCESS, LARGELY THANKS TO ITS MAIN THREAD, FOLLOWS THIS PATH:

- PARSING
- STYLE CALCULATION
- LAYOUT
- PAINT
- COMPOSITING

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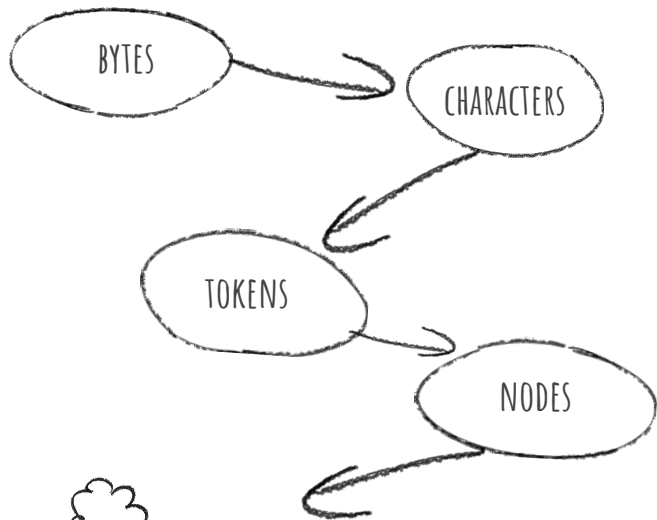
PARSING

DATA IS SENT OVER THE INTERNET AS PACKETS, AND THE BROWSER READS THE RAW BYTES OF THE HTML (EVEN FROM THE HARD DISK).

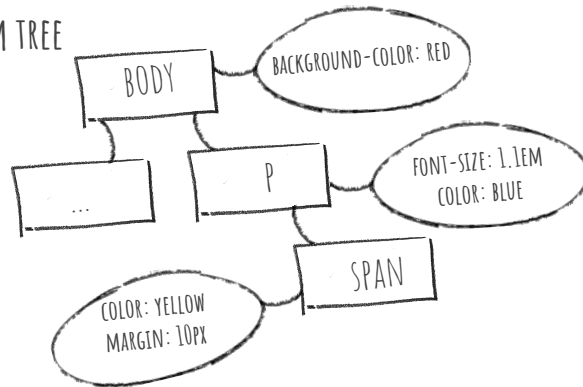
THE MAIN THREAD HAS THE TASK OF:

- BYTES -> CHARACTERS
- CHARACTERS -> TOKEN
- TOKEN -> NODES
- NODES -> **DOM** (FINALLY!)
- SUBRESOURCE LOADING





CSSOM TREE

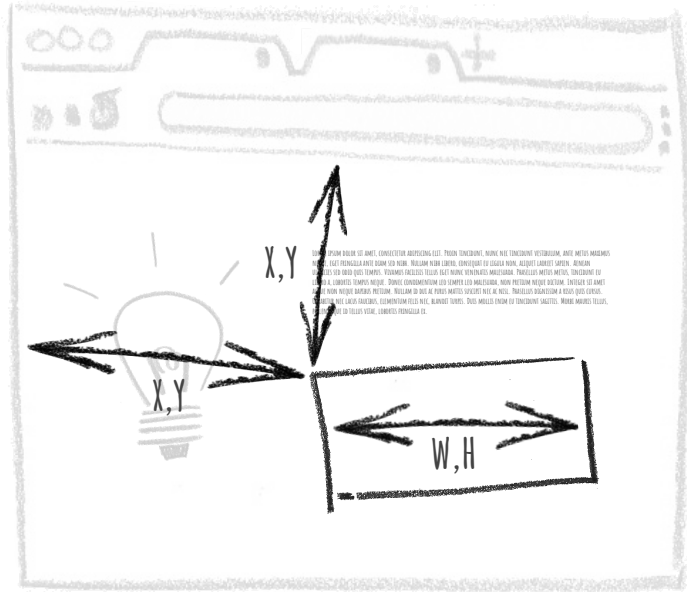


STYLE CALCULATION

THE MAIN THREAD PARSES CSS AND DETERMINES THE COMPUTED STYLE FOR EACH DOM NODE BASED ON THE CSS SELECTORS.

- CSS BYTES -> CHARACTERS
- CHARACTERS -> TOKEN
- TOKEN -> NODES
- NODES -> CSSOM
- LAYOUT (OR RENDER) TREE!

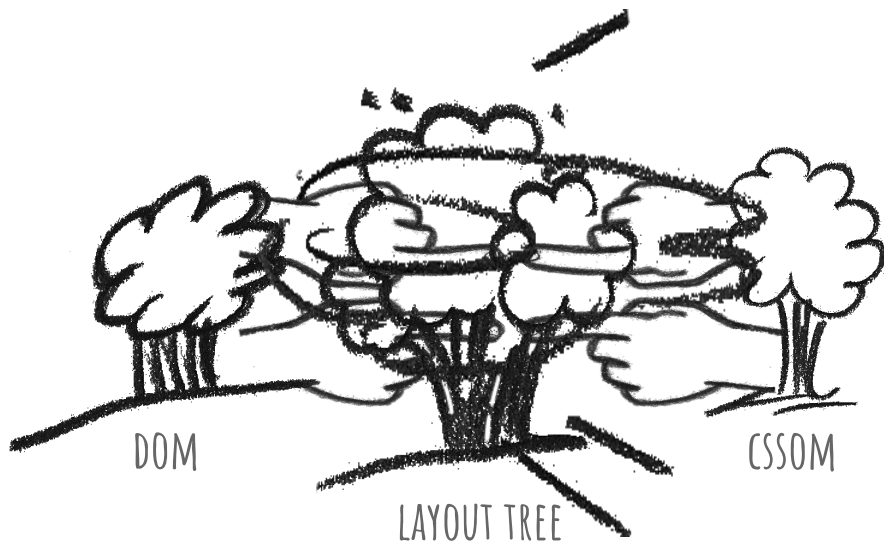
LAYOUT



LAYOUT (OR REFLOW) IS THE PROCESS WHERE THE MAIN THREAD GOES THROUGH THE DOM AND STYLES AND CREATES **THE LAYOUT TREE (OR RENDER TREE)**, WHICH CONTAINS INFORMATION SUCH AS THE COORDINATES AND DIMENSIONS OF THE ELEMENTS.

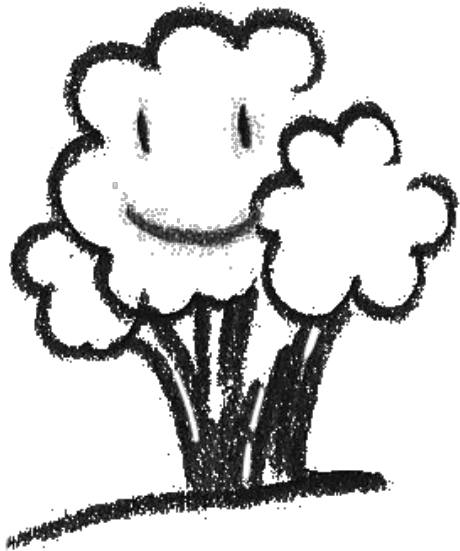
THE LAYOUT PROCESS IS EXTREMELY EXPENSIVE FOR THE BROWSER BECAUSE IT MUST CALCULATE THE EXACT POSITION AND SIZE OF EVERY ELEMENT ON THE PAGE!

LAYOUT (0 REFLOW)



DOM + CSSOM = LAYOUT (OR RENDER) TREE

LAYOUT - LAYOUT TREE OR RENDER TREE

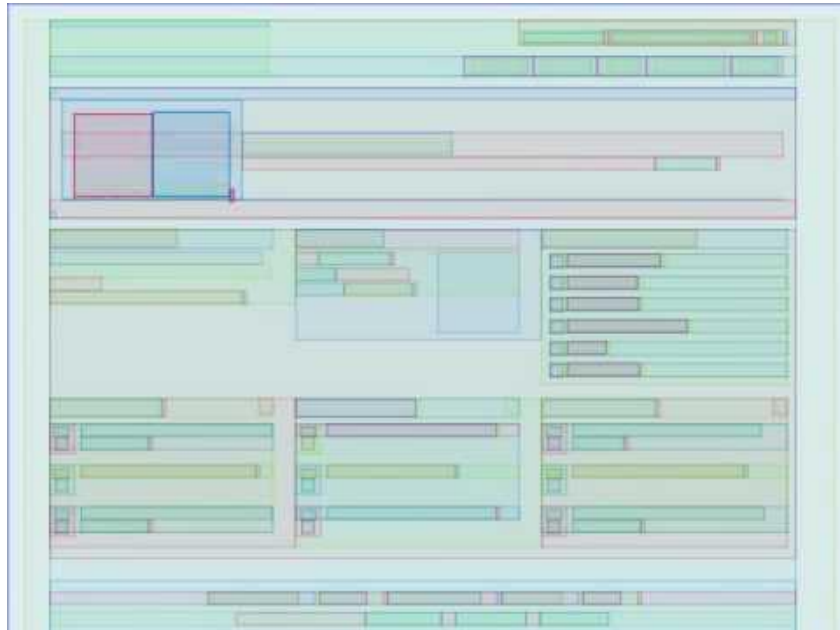


LAYOUT TREE

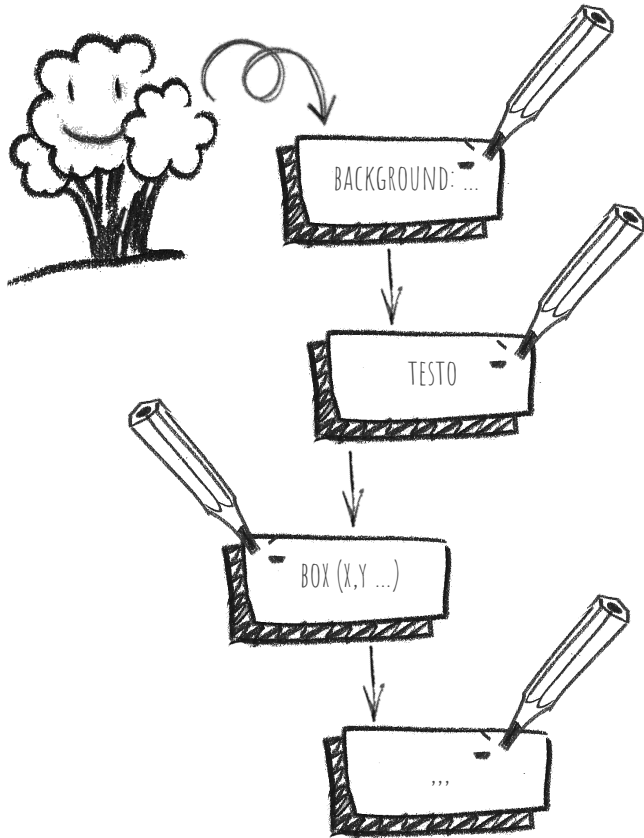
TO BUILD THE LAYOUT (OR RENDER) TREE, THE BROWSER WILL HAVE TO:

- RECURSIVELY TRAVERSE THE DOM AND SEARCH FOR VISIBLE ELEMENTS
- BUILD/UPDATE THE TREE LAYOUT NODE BY POINTING TO THE DOM NODE
- DERIVE THE COMPUTED STYLES FOR THE DOM NODE, AND ASSOCIATE THEM WITH THE LAYOUT TREE NODE

LAYOUT PHASE



THIS IS ACTUALLY GECKO REFLOW

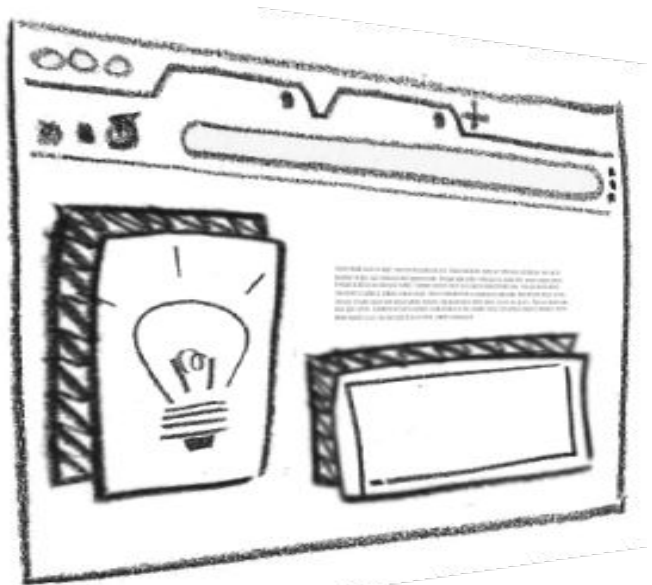


PAINT

WE KNOW THE DIMENSIONS AND POSITIONS OF THE ELEMENTS BUT NOT THE ORDER IN WHICH WE WILL DRAW THEM ON OUR PAGE.

THE MAIN THREAD TRAVERSES THE LAYOUT TREE TO BUILD A QUEUE OF **PAINT RECORDS**, WHICH ALLOWS YOU TO MANAGE THE DRAWING ORDER OF THE ELEMENTS.

COMPOSITING

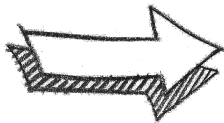


COMPOSITING IS A TECHNIQUE FOR LAYERING PARTS OF A PAGE, RASTERIZING THEM SEPARATELY, AND COMPOSITING THEM AS A PAGE IN A SEPARATE THREAD CALLED A **COMPOSER THREAD**.

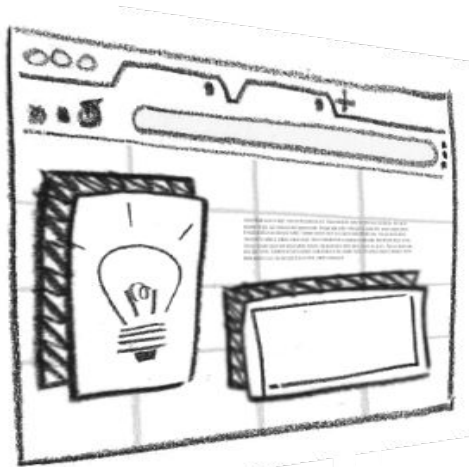
IF SCROLLING OCCURS (ONE OF THE MOST ONEROUS BUT COMMON OPERATIONS), SINCE THE LAYERS ARE ALREADY RASTERIZED, HE MUST COMPOSE A NEW FRAME.



LAYOUT
TREE



LAYER
TREE



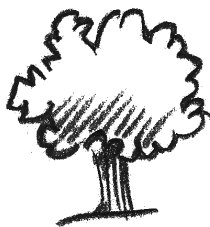
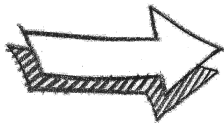
COMPOSITING

- THE MAIN THREAD TRAVERSALS THE LAYOUT TREE TO GENERATE THE LAYER TREE
- THE MAIN THREAD SENDS THIS INFORMATION IN THE COMPOSER THREAD
- THE COMPOSER THREAD RASTERIZES EACH LAYER
- THE COMPOSER THREAD DIVIDES INTO PANES AND SENDS EACH SQUARE (DRAW QUAD) TO THE RASTER THREAD
- A COMPOSER FRAME IS THEN SENT TO THE BROWSER PROCESS VIA IPC

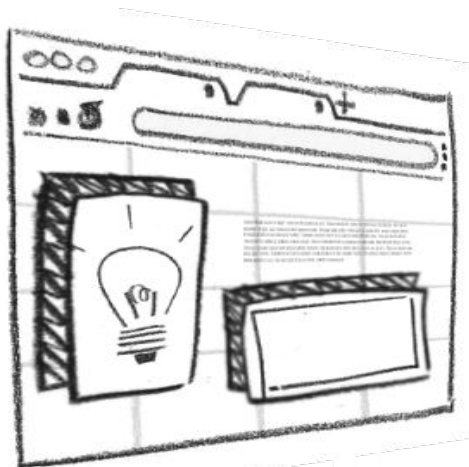




LAYOUT
TREE



LAYER
TREE

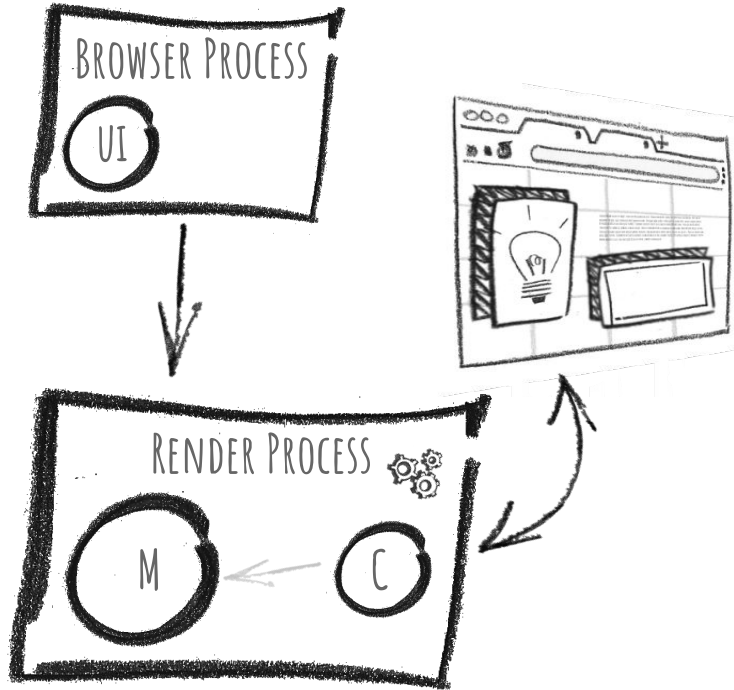


COMPOSITING

- **DRAW QUADS**
CONTIENE LE INFORMAZIONI, COME LA POSIZIONE DELLA TILE IN MEMORIA E DOVE DISEGNARLA NELLA PAGINA.
- **COMPOSITOR FRAME**
UNA RACCOLTA DI DRAW QUADS CHE RAPPRESENTANO IL FRAME DI UNA PAGINA.

THE ADVANTAGE OF COMPOSITING IS THAT IT IS DONE WITHOUT INVOLVING THE MAIN THREAD!

COMPOSITING - EVENTS



- BROWSER PROCESS RECEIVES A GESTURE (CLICK) AND SENDS THE EVENT TYPE AND COORDINATES TO THE RENDERER PROCESS
- RENDERER PROCESS MANAGES THE EVENT IF THERE IS A LISTENER
- IF IT IS NOT THERE, THE COMPOSITOR THREAD CREATES A FRAME WITHOUT ASKING ANYTHING FROM THE MAIN THREAD!
- THE COMPOSITOR THREAD MARKS AND ASSOCIATES THE EVENT HANDLERS TO THE AREAS OF THE PAGE (NON-FAST SCROLLABLE REGION)

IF THE EVENT TAKES PLACE OUTSIDE THE REGIONS, THE COMPOSITOR THREAD DOES NOT ASK FOR ANYTHING FROM THE MAIN THREAD AGAIN



CRITICAL RENDERING PATH (CRP)

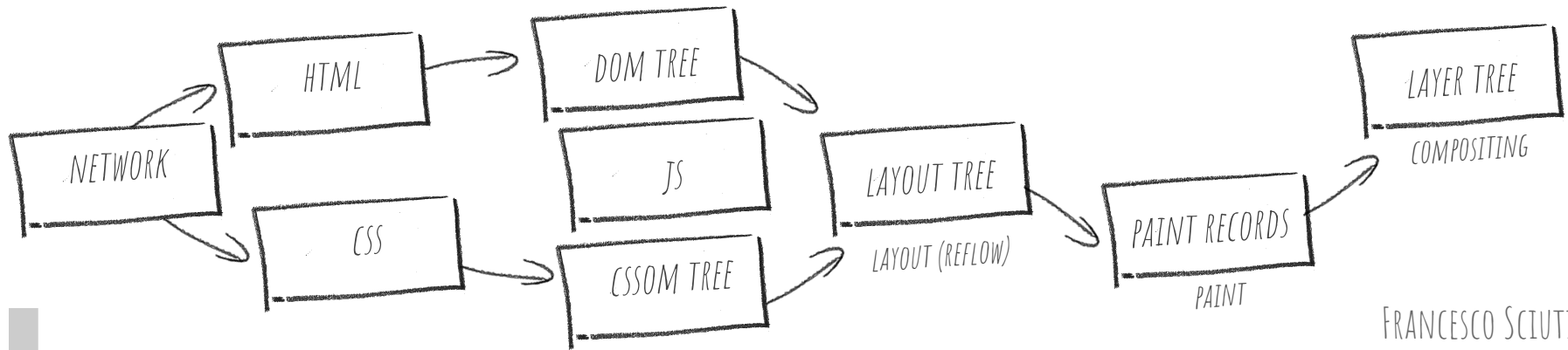
ANY DELAY IS CRITICAL!



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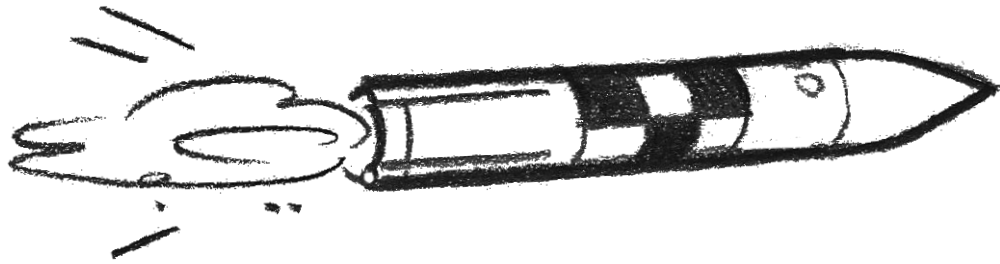
CRITICAL RENDERING PATH (CRP)

THE ENTIRE PROCESS BETWEEN RECEIVING HTML, CSS AND JS BYTES AND TRANSFORMING THEM INTO PIXELS RENDERED ON THE SCREEN IS CALLED **CRITICAL RENDERING PATH (CRP)**.



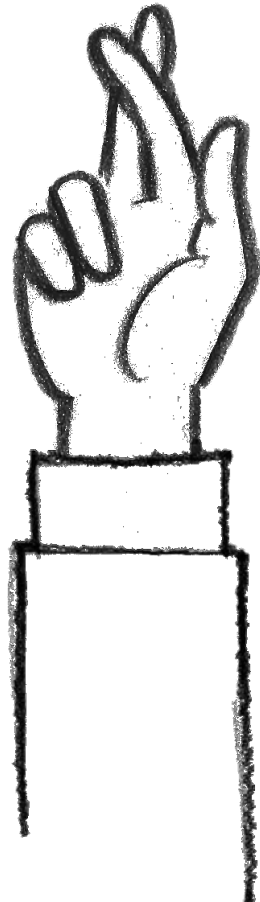
CRITICAL RENDERING PATH (CRP)

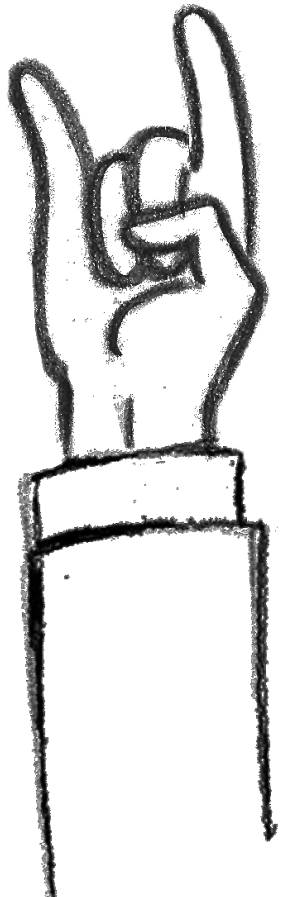
IF AN ANIMATION OR TRANSITION IS RUNNING, THE USER IS SCROLLING PAGES OR ZOOMING; THE BROWSER MUST CREATE FRAMES AT THE DEVICE'S REFRESH RATE.



THERE ARE 60 FRAMES PER SECOND TO ENSURE THAT AN ANIMATION IS FLUID, FORCING THE BROWSER TO RESOLVE THE RENDERING PIPELINE IN ABOUT 10 MS!

CRITICAL!





JANK - YOUR WORST ENEMY

WHEN THE BROWSER FAILS TO ACHIEVE THIS, THE FRAME RATE DROPS, AND THE CONTENT WILL NOT APPEAR FLUID, AND THIS WILL HAVE A NEGATIVE IMPACT ON THE USER EXPERIENCE!

THIS IS OFTEN REFERRED TO AS **JANK!**

0-100 MS - INSTANT FEEL, CONSTANT FLOW;

100-300 MS - SLIGHT PERCEPTIBLE DELAY;

300-1000 MS - LOSS OF TASK FOCUS, PERCEPTIBLE DELAY;

1 S+ - MENTAL CONTEXT SWITCH;

10S+ - USER LEAVES!

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CRITICAL RENDERING PATH (CRP)

... > STYLE > LAYOUT > PAINT > COMPOSITING

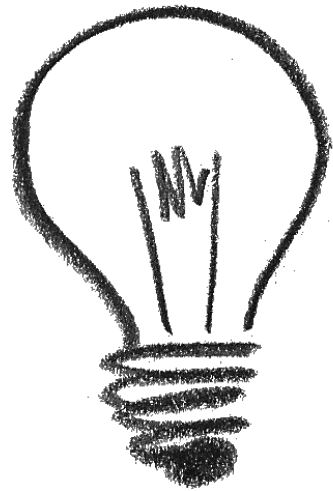
WHEN THERE ARE CHANGES ON GEOMETRIES, DIMENSIONS, POSITIONS, ...

... > STYLE > LAYOUT > PAINT > COMPOSITING

WHEN THERE ARE CHANGES IN WHAT DOES NOT AFFECT THE LAYOUT (BACKGROUND IMAGE, TEXT COLOR, ...)

... > STYLE > LAYOUT > PAINT > COMPOSITING

IN SHORT, WHAT DOES NOT INFLUENCE THE LAYOUT AND THE PAINT (TRANSFORM, OPACITY)



*DOPO IL CARICAMENTO, LA PAGINA CAMBIA IN RISPOSTA A DUE TIPOLOGIE DI INPUT:
INTERAZIONE DELL'UTENTE ED AGGIORNAMENTI AL DOM EFFETTUATI DA JAVASCRIPT.*



MAIN THREAD

SOME IMPORTANT CLARIFICATIONS



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A QUICK DISTINCTION

WEB APPLICATIONS ARE GIVEN A SINGLE THREAD, THE MAIN THREAD, TO EXECUTE MOST OF THE APPLICATION AND USER INTERFACE LOGIC.

WEB BROWSERS ARE DEFINITELY NOT A SINGLE-THREADED ENVIRONMENT!



BROWSER EVENT LOOP

THE BROWSER EVENT LOOP IS PROBABLY THE MOST IMPORTANT FRONTEND PERFORMANCE CONCEPT TO UNDERSTAND...BUT WE ALREADY KNOW IT, RIGHT?

ALL WE NEED TO KNOW IS THAT IT LIVES INSIDE THE MAIN THREAD!

THE BEHAVIOR OF THE EVENT LOOP DETERMINES THE BEHAVIOR OF WEB APPLICATIONS AT RUNTIME AND IS USED FOR ASYNCHRONY..





BROWSER EVENT LOOP

THE EVENT LOOP IS ESSENTIALLY AN INFINITE LOOP, RESPONSIBLE FOR:

- SELECT AN AVAILABLE TASK FROM THE TASK QUEUE AND PLACE IT IN THE MAIN THREAD TO RUN TO COMPLETION
- OCCASIONALLY SELECTING A RENDER STEPS TASK INSTEAD OF READING FROM THE TASK QUEUE TO GENERATE A FRAME





BROWSER EVENT LOOP

```
WHILE(TRUE) {  
  TASKLISTS.PICKFULLLIST().POP().EXECUTE();  
  
  WHILE(MICROTASKS.LENGTH) {  
    MICROTASKS.POP().EXECUTE();  
  }  
  
  IF(SHOULDERENDER()) {  
    RUNANIMATIONS();  
    RENDER();  
  }  
}
```

MICROTASKS = PROMISES, OBSERVERS, QUEUEMICROTASK





BROWSER EVENT LOOP - TASK

TASKS ARE THE RUNTIME EXECUTION UNITS EXECUTED ON THE MAIN THREAD.

- HTML/CSS PARSING
- INPUT EVENT MANAGEMENT
- JAVASCRIPT COMPILING/EXECUTION
- NETWORK DATA
- RENDER STEP





RECAP



RENDER PROCESS

GPU PROCESS

COMPOSITOR THREAD

MAIN THREAD

GPU THREAD

FRAME START



INPUT HANDLER

REQUEST ANIMATION FRAME

PARSE HTML

CALC STYLE

LAYOUT

PAINT

COMPOSITE

REQUEST IDLE FRAME



RAST. SCHEDULE



RASTERIZE



FRAME END



PIXEL TO SCREEN

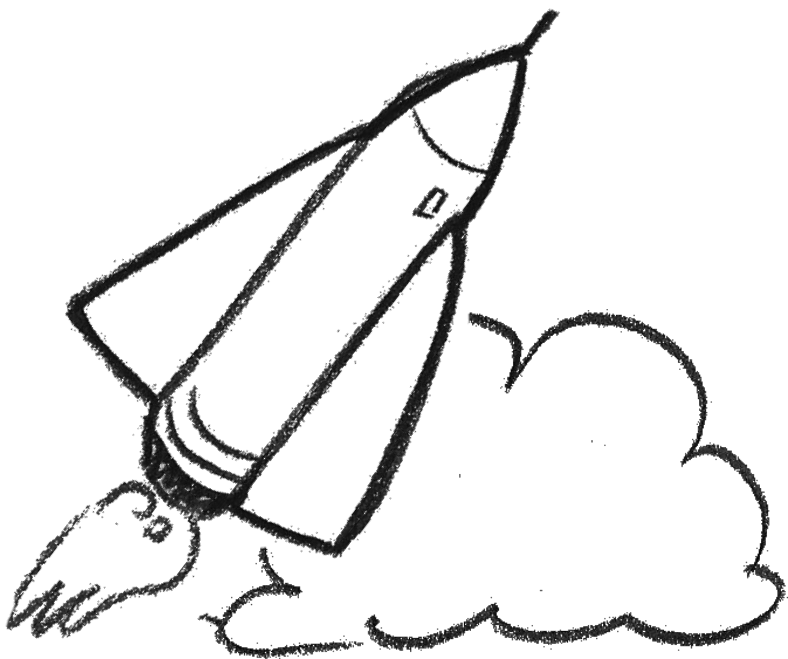


I MOTORI

WE'RE NOT INSIDE GRAN TURISMO BUT ENGINES MATTER!



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WHAT DO THEY USE?

- CHROME, EDGE, BRAVE
 - RENDER ENGINE: BLINK (BLINKNG)
 - JS ENGINE: V8
- FIREFOX
 - RENDER ENGINE: GECKO (QUANTUM)
 - JS ENGINE: SPIDER MONKEY
- SAFARI
 - RENDER ENGINE: WEBKIT
 - JS ENGINE: NITRO (JAVASCRIPTCORE)

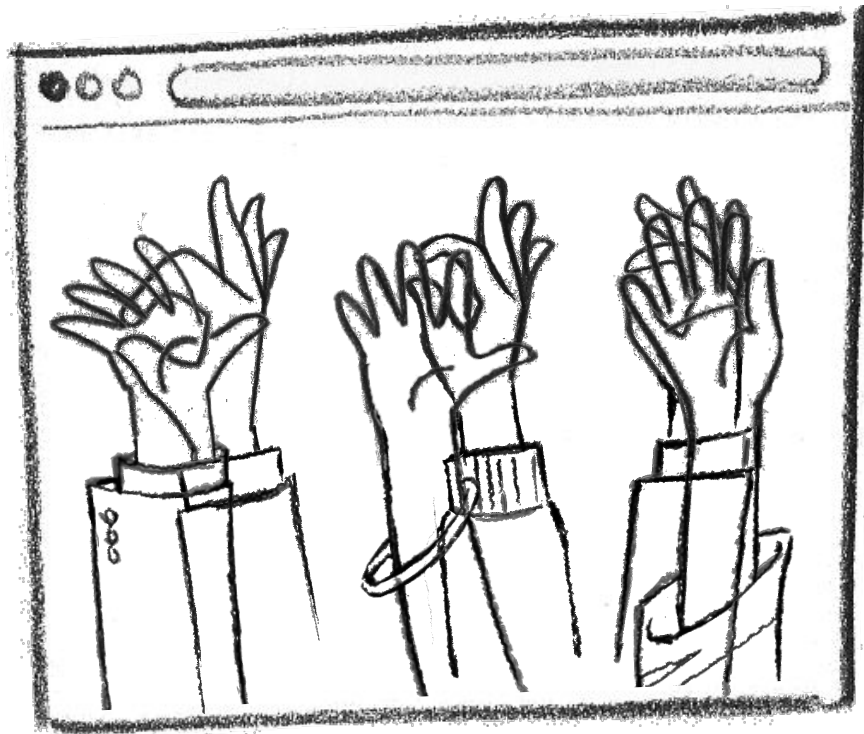


MAYBE IT'S NOT WHAT WE THOUGHT

THE POOR BROWSER, PERHAPS, THEREFORE DOES NOT HAVE SUCH AN EASY LIFE



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ANY IDEAS?

- REQUESTANIMATIONFRAME / REQUESTIDLEFRAME
- WILL-CHANGE (HANDLE WITH CARE)
- ASYNC / DEFER TAG SCRIPT ATTRIBUTES
- WORKERS
- RESOURCES PRIORITY (PRELOAD)
- EVALUATE CSS TRIGGERS
- EVALUATE LAYOUT & PAINT API TRIGGERS

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LET'S HELP THE TOOL THAT MAKES US TRAVEL
THROUGH BILLIONS OF PAGES FULL OF THINGS TO
LEARN (AND KITTENS) EVERY DAY!



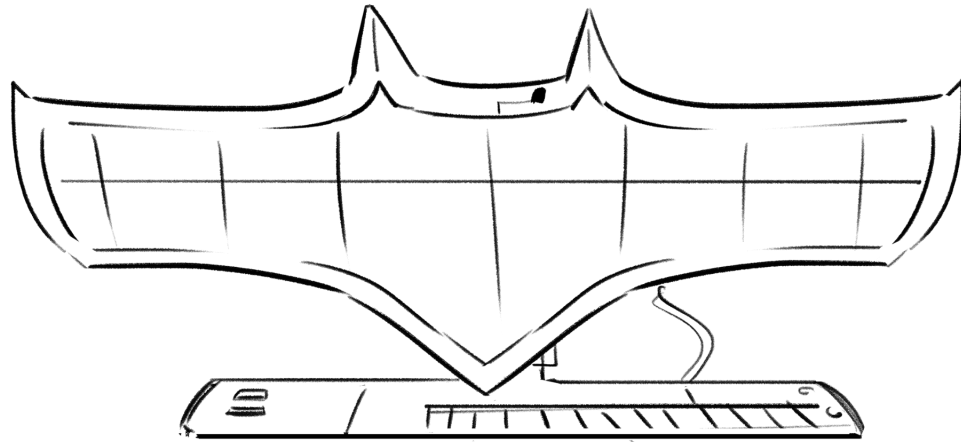
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I DO IT MY WAY...



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...I USE THE BATCOMPUTER,

WHICH IS POWERFUL AND I DON'T CARE!



...NO...NOT LIKE THAT...

BUT TRYING TO WRITE

BETTER CODE!



LINKS

QUICK REFERENCES

- [HTTPS://GITHUB.COM/GOOGLECHROMEELABS/CSS-TRIGGERS](https://github.com/googlechromelabs/css-triggers)
- [HTTPS://CSSTRIGGERS.COM/](https://csstriggers.com/)
- [HTTPS://GIST.GITHUB.COM/PAULIRISH/5D52FB081B3570C81E3A](https://gist.github.com/paulirish/5d52fb081b3570c81e3a)

INSIDE BROWSER

- [HTTPS://DEVELOPER.CHROME.COM/BLOG/INSIDE-BROWSER-PART1/](https://developer.chrome.com/blog/inside-browser-part1/)
- [HTTPS://DEVELOPER.CHROME.COM/BLOG/INSIDE-BROWSER-PART2/](https://developer.chrome.com/blog/inside-browser-part2/)
- [HTTPS://DEVELOPER.CHROME.COM/BLOG/INSIDE-BROWSER-PART3/](https://developer.chrome.com/blog/inside-browser-part3/)
- [HTTPS://DEVELOPER.CHROME.COM/BLOG/INSIDE-BROWSER-PART4/](https://developer.chrome.com/blog/inside-browser-part4/)

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LINKS

RENDERING NG

- [HTTPS://DEVELOPER.CHROME.COM/ARTICLES/RENDERINGNG/](https://developer.chrome.com/articles/renderingng/)
- [HTTPS://DEVELOPER.CHROME.COM/ARTICLES/RENDERINGNG-ARCHITECTURE/](https://developer.chrome.com/articles/renderingng-architecture/)
- [HTTPS://DEVELOPER.CHROME.COM/ARTICLES/RENDERINGNG-DATA-STRUCTURES/](https://developer.chrome.com/articles/renderingng-data-structures/)
- [HTTPS://DEVELOPER.CHROME.COM/ARTICLES/BLINKNG/](https://developer.chrome.com/articles/blinkng/)
- [HTTPS://DEVELOPER.CHROME.COM/ARTICLES/LAYOUTNG/](https://developer.chrome.com/articles/layoutng/)
- [HTTPS://DEVELOPER.CHROME.COM/ARTICLES/VIDEONG/](https://developer.chrome.com/articles/videng/)





LINKS

ARTICLES & SITES

- [HTTPS://WEB.DEV/MAINTHREAD-WORK-BREAKDOWN/](https://web.dev/mainthread-work-breakdown/)
- [HTTPS://WEB.DEV/FAST/#PRIORITIZE-RESOURCES](https://web.dev/fast/#prioritize-resources)
- [HTTPS://WEB.DEV/OPTIMIZE-JAVASCRIPT-EXECUTION/](https://web.dev/optimize-javascript-execution/)
- [HTTPS://WEB.DEV/SIMPLIFY-PAINT-COMPLEXITY-AND-REDUCE-PAINT-AREAS/](https://web.dev/simplify-paint-complexity-and-reduce-paint-areas/)
- [HTTPS://WEB.DEV/AVOID-LARGE-COMPLEX-LAYOUTS-AND-LAYOUT-THRASHING](https://web.dev/avoid-large-complex-layouts-and-layout-thrashing)
- [HTTPS://WEB.DEV/STICK-TO-COMPOSITOR-ONLY-PROPERTIES-AND-MANAGE-LAYER-COUNT/](https://web.dev/stick-to-compositor-only-properties-and-manage-layer-count/)
- [HTTPS://WWW.IAMTK.CO/WEB-PERFORMANCE-ROADMAP](https://www.iamtk.co/web-performance-roadmap)





LINKS

ARTICLES & SITES

- [HTTPS://WWW.WEBPERF.TIPS/](https://www.webperf.tips/)
- [HTTPS://WWW.HTML5ROCKS.COM/EN/TUTORIALS/INTERNALS/HOWBROWSERSWORK](https://www.html5rocks.com/en/tutorials/internals/howbrowserswork)
- [HTTPS://BLOG.LOGROCKET.COM/HOW-BROWSER-RENDERING-WORKS-BEHIND-SCENES/](https://blog.logrocket.com/how-browser-rendering-works-behind-scenes/)
- [HTTPS://WWW.TOPTAL.COM/WEB/WEBSITE-PERFORMANCE-CRITICAL-RENDERING-PATH/](https://www.toptal.com/web/website-performance-critical-rendering-path/)
- [HTTPS://GROSSKURTH.CA/PAPERS/BROWSER-REFARCH.PDF](https://grosskurth.ca/papers/browser-refarch.pdf)

DEMOS

- [HTTPS://GOOGLECHROME.GITHUB.IO/DEVTOOLS-SAMPLES/JANK/](https://googlechrome.github.io/devtools-samples/jank/)
- [HTTPS://COFFEE-CART.NETLIFY.APP/?AD=1](https://coffee-cart.netlify.app/?ad=1)





FRANCESCO SCIUTI

DEVELOPER BY CHOICE AND PASSION,
LOVER OF NERD STUFF OF ALL KINDS
AND LOVER OF SHARING KNOWLEDGE!

FRANCESCO SCIUTI

GOOGLE DEVELOPER EXPERT / MICROSOFT MVP / CODEMOTION DEVREL

SOFTWARE FACTORY

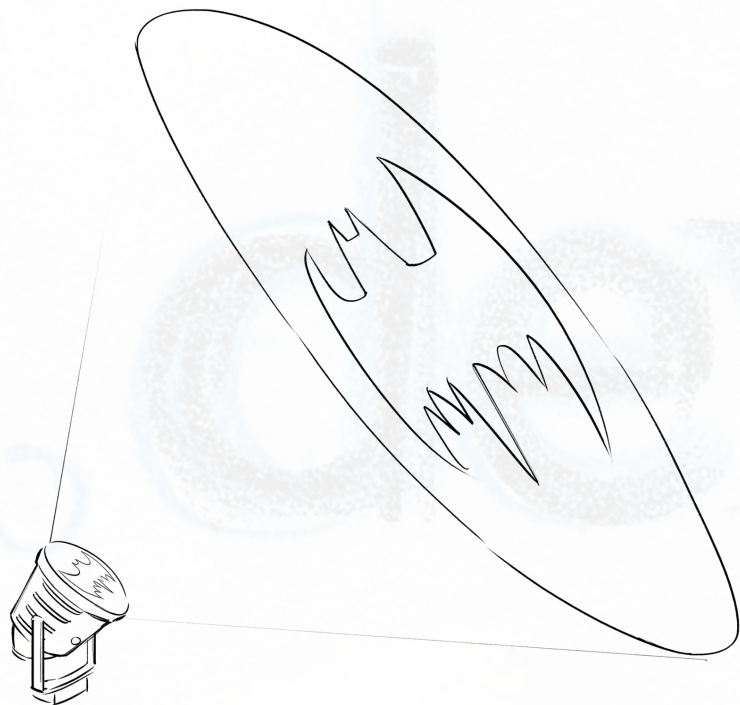
- PROJECT MANAGEMENT
- ARCHITECTURE DESIGN
- TEAM AUGMENTATION
- CODE REVIEW
- MENTORING
- OUTSOURCING

LEARNING FACTORY

- FORMAZIONE IN AZIENDA
- CORSI E WORKSHOP
- EVENTI ONLINE E OFFLINE
- QUESTO TALK!



THANK YOU!



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FEEDBACK TIME!



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