Liquid IT : Toward a better compromise between development scalability and performance scalability not definitive

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Abstract

TODO translate from below when ready

Résumé

Internet étend l'économie à une échelle spatiale et temporelle sans précédent. Il permet à chacun de mettre un service à disposition de milliards d'utilisateurs, en seulement quelques heures. La plupart des grands services actuels ont commencés comme de simples applications créées dans un garage par une poignée de personnes. C'est cette facilité à l'entrée qui a permis jusqu'à maintenant une telle croissance sur le web. Google, Facebook ou Twitter en sont les exemples les plus flagrants. Pendant le développement d'une application, il est important de suivre cette croissance, au risque de se faire rattraper par la concurrence. Le développement est guidé par les besoins en terme de fonctionnalités, afin de vérifier rapidement si le service peut satisfaire l'audience. Des langages tel que Ruby ou Java se sont imposés comme les languages du web, justement parce qu'ils permettent d'intégrer facilement de nouvelles fonctionnalités.

Si une application répond correctement aux besoins, elle atteindra de manière virale un nombre important d'utilisateurs. Son audience peut prendre plusieurs ordres de grandeurs en quelques jours seulement, ou même en quelques heures suivant comment elle est relayée. Une application est dites scalable si elle peut absorber ces augmentations d'audience. Or il est difficile pour une application dont le développement est guidé par les fonctionnalités d'être scalable.

Au moment où l'audience commence à devenir trop importante, il est nécessaire de modifier l'approche de développement de l'application. Le plus souvent cela implique de la réécrire complètement en utilisant des infrastructures scalables qui imposent des modèles de programmation et des API spécifiques. Cela représente une charge de travail conséquente et incertaine. De plus, l'équipe de développement dois concilier cette nouvelle approche de développement scalable, avec la demande en fonctionnalités. Aucun langage n'a clairement réussi le compromis entre ces deux objectifs.

Pour ces raisons, ce changement est un risque pour la pérennité de l'application. D'autant plus que le cadre économique accorde peu de marges d'erreurs, comme c'est le cas dans la plupart des start-up, mais également dans de plus grandes structures.

Mon travail consiste à tenter d'écarter ce risque dans une certaine mesure. Ma thèse se base sur les deux observations suivantes. D'une part, Javascript

est un langage qui a énormément gagné en popularité ces dernières années. Il est omniprésent sur les clients, et commence à s'imposer également sur les serveurs avec Node.js. Il a accumulé une communauté de développeur importante, et est l'environnement d'exécution le plus largement déployé. De ce fait, il se place comme le langage principal du web, détrônant Ruby ou Java. D'autre part, l'execution de Javascript a la particularité de ressembler à un pipeline. La boucle événementielle de Javascript est un pipeline qui s'exécute sur un seul cœur pour profiter d'une mémoire globale. On observe le même flux de messages traversant cette boucle événementielle que dans un pipeline.

L'objectif de ma thèse est de permettre à des applications développées en Javascript d'être automatiquement transformées vers un pipeline d'exécutions repartis. Nous construisons un compilateur permettant d'identifier les fonctions de Javascript et de les isoler dans ce que nous appelons des Fluxions. Un conteneur qui peut exécuter une fonction à la réception d'un message, et envoyer des messages pour continuer le flux vers d'autres fluxions. Les fluxions étant indépendantes, elles peuvent être déplacées d'une machine à l'autre. En transformant automatiquement un programme Javascript en Fluxions, on le rend scalable, sans effort.

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TODO 5p

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Context and objectives

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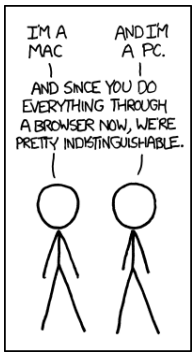
2.1 The Web as a platform

2.1.1 From operating systems to the web



TODO this subsection needs reviews, it is poorly written. The vocabulary is very imprecise. Hardware is of no use without software. With the emergence of home computer, appeared the market for software applications. Operating systems were the platform on which these software were released. Like with all the platform, a bigger user share attracts more provider, which in turns attract users with more diversity, and so on. Operating systems battled over the user shares.

Home computers allowed to release economic products at unprecedented scale. Software are virtual products. With one initial development phase, they can be sent infinitely. This is about increasing the market to release products on larger scale. It is all about economics.

However, the medium to distribute copies of software are still bounded to the unvirtual world. It still takes time to burn a CD, or a floppy, and to bring it to the consummer's home. Sir Tim Berners Lee invented the world wide web in 1989. It was designed to share documents. But it replaced the medium to distribute software. The web can release software on larger scales than Discs. And it is a serious concurrent to the operating system platform. Now that everything is done in a web browser, the choice of an operating system doesn't really matter anymore for the user to access applications. And with the standardization of the web, the choice of a web browser doesn't really matter as well. The web is the platform for every application, no matter the browser used.

side note TODO has this paragraph its place in this subsection ? With web services, the economy completely shifted. The distribution medium of software product is so transparent that owning a product to have an easier access is no longer relevant. It is shifting from owning to accessing, and this shift is cascading downward to every strates of our everyday lives.

2.1.2 The languages of the web

TODO This subsection needs reviews, it is poorly written.

In the early 90's, at the same time the web started developing, most of the more popular programming langauges were released. Python(1991), Ruby(1993), Java(1994), PHP(1995) and Javascript(1995).

Java, propulsed by Sun Microsystems, imposes itself early as a language of choice and never really decreased. The language is executed on a virtual machine, allowing to write an application once, and to deploy it an heterogeneous machines. Additionally, it presents many hardware abstractions, such as memory garbage collection, and references, instead of manual memory allocation and pointers. For these reasons, it is easier to develop with, but shows slower performance than lower level languages like C/C++. With Moore's law, the industry realized that the performances is increasing exponentially, so that development time is more expensive than hardware. It quickly replaced C++ as the software industry standard. And became the language the most used to build web applications. It is currently the most used language on StackOverflow, and the second on Github. It is generally in the first place of all the language popularity indexes.

However, the software industry wants stable and safe solutions. It slows down Java evolution. TODO More arguments needed here. Java is too verbose, it is not dynamic enough : OOP is outdated, and it lacks lambdas, and so on ... Some languages

Some of the more popular languages are interesting alternatives to build web applications.

Python is the second best language for everything. It is a general purpose language, currently quite popular for data science. In 2003, the release of the Django web framworks allows to develop web application in python.

Ruby was confined in Japan and almost unknown to the world until the release of Rails in 2005. With the release of this web framework, Ruby took-off and is still in active use.

PHP was designed for web since the beginning. It is probably one of the easiest solution to start web development. However, according to several language popularity indexes, it is on a slow decline since a few years.

Since a few years, Javascript is imposing itself as the main language of the web. It is omnipresent. It is included in every browser, and is now available on the server as well because of Node.js. Because of this unavoidable position, it became fast (V8, ASM.js ...) and usable (ES6, ES7). Additionally, it is a target for LLVM, allowing many languages to compile to Javascript, strengthening again its omnipresent position.

2.1.3 Explosion of Javascript popularity

2.1.3.1 In the beginning

Javascript was created by Brendan Eich at Netscape around May 1995, and released to the public in September. The initial name of the project was Mocha, then LiveScript, the name Javascript was finally adopted to leverage the trend around Java. The latter was considered the hot new web programming language at this time. It was quickly adopted as the main language for web servers, and everybody was betting on pushing Java to the client as well. The history proved them wrong.

In 1995, when Javascript was released, the world wide web started its wide adoption.[1] Browsers were emerging, and started a battle to show off the best features and user experience to attract the wider public.[2] Microsoft released their browser Internet Explorer 3 in June 1996 with a concurrent implementation of Javascript. They changed the name to JScript, to avoid trademark conflict with Oracle Corporation, who owns the name Javascript. The differences between the two implementations made difficult for a script to be compatible to both. At the time, signs started to appear on web pages to warn the user about the ideal web browser to use for the best experience on this page. This competition was fragmenting the web.

To stop this fragmentation, Netscape submitted Javascript to Ecma International for standardization in November 1996. In June 1997, ECMA International released ECMA-262, the first specification of ECMAScript, the standard for Javascript. A standard to which all browser should refer for their implementations.

The base for this specification was designed in a rush. The version released in 1995 was finished within 10 days. Because of this precipitation, the language has often been considered poorly designed and unattractive. Moreover, Javascript was intended to be simple enough to attract unexperienced developers, by opposition to Java or C++, which targeted professional developers. For these reasons, Javascript started with a poor reputation among the developer community.

But things evolved drastically since. When a language is released, available freely at a world wide scale, and simple enough to be handled by a generation of teenager inspired by the technology hype, it produce an effer-

[1] `http://www.internetlivestats.com/internet-users/`

[2] to get an idea of the web in 1997 : `http://1x-upon.com/`

vescent community around what is now one of the most popular and widely used programming language.

2.1.3.2 Rising of the unpopular language

TODO why is Javascript unpopular ? cite some blog post like : https://wiki.theory.org/YourLangua
and add many blog posts titles in a mozaïc

Javascript started as a programming language to implement short interactions on web pages. The best usage example was to validate some forms on the client before sending the request to the server. This situation hugely improved since the beginning of the language. So much that web-based, Javascript applications are currently now favored instead of rich, native desktop applications.

ECMA International released several version in the few years following the creation of Javascript. The first and second version, released in 1997 and 1998, brought minor revisions to the initial draft. However, the third version, released in the late 1999, contributed to give Javascript a more complete and solid foundation as a programming language. From this point on, the consideration for Javascript keep improving.

An important reason for this reconsideration started in 2005. James Jesse Garrett released *Ajax: A New Approach to Web Applications*, a white paper coining the term Ajax [**Garrett2005**]. This paper point the trend in using this technique, and explain the consequences on user experience. Ajax stands for Asynchronous Javascript And XML. It consists of using Javascript to dynamically request and refresh the content of a web page. The advantage is that it avoids to request a full page from the server. Javascript is not anymore confined to the realm of small user interactions on a terminal, it can be proactive and responsible for a bigger part in the system spanning from the server to the client. Indeed, this ability to react instantly to the user started to narrow the gap between web and native applications. At the time, the first web applications to use Ajax were Gmail, and Google maps[3].

Around this time, the Javascript community started to emerge. The third version of ECMAScript had been released, and the support for Javascript was somewhat homogeneous on the browsers but far from perfect. Moreover, Javascript is only a small piece in the architecture of a web-based client application. The DOM, and the `XMLHttpRequest` method, two components on

[3]A more in-depth analysis of the history of Ajax, given by late Aaron Swartz `http://www.aaronsw.com/weblog/ajaxhistory`

which AJAX relies, still present heterogeneous interfaces among browsers. To leverage the latent capabilities of Ajax, and more generally of the web, Javascript framework were released with the goal to straighten the differences between browsers implementations. Prototype[4] and DOJO[5] are early famous examples, and later jQuery[6] and underscore[7]. These frameworks are responsible in great part to the wide success of Javascript and of the web technologies.

In the meantime, in 2004, the Web Hypertext Application Technology Working Group[8] formed to work on the fifth version of the HTML standard. This new version provide new capabilities to web browsers, and a better integration with the native environment. It features geolocation, file API, web storage, canvas drawing element, audio and video capabilities, drag and drop, browser history manipulation, and many mores It gave Javascript the missing pieces to become a true language for developing rich application. The first public draft of HTML 5 was released in 2008, and the fifth version of ECMAScript was released in 2009. With these two releases, ECMAScript 5 and HTML5, it is a next step toward the consideration of Web-based technologies as equally capable, if not more, than native rich applications on the desktop. Javascript became the programming language of this rising application platform.

However, if web applications are overwhelmingly adopted for the desktop, HTML5 is not yet widely accepted as ready to build complete application on mobile, where performance and design are crucial. Indeed web-technologies are often not as capable, and well integrated as native technologies. But even for native development, Javascript seems to be a language of choice. An example is the React Native Framework[9] from Facebook, which allow to use Javascript to develop native mobile applications. They prone the philosophy *"learn once, write anywhere"*, in opposition to the usual slogan *"write once, run everywhere"*.[10]

[4] `http://prototypejs.org/`
[5] `https://dojotoolkit.org/`
[6] `https://jquery.com/`
[7] `http://underscorejs.org/`
[8] `https://whatwg.org/`
[9] `https://facebook.github.io/react-native/`
[10] Used firstly by Sun for Java, but then stolen by many others

2.1.3.3 Current situation

"When JavaScript was first introduced, I dismissed it as being not worth my attention. Much later, I took another look at it and discovered that hidden in the browser was an excellent programming language."

—Douglas Crockford

The success of Javascript is due to many factors ; I mentioned previously the standardization, Ajax libraries and HTML5. Another factor, maybe the most important, is the View Source menu that reveals the complete source code of any web application. *The view source menu is the ultimate form of open source*[11]. It is the vector of the quick dissemination of source code to the community, which picks, emphasizes and reproduces the best techniques. This brought open source and collaborative development before github. TODO neither open source nor collaborative development are the correct terms Moreover, all modern web browsers now include a Javascript interpreter, making Javascript the most ubiquitous runtime in history [**Flanagan2006**].

When a language like Javascript is distributed freely with the tools to reproduce and experiment on every piece of code. When this distribution is carried during the expansion of the largest communication network in history. Then an entire generation seizes this opportunity to incrementally build and share the best tools they can. This collaboration is the reason for the popularity of Javascript on the Web.

It seems to also infiltrate many other fields of IT, but it is hard to give an accurate picture of the situation. There is no right metrics to measure programming language popularity. In the following paragraphs, I report some popular metrics and indexes available on the net. More detailed informations are available section A.

Search engines The TIOBE Programming Community index is a monthly indicator of the popularity of programming languages. It uses the number of results on many search engines as a measure of the activity of a programming language. Javascript ranks 6th on this index, as of April 2015, and it was the most rising language in 2014. However, the measure used by the TIOBE is controversial. Some says that the measure is not representative. It is a

[11] `http://blog.codinghorror.com/the-power-of-view-source/`

lagging indicator, and the number of pages doesn't represent the number of readers.

On the other hand, the PYPL index is based on Google trends to measure the activity of a programming language. Javascript ranks 7th on this index, as of May 2015.

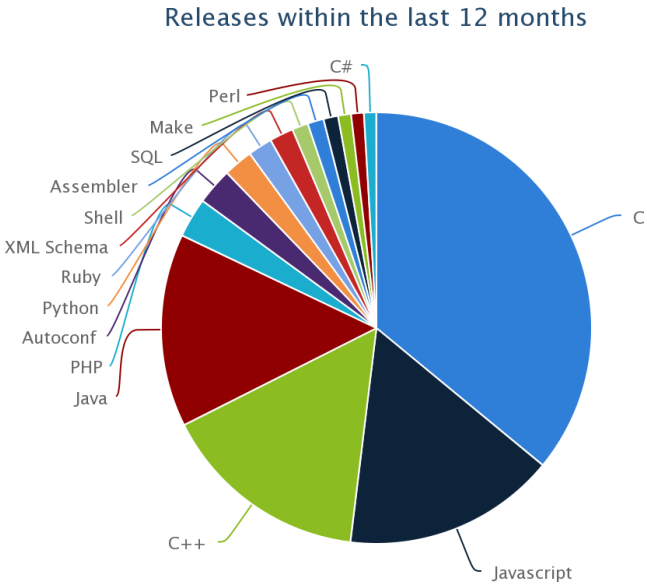
From these indexes, the major programming languages are Java, C/C++ and C#. The three languages are still the most widely taught, and used to write softwares. But Javascript is rising to become one of these important languages.

Developers collaboration platforms Github is the most important collaborative development platform, with around 9 millions users. Javascript is the most used language on github since mid-2011, with more than 320 000 repositories. The second language is Java with more than 220 000 repositories.

TODO : graph of Github repositories by languages

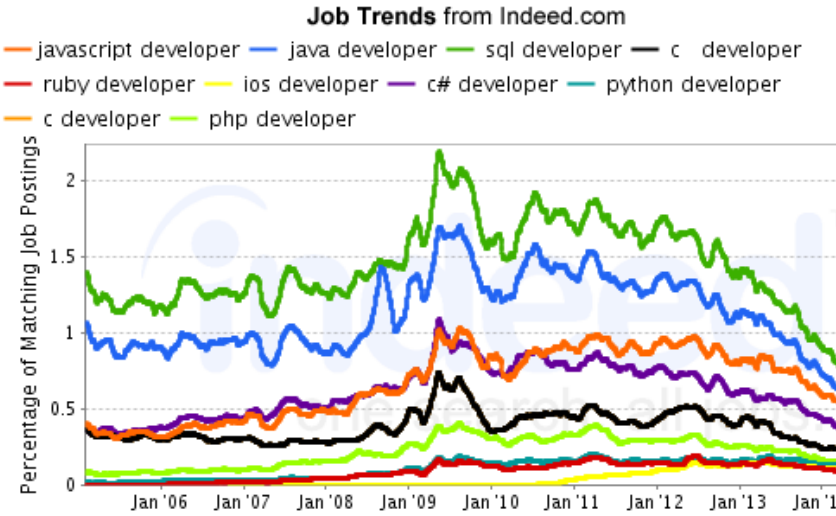
StackOverflow, is the most important Q&A platform for developers. It is a good representation of the activity around a language. Javascript is the second language showing the most activity on StackOverflow, with more than 840 000 questions. The first one is Java with more than 850 000 questions.

Black Duck knowledgebase analyzes 1 million repositories over various forges, and collaborative platforms to produce an index of the usage of programming language in open source communities. Javascript ranks second. C is first, and C++ third. Along with Java, the four first languages represent about 80% of all programming language usage.



TODO redo this graph, it is ugly.

Jobs All these metrics are representing the visible activity about programming language. But not the entire software industry is open source, and the activity is rather opaque. To get a hint on the popularity of programming languages used in the software industry, let's look at the job offerings. Indeed provide some insightful trends. Javascript developers ranked at the third position, right after SQL developers and Java developers. Then come C# and C developers.



TODO redo this graph, it is ugly.

All these metrics represent different faces of the current situation of Javascript adoption. We can safely say that Javascript is one of most important language of this decade, along with Java, C/C++. It is widely used in open source projects, and everywhere on the web. But it is also trending, and maybe slowly replacing languages like Java.

2.2 Highly concurrent web servers

2.2.1 Concurrency

2.2.1.1 Scalability

The internet allows interconnection at an unprecedented scale. There is currently more than 16 billions devices connected to the internet, and it is growing exponentially[12]. This massively interconnected network gives the ability for a web applications to be reached at the largest scale. A large web application like google search receive about 40 000 requests per seconds. That is about 3.5 billions requests a day[13]. This traffic is huge, but it remains sensibly stable because the position of Google is assured.

However, the traffic at the beginning of a web application is much more uncertain. If the service propose a good service, it might become viral at some point because it is efficiently relayed in the media. As a concrete example,

[12] http://blogs.cisco.com/news/cisco-connections-counter

[13] http://www.internetlivestats.com/google-search-statistics/

when a web application appears in the evening news, it might expect a huge spike in traffic. But most of the time, the spikes are unpredictable.

A young web application needs to follow the growth of its audience. This growth might be steady enough to be planned, or it might be unexpected and challenging to meet. Scalability is the ability for a web application to adapt its load to the demand in a reasonable time.

Scalability mainly holds on the ability of a web application to requests many concurrent requests. For this thesis, I reduce scalability to concurrency. A server is highly scalable if it is highly concurrent. TODO better explanation of this simplification A highly concurrent server is able to manage a large number of simultaneous request. It represent an uninterrupted flow of requests, with a growing throughput. With the growing number of connected devices on the internet, concurrency is a very important property in the design of web servers. As examples, around the year 2000, Dan Kegel wrote about the C10K[14] problem. How to handles 10K simultaneous connection on a web server. More recently, in 2013, Robert Graham wrote about the C10M[15] problem.

2.2.1.2 Tow faces of concurrency

Concurrency is the ability for an application to make progress on several tasks at the same time. It can be achieved either by parallelism, or by time-slicing concurrency.

The term Parallelism refers to techniques to make programs faster by performing several computations in parallel. This requires hardware with multiple processing units. Such hardware is nowadays omnipresent. [16]

However, concurrency can be achieved on a single processing unit as well. The executions of the different tasks are interleaved in time. As an example, it is used to give multi-tasking ability to operating systems.

Concurrency allows to stretch the computation on one, or many cores. It enables scalability. TODO review that.

Parallelism improves performances for computation at a price. It is necessary for the concurrent tasks to be independent. Otherwise, two tasks could modify a shared state simultaneously resulting in a corrupted state.

[14] `http://www.kegel.com/c10k.html`

[15] `http://c10m.robertgraham.com/p/manifesto.html`

[16] `https://wiki.haskell.org/Parallelism_vs._Concurrency`

In time-slicing concurrency, the concurrent tasks can more or less benefit of a shared state, depending on the scheduling strategy. In this thesis I focus on the cooperative scheduling used in the event-loop. It allows for a truly global memory and seems to be one of the easiest way for developers to write concurrent programs efficiently. Indeed, I presented in the previous section the popularity of Javascript, which uses this scheduling strategy.

The other main scheduling strategy is preemptive scheduling. It is used in most execution environment in conjunction with multi-threading. However, it is known to be hard to manage, and should be avoided except when true concurrency is needed in concert with true shared state. Shared state could probably always be emulated with isolated memory and message passing.

2.2.2 Technological shift

2.2.2.1 Power wall

Around 2004, the so-called Power Wall was reached. The clock of CPU is stuck at 3GHz because of the inability to dissipate the heat generated for higher frequencies. Additionally, the parallelism inside the stream of instructions is limited. Because of these limitations, a processor is limited in the number of instruction per second it can execute. Therefore, parallelism is the only option to achieve high concurrency. And with parallelism, the isolation of the memory of each independent task.

2.2.2.2 The case for global memory

The best practice in software development advocates to design a software into isolated modules. By following the best practice, the code base is split into modules. Modularity allows to understand each module of the application by itself, without an understanding of the rest. And to understand the application as the interconnections between modules. The principles are encapsulation, a module contains the data, and the functions to manipulate this data ; separation of concerns, each module should have a clear scope of action, and it should not overlap with other scopes ; and loose coupling, each module should require no, or as little as possible knowledge about the definition of other modules. The main goal followed by these principles, is to help the developer to develop and maintain a large code-base.

Modularity is intended to avoid a different problem than the isolation

required by parallelism. The former intends to avoid unintelligible spaghetti code. While the latter avoids conflicting memory accesses resulting in corrupted state. The two goals are overlapping in the design of the application. Therefore, any language needs to provide a compromise between these two goals.

I argue that the more accessible, hence popular programming languages choose to provide modularity over isolation. They provide a global memory at the sacrifice of the performance of provided by parallelism. The more efficient languages sacrifice the readability and maintainability, to provide a model closer to parallelism, to allow better performances. TODO here I use language in both cases, it would be better to use a more generic term to refer to language or infrastructure

2.2.2.3 Rupture

Between the early development, and the mature development of a web application, its needs are radically different. In its early development, a web application needs to quickly get feedback from its users. The first reason of startup failures is the lack of market need[17]. The development speed is crucial. Therefore, the development team opt for a popular, and accessible language. The development team quickly releases a Minimum Viable Product as to get these feedbacks. *"Release early, release often"*, and *"Fail fast"* are the punchlines of the web entrepreneurial community.

As the application matures and its audience grows, the focus shift from the development speed to the scalability of the application. The ability of the application to handle a large amount of simultaneous request. The development team then shift for a language providing parallelism.

From this shift derives two problems. The first is that this shift is a risk for the future of the application. It usually implies for the development team to rewrite the code base to adapt it to a completely different paradigm, with imposed interfaces. It is hard for the development team to find the time, hence the money, or the competences to operate this shift. Indeed, the number two and three reasons for startup failures are running out of cash, and missing the right competences. The second problem is that after this shift, the development pace is different. Parallel languages are incompatible with the commonly learned design principles. The development team cannot

[17] `https://www.cbinsights.com/blog/startup-failure-post-mortem/`

react as quickly to user feedbacks as with the first paradigm.

The technological rupture operated during the evolution of a web application is the demonstration that economically, there is a need for a language that exposes a more sustainable abstraction. An abstraction that it is easy to develop with, like in the beginning of a web application development, and yet parallelizable, so as to be scalable when the application matures.

2.2.3 A problem of memory

The problem I focus on is the coordination of state between the concurrent execution in concurrent programming. Precisely, I focus on a solution to leverage parallelism while keeping the global memory for developers.

I presented earlier the three main strategies to manage the memory in concurrent programming. The main difference for the developer is how each model exposes the assurance of an invariance in the memory state. I call invariance the assurance given to the developer that the global state of the application is not corrupted by the coordination between the concurrent executions.

In applications composed of multiple parallel processes, the memory of each processes is exclusive. The developer is aware that only the process can modify its memory. The processes propagate a modification to the state of the application by sending messages. Each process treat these messages one after the other. There is no risk of corrupted state by simultaneous, conflicting accesses. The invariance is explicit because the memory is isolated inside each process.

In applications composed of multiple parallel threads, the memory is shared between all the threads. The developer is aware that because of the preemptive scheduling strategy, the shared memory states of the application can be modified at any time by any thread. To prevent conflicting accesses on the memory, the developer locks every shared memory state during a modification. The developer assures itself the invariance of the memory.

In application using cooperative scheduling on an event-loop, like Javascript, the memory is global. All the events are executed sequentially, so there is no possible simultaneous memory access. The developer is aware of the points where the scheduler switches from one concurrent execution to the other, so it can manage its state in atomic modification.

The invariance exposed by the isolated processes and the event-loop are similar. The developer defines sequence of instructions with atomic access

to the memory. And in both paradigms, these sequences communicate by sending messages to each other. The difference lies in the isolation of this memory. TODO this paragraph needs review

I argue that the language should adapt to the developer and expose a concurrent paradigm with a global memory. Then a compiler, or the execution engine, can isolate the memory so as to parallelize the concurrent executions. So as to provide to the developer a usable, yet efficient compromise.

2.3 Compilation

We propose to find an equivalence between an event loop and a network of isolated processes. This equivalence should allow a compiler to transform an event loop into several parallel processes communicating by messages.

With this compiler, it would be possible to express an application with a global, so as to follow the design principles of software development. And yet, the execution engine could adapt itself to any parallelism of the computing machine, from a single core, to a distributed cluster.

This equivalence intend not to be universal. It focuses on a precise class of applications : real-time Web applications processing stream of requests from users.

2.3.1 Real-time web services

Web applications are now written in a stream fashion. Indeed, as I showed previously, the event loop is executed like a pipeline. Web services can be seen as pipelines processing streams of requests.

In a stream processing application, there is roughly two kinds of usage of the global memory : data and state. Naively, the data represent a communication channel between different point in the application space, and the state represents a communication channel between different instant in time. The data flow from stage to stage through the pipeline, and are never stored on any fluxion. The state, on the other hand, remains in the memory to impact the future behaviors of the application. State might be shared by several parts of the application.

There are different kinds of state dependencies in applications components leading to different kinds of parallelism. In this thesis I argue that it is possible to parallelize a real-time web applications written on an event-loop

because the strong dependencies mainly remains within a closed number of concurrent executions.

Chapter 3

State of the art

3.1 Javascript

3.1.1 Overview of the language

3.1.1.1 Functions as First-Class citizens

3.1.1.2 Lexical Scoping

3.1.1.3 Closure

3.2 Concurrency

3.2.1 Two known concurrency model

3.2.1.1 Thread

3.2.1.2 Event

3.2.1.3 Orthogonal concepts

3.2.2 Differentiating characteristics

3.2.2.1 Scheduling

3.2.2.2 Coordination strategy

3.2.3 Turn-based programming

3.2.3.1 Event-loop

3.2.3.2 Promises

3.2.3.3 Generators

3.2.4 Message-passing / pipeline parallelism -> DataFlow programming ?

3.3 Scalability

3.3.2 Scalability outside computer science (only if I have time)

If I have time, I would like to try to explain why scalability is at the core of material engagement and information theory, and is at the core of our universe : the propagation of Gravity wave is an example : it is impossible to scale

3.4 Framworks for web application distribution

3.4.1 Micro-batch processing

3.4.2 Stream Processing

3.5 Flow programming

3.5.1 Functional reactive programming

3.5.2 Flow-Based programming

3.6 Parallelizing compilers

OpenMP and so on

3.7 Synthesis

There is no compiler focusing on event-loop based applications

Chapter 4

Fluxion

4.1 Fluxionnal Compiler

Some parts of this are already written in the first paper. It needs a lot additional explanations and rewritting

4.1.1 Identification

4.1.1.1 Continuation and listeners

4.1.1.2 Dues

4.1.2 Isolation

4.1.2.1 Scope identification

Scope leaking

4.1.2.2 Execution and variable propagation

4.1.3 distribution

4.2 Fluxionnal execution model

Everything here is already written in the first paper : flx-paper. It only needs to be rewritten

4.2.1 Fluxion encapsulation

4.2.1.1 Execution

4.2.1.2 Name

4.2.1.3 Memory

4.2.2 Messaging system

Chapter 5

Evaluation

5.1 Due compiler

5.2 Fluxionnal compiler

5.3 Fluxionnal execution model

Chapter 6

Conclusion

Appendix A

Language popularity

A.1 PopularitY of Programming Languages (PYPL)

[1] The PYPL index uses Google trends[2] as a leading indicator of the popularity of a programming language. It search for the trend for each programming language by counting the number of searches of this language and the word "tutorial".

PYPL for May 2015

[1] http://pypl.github.io/PYPL.html
[2] https://www.google.com/trends/

Rank	Change	Language	Share	Trend
1		Java	24.1%	-0.9%
2		PHP	11.4%	-1.6%
3		Python	10.9%	+1.3%
4		C#	8.9%	-0.7%
5		C++	8.0%	-0.2%
6		C	7.6%	+0.2%
7		Javascript	7.1%	-0.6%
8		Objective-C	5.7%	-0.2%
9		Matlab	3.1%	+0.1%
10	2× ↑	R	2.8%	+0.7%
11	5× ↑	Swift	2.6%	+2.9%
12	1× ↓	Ruby	2.5%	+0.0%
13	3× ↓	Visual Basic	2.2%	-0.6%
14	1× ↓	VBA	1.5%	-0.1%
15	1× ↓	Perl	1.2%	-0.3%
16	1× ↓	lua	0.5%	-0.1%

A.2 TIOBE

[3]

The TIOBE index uses many search engines as an indicator of the current popularity of programming languages. It count the number of pages each search engine find when queried with the language name and the word "programming". This indicator indicates the number of resources available, and the discussions about a given programming language.

Javascript was the most rising language of 2014 in the TIOBE index.

TIOBE for April 2015

[3] http://www.tiobe.com/index.php/content/paperinfo/tpci/index.html

Apr 2015	Apr 2014	Change	Programming Language	Ratings	Change
1	2	↑	Java	16.041%	-1.31%
2	1	↓	C	15.745%	-1.89%
3	4	↑	C++	6.962%	+0.83%
4	3	↓	Objective-C	5.890%	-6.99%
5	5		C#	4.947%	+0.13%
6	9	↑	JavaScript	3.297%	+1.55%
7	7		PHP	3.009%	+0.24%
8	8		Python	2.690%	+0.70%
9	-	2× ↑	Visual Basic	2.199%	+2.20%

A.3 Programming Language Popularity Chart

[4]

The programming language popularity chart indicates the activity of a given language in the online communities. It uses two indicators to rank languages : the number of line changed in github of, and the number of questions tagged with a certain language.

Javascript is ranked number one in this index. The Javascript community is particularly active online, and in the open source.

indeed.com

A.4 Black Duck Knowledge

[5]

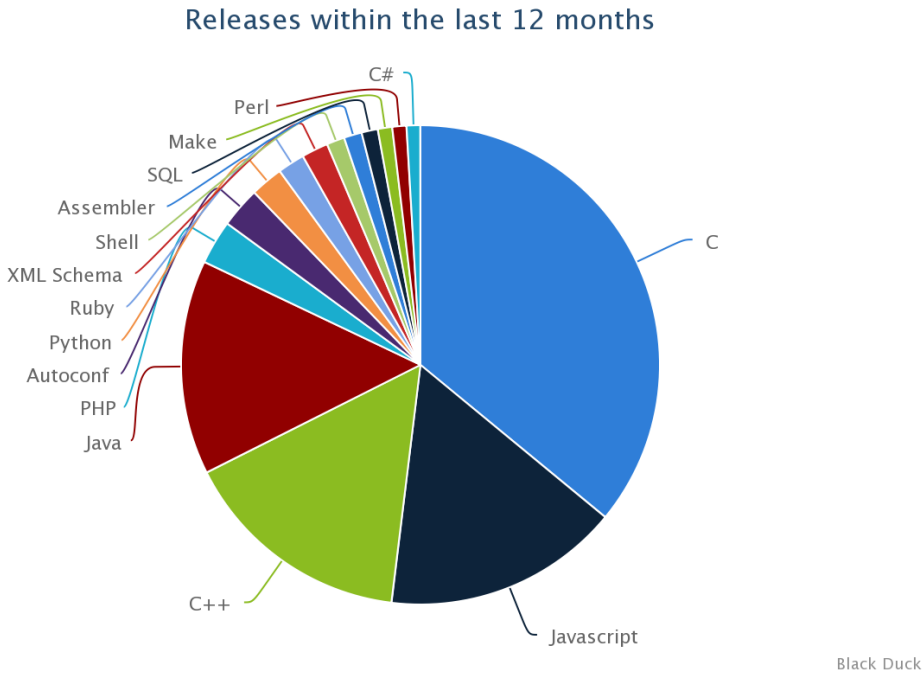
The black-duck, which analyze the usage of language on many forges, and collaborative hosts, rank Javascript number 2, after C, and with about the same usage as C++.

github.com sourceforge.net cpan.org rubyforge7.org planetsourcecode.com ddj.com

[4] http://langpop.corger.nl

[5] https://www.blackducksoftware.com/resources/data/this-years-language-use

Language	%
C	34.80
Javascript	15.45
C++	15.13
Java	14.02
PHP	2.87
Autoconf	2.65
Python	2.15
Ruby	1.77
XML Schema	1.73
Shell	1.18
Assembler	1.16
SQL	1.07
Make	0.94
Perl	0.92
C#	0.90



A.5 Github

http://githut.info/

A.6 HackerNews Poll

https://news.ycombinator.com/item?id=3746692

Language	Count
Python	3335
Ruby	1852
JavaScript	1530
C	1064
C#	907
PHP	719
Java	603
C++	587
Haskell	575
Clojure	480
CoffeeScript	381
Lisp	348
Objective C	341
Perl	341
Scala	255
Scheme	202
Other	195
Erlang	171
Lua	150
Smalltalk	130
Assembly	116
SQL	112
Actionscript	109
OCaml	88
Groovy	83
D	79
Shell	76
ColdFusion	51
Visual Basic	47
Delphi	45
Forth	41
Tcl	34
Ada	29
Pascal	28
Fortran	26
Rexx	13
Cobol	12