



EÖTVÖS LORÁND UNIVERSITY

FACULTY OF INFORMATICS

DEPT. OF SOFTWARE TECHNOLOGY AND METHODOLOGY

Auto-Scaling with Infrastructure-as-Code for Kubernetes-Driven Architectures

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The dynamic scaling of cloud-based architectures is an integral aspect of cost optimization, as these structures' expenses are intrinsically tied to their usage. Therefore, even minor optimizations can lead to substantial savings in overall cloud expenditure.

The objective here is to conduct a comparative assessment of two different scaling strategies: one rooted in the application code, and the other employing the capabilities of Infrastructure-as-Code (IaC) in a Kubernetes context. This investigation will focus on at least two different language implementations, with each language representing one approach. In each case, one implementation will exhibit native scalability within its language, while the other maintains a distributed layout, but scales within the Kubernetes infrastructure via IaC.

The study seeks to identify the most effective architecture and provide guidelines for its implementation, placing a particular emphasis on managing the complexity and maintainability of the code.

Budapest, 2023. 06. 09.

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Chapter 1

Introduction

What's the purpose of software development? As wikipedia states: Software development is the process used to create software. I would say this only used to be the process to create software. Today you don't have to develop anymore to create software. It's even kind of an antipattern to write code nowadays. We would like to use reusable components with well defined behavior which are interchangeable and replaceable. Software development where you code is like to using a cypher or a poem to express something. We would like to avoid this kind of artisan component as much as possible. Definitely some components has to be chiveled the old way. But that starts to be a rare and occasionally used exception. The new way of software creation must be as close to human language as possible and closer to the people who bring value. Software created value starts to shrink with all the redundancy, numbness of software using customers, less low hanging fruits and the liberation of software creation. The no code movement kind of reached it's final stage with AI where human language engineering is nearly capable to exclude the computer engineers from the equation. You can plan, design, create and host any idea without much engineering overhead which not only reduces cost on engineering hours but increases maintainability at the same time. The main topic of my thesis is infrastructure as a code. The tool which elevates software from mathematics to practice is the hardware which hosts and enables software to accelerate. Hardware management traditionally developed like plant machine maintenance. Every software offering company become a small or huge plant owner who had to maintain its hardware plant, it's hardware maintaining employees and creating processes around the hardware anblement. This paradigm evolved naturally with the digital revolution. Automation was key not

only by the manufacturing side but it circled in the Software developement has to be rethought since the new paradigmes. Shifting round and around.

Chapter 2

User documentation

Lorem ipsum dolor sit amet \mathbb{N} , consectetur adipiscing elit. Duis nibh leo, dapibus in elementum nec, aliquet id sem. Suspendisse potenti. Nullam sit amet consectetur nibh. Donec scelerisque varius turpis at tincidunt. Cras a diam in mauris viverra vehicula. Vivamus mi odio, fermentum vel arcu efficitur, lacinia viverra nibh. Aliquam aliquam ante mi, vel pretium arcu dapibus eu. Nulla finibus ante vel arcu tincidunt, ut consectetur ligula finibus. Mauris mollis lectus sed ipsum bibendum, ac ultrices erat dictum. Suspendisse faucibus euismod lacinia \mathbb{Z} .

2.1 Enumerations and lists

Etiam vel odio ante. Etiam pulvinar nibh quis massa auctor congue. Pellentesque quis odio vitae sapien molestie vestibulum sit amet et quam. Pellentesque vel dui eget enim hendrerit finibus at sit amet libero. Quisque sollicitudin ultrices enim, nec porta magna imperdiet vitae. Cras condimentum nunc dui, eget molestie nunc accumsan vel.

- Fusce in aliquet neque, in pretium sem.
- Donec tincidunt tellus id lectus pretium fringilla.
- Nunc faucibus, erat pretium tempus tempor, tortor mi fringilla neque, ac congue ex dui vitae mauris.

Donec dapibus sodales ante, at scelerisque nunc laoreet sit amet. Mauris porttitor tincidunt neque, vel ullamcorper neque pulvinar et. Integer eu lorem euismod,

faucibus lectus sed, accumsan felis. Nunc ornare mi at augue vulputate, eu venenatis magna mollis. Nunc sed posuere dui, et varius nulla. Sed mollis nibh augue, eget scelerisque eros ornare nec.

1. Donec pretium et quam a cursus. Ut sollicitudin tempus urna et mollis.
2. Aliquam et aliquam turpis, sed fermentum mauris. Nulla eget ex diam.
3. Donec eget tellus pharetra, semper neque eget, rutrum diam Step 1.

Praesent porta, metus eget eleifend consequat, eros ligula eleifend ex, a pellen-tesque mi est vitae urna. Vivamus turpis nunc, iaculis non leo eget, mattis vulpu-tate tellus. Maecenas rutrum eros sem, pharetra interdum nulla porttitor sit amet. In vitae viverra ante. Maecenas sit amet placerat orci, sed tincidunt velit. Vivamus mattis, enim vel suscipit elementum, quam odio venenatis elit¹, et mollis nulla nunc a risus. Praesent purus magna, tristique sed lacus sit amet, convallis malesuada magna.

Vestibulum venenatis malesuada enim, ac auctor erat vestibulum et. Phasellus id purus a leo suscipit accumsan.

Orci varius natoque penatibus et magnis dis parturient montes, nascetur ridicu-lus mus. Nullam interdum rhoncus nisl, vel pharetra arcu euismod sagittis. Vestibulum ac turpis auctor, viverra turpis at, tempus tellus.

Morbi dignissim erat ut rutrum aliquet. Nulla eu rutrum urna. Integer non urna at mauris scelerisque rutrum sed non turpis.

2.1.1 Lists with narrow spacing inbetween items

Phasellus ultricies, sapien sit amet ultricies placerat, velit purus viverra ligula, id consequat ipsum odio imperdiet enim:

1. Maecenas eget lobortis leo.
2. Donec eget libero enim.
3. In eu eros a eros lacinia maximus ullamcorper eget augue.

¹Phasellus faucibus varius purus, nec tristique enim porta vitae.

In quis turpis metus. Proin maximus nibh et massa eleifend, a feugiat augue porta. Sed eget est purus. Duis in placerat leo. Donec pharetra eros nec enim convallis:

- Pellentesque odio lacus.
- Maximus ut nisl auctor.
- Sagittis vulputate lorem.

Vestibulum ante ipsum primis in faucibus orci luctus et ultrices posuere cubilia Curae; Sed lorem libero, dignissim vitae gravida a, ornare vitae est.

Cras maximus massa commodo pellentesque viverra.

Morbi sit amet ante risus. Aliquam nec sollicitudin mauris

Ut aliquam rhoncus sapien luctus viverra arcu iaculis posuere

2.2 Images and figures

Aliquam vehicula luctus mi a pretium. Nulla quam neque, maximus nec velit in, aliquam mollis tortor. Aliquam erat volutpat. Curabitur vitae laoreet turpis. Integer id diam ligula. Nulla sodales purus id mi consequat, eu venenatis odio pharetra. Cras a arcu quam. Suspendisse augue risus, pulvinar a turpis et, commodo aliquet turpis. Nulla aliquam scelerisque mi eget pharetra. Mauris sed posuere elit, ac lobortis metus. Proin lacinia sit amet diam sed auctor. Nam viverra orci id sapien sollicitudin, a aliquam lacus suscipit, Figure 2.1:

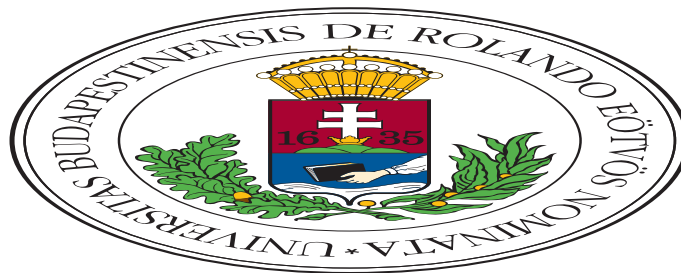


Figure 2.1: Quisque ac tincidunt leo

2.2.1 Framing figures

Ut aliquet nec neque eget fermentum. Cras volutpat tellus sed placerat elementum. Quisque neque dui, consectetur nec finibus eget, blandit id purus. Nam eget ipsum non nunc placerat interdum.



Figure 2.2: Quisque ac tincidunt leo

2.2.2 Subfigures

In non ipsum fermentum urna feugiat rutrum a at odio. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Nulla tincidunt mattis nisl id suscipit. Sed bibendum ac felis sed volutpat. Nam pharetra nisi nec facilisis faucibus. Aenean tristique nec libero non commodo. Nulla egestas laoreet tempus. Nunc eu aliquet nulla, quis vehicula dui. Proin ac risus sodales, gravida nisi vitae, efficitur neque, Figure 2.3:

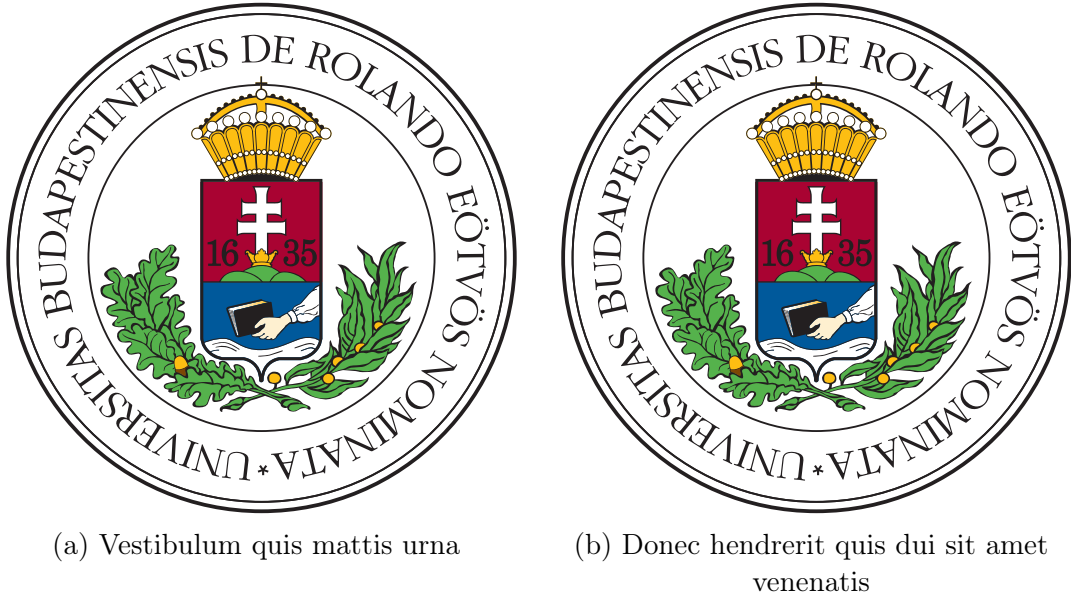


Figure 2.3: Aenean porttitor mi volutpat massa gravida

Nam et nunc eget elit tincidunt sollicitudin. Quisque ligula ipsum, tempor vitae tortor ut, commodo rhoncus diam. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Phasellus vehicula quam dui, eu convallis metus porta ac.

2.3 Tables

Nam magna ex, euismod nec interdum sed, sagittis nec leo. Nam blandit massa bibendum mattis tristique. Phasellus tortor ligula, sodales a consectetur vitae, placerat vitae dolor. Aenean consequat in quam ac mollis.

| Phasellus tortor | Aenean consequat |
|-----------------------|--|
| <i>Sed malesuada</i> | Aliquam aliquam velit in convallis ultrices. |
| <i>Purus sagittis</i> | Quisque lobortis eros vitae urna lacinia euismod. |
| <i>Pellentesque</i> | Curabitur ac lacus pellentesque, eleifend sem ut, placerat enim. Ut auctor tempor odio ut dapibus. |

Table 2.1: Maecenas tincidunt non justo quis accumsan

2.3.1 Multi rows and multi columns

Mauris a dapibus lectus. Vestibulum commodo nibh ante, ut maximus magna eleifend vel. Integer vehicula elit non lacus lacinia, vitae porttitor dolor ultrices. Vivamus gravida faucibus efficitur. Ut non erat quis arcu vehicula lacinia. Nulla felis mauris, laoreet sed malesuada in, euismod et lacus. Aenean at finibus ipsum. Pellentesque dignissim elit sit amet lacus congue vulputate.

| Quisque | Suspendisse | | Aliquam | | Vivamus | |
|---------|-------------|------|---------|--------|---------|-------|
| | Proin | Nunc | Proin | Nunc | Proin | Nunc |
| Leo | 2,80 MB | 100% | 232 KB | 8,09% | 248 KB | 8,64% |
| Vel | 9,60 MB | 100% | 564 KB | 5,74% | 292 KB | 2,97% |
| Auge | 78,2 MB | 100% | 52,3 MB | 66,88% | 3,22 MB | 4,12% |

Table 2.2: Vivamus ac arcu fringilla, fermentum neque sed, interdum erat. Mauris bibendum mauris vitae enim mollis, et eleifend turpis aliquet.

2.3.2 Long tables over multiple pages

Nunc porta placerat leo, sit amet porttitor dui porta molestie. Aliquam at fermentum mi. Maecenas vitae lorem at leo tincidunt volutpat at nec tortor. Vivamus semper lacus eu diam laoreet congue. Vivamus in ipsum risus. Nulla ullamcorper finibus mauris non aliquet. Vivamus elementum rhoncus ex ut porttitor.

| Praesent aliquam mauris enim | |
|------------------------------|---|
| <i>Suspendisse potenti</i> | <i>Lorem ipsum dolor sit amet</i> |
| <i>Praesent</i> | Nulla ultrices et libero sit amet fringilla. Nunc scelerisque ante tempus sapien placerat convallis. |
| <i>Luctus</i> | Integer hendrerit erat massa, non hendrerit risus convallis at. Curabitur ultrices, justo in imperdiet condimentum, neque tortor luctus enim, luctus posuere massa erat vitae nibh. |
| <i>Egestas</i> | Duis fermentum feugiat augue in blandit. Mauris a tempor felis. Pellentesque ultricies tristique dignissim. Pellentesque aliquam semper tristique. Nam nec egestas dolor. Vestibulum id elit quis enim fringilla tempor eu a mauris. Aliquam vitae lacus tellus. Phasellus mauris lectus, aliquam id leo eget, auctor dapibus magna. Fusce lacinia felis ac elit luctus luctus. |
| <i>Dignissim</i> | Praesent aliquam mauris enim, vestibulum posuere massa facilisis in. Suspendisse potenti. Nam quam purus, rutrum eu augue ut, varius vehicula tellus. Fusce dui diam, aliquet sit amet eros at, sollicitudin facilisis quam. Phasellus tempor metus vel augue gravida pretium. Proin aliquam aliquam blandit. Nulla id tempus mi. Fusce in aliquam tortor. |
| <i>Pellentesque</i> | Donec felis nibh, imperdiet a arcu non, vehicula gravida nibh. Quisque interdum sapien eu massa commodo, ac elementum felis faucibus. |
| <i>Molestie</i> | Cras ullamcorper tellus et auctor ultricies. Maecenas tincidunt euismod lectus nec venenatis. Suspendisse potenti. Pellentesque pretium nunc ut euismod cursus. Nam venenatis condimentum quam. Curabitur suscipit efficitur aliquet. Interdum et malesuada fames ac ante ipsum primis in faucibus. |

| | |
|----------------------------|--|
| <i>Suspendisse potenti</i> | <i>Lorem ipsum dolor sit amet</i> |
| <i>Vivamus semper</i> | In purus purus, faucibus eu libero vulputate, tristique sodales nunc. Nulla ut gravida dolor. Fusce vel pellentesque mi, vel efficitur eros. Nunc vitae elit tellus. Sed vestibulum auctor consequat. |
| <i>Condimentum</i> | Nulla scelerisque, leo et facilisis pretium, risus enim cursus turpis, eu suscipit ipsum ipsum in mauris. Praesent eget pulvinar ipsum, suscipit interdum nunc. Nam varius massa ut justo ullamcorper sollicitudin. Vivamus facilisis suscipit neque, eu fermentum risus. Ut at mi mauris. |

Table 2.3: Praesent ullamcorper consequat tellus ut eleifend

Chapter 3

Developer documentation

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis nibh leo, dapibus in elementum nec, aliquet id sem. Suspendisse potenti. Nullam sit amet consectetur nibh. Donec scelerisque varius turpis at tincidunt.

3.1 Theorem-like environments

Definition 1. Mauris tristique sollicitudin ultrices. Etiam tristique quam sit amet metus dictum imperdiet. Nunc id lorem sed nisl pulvinar aliquet vitae quis arcu. Morbi iaculis eleifend porttitor.

Maecenas rutrum eros sem, pharetra interdum nulla porttitor sit amet. In vitae viverra ante. Maecenas sit amet placerat orci, sed tincidunt velit. Vivamus mattis, enim vel suscipit elementum, quam odio venenatis elit, et mollis nulla nunc a risus. Praesent purus magna, tristique sed lacus sit amet, convallis malesuada magna. Phasellus faucibus varius purus, nec tristique enim porta vitae.

Theorem 1. *Nulla finibus ante vel arcu tincidunt, ut consectetur ligula finibus. Mauris mollis lectus sed ipsum bibendum, ac ultrices erat dictum. Suspendisse faucibus euismod lacinia. Etiam vel odio ante.*

Proof. Etiam pulvinar nibh quis massa auctor congue. Pellentesque quis odio vitae sapien molestie vestibulum sit amet et quam. Pellentesque vel dui eget enim hendrerit finibus at sit amet libero. Quisque sollicitudin ultrices enim, nec porta magna imperdiet vitae. Cras condimentum nunc dui. □

Donec dapibus sodales ante, at scelerisque nunc laoreet sit amet. Mauris porttitor tincidunt neque, vel ullamcorper neque pulvinar et. Integer eu lorem euismod, faucibus lectus sed, accumsan felis.

Remark. Nunc ornare mi at augue vulputate, eu venenatis magna mollis. Nunc sed posuere dui, et varius nulla. Sed mollis nibh augue, eget scelerisque eros ornare nec. Praesent porta, metus eget eleifend consequat, eros ligula eleifend ex, a pellentesque mi est vitae urna. Vivamus turpis nunc, iaculis non leo eget, mattis vulputate tellus.

Fusce in aliquet neque, in pretium sem. Donec tincidunt tellus id lectus pretium fringilla. Nunc faucibus, erat pretium tempus tempor, tortor mi fringilla neque, ac congue ex dui vitae mauris. Donec pretium et quam a cursus.

Note. Aliquam vehicula luctus mi a pretium. Nulla quam neque, maximus nec velit in, aliquam mollis tortor. Aliquam erat volutpat. Curabitur vitae laoreet turpis. Integer id diam ligula.

Ut sollicitudin tempus urna et mollis. Aliquam et aliquam turpis, sed fermentum mauris. Nulla eget ex diam. Donec eget tellus pharetra, semper neque eget, rutrum diam.

3.1.1 Equations, formulas

Duis suscipit ipsum nec urna blandit, $2 + 2 = 4$ pellentesque vehicula quam fringilla. Vivamus euismod, lectus sit amet euismod viverra, dolor metus consequat sapien, ut hendrerit nisl nulla id nisi. Nam in leo eu quam sollicitudin semper a quis velit.

$$a^2 + b^2 = c^2$$

Phasellus mollis, elit sed convallis feugiat, dolor quam dapibus nibh, suscipit consectetur lacus risus quis sem. Vivamus scelerisque porta odio, vitae euismod dolor accumsan ut.

In mathematica, identitatem Euleri (equation est scriptor vti etiam notum) sit aequalitatem Equation 3.1:

$$e^{i \times \pi} + 1 = 0 \tag{3.1}$$

Vestibulum ante ipsum primis in faucibus orci luctus et ultrices posuere cubilia curae; Nullam pulvinar purus at pharetra elementum. Aequationes adsignans aequa-

tionis signum:

$$A = \frac{\pi r^2}{2} \tag{3.2}$$

$$= \frac{1}{2}\pi r^2 \tag{3.3}$$

Proin tempor risus a efficitur condimentum. Cras lobortis ligula non sollicitudin euismod. Fusce non pellentesque nibh, non elementum tellus. Omissa numeratione aliquarum aequationum:

$$\begin{aligned} f(u) &= \sum_{j=1}^n x_j f(u_j) \\ &= \sum_{j=1}^n x_j \sum_{i=1}^m a_{ij} v_i \\ &= \sum_{j=1}^n \sum_{i=1}^m a_{ij} x_j v_i \end{aligned} \tag{3.4}$$

3.2 Source code samples

Nulla sodales purus id mi consequat, eu venenatis odio pharetra. Cras a arcu quam. Suspendisse augue risus, pulvinar a turpis et, commodo aliquet turpis. Nulla aliquam scelerisque mi eget pharetra. Mauris sed posuere elit, ac lobortis metus. Proin lacinia sit amet diam sed auctor. Nam viverra orci id sapien sollicitudin, a aliquam lacus suscipit. Quisque ac tincidunt leo

Code 3.1 and 3.2:

```
1 #include <stdio>
2
3 int main()
4 {
5     int c;
6     std::cout << "Hello World!" << std::endl;
7
8     std::cout << "Press any key to exit." << std::endl;
9     std::cin >> c;
10
11     return 0;
12 }
```

Code 3.1: Hello World in C++


```

1 using System;
2 namespace HelloWorld
3 {
4     class Hello
5     {
6         static void Main()
7         {
8             Console.WriteLine("Hello World!");
9
10            Console.WriteLine("Press any key to exit.");
11            Console.ReadKey();
12        }
13    }
14 }

```

Code 3.2: Hello World in C#

3.2.1 Algorithms

A general Interval Branch and Bound algorithm is shown in Algorithm 1. An appropriate selection rule is applied in Step 3.

Source of example: Acta Cybernetica ([this is a hyperlink](#)).

Algorithm 1 A general interval B&B algorithm

Func $\text{IBB}(S, f)$

```

1: Set the working list  $\mathcal{L}_W := \{S\}$  and the final list  $\mathcal{L}_Q := \{\}$ 
2: while (  $\mathcal{L}_W \neq \emptyset$  ) do
3:     Select an interval  $X$  from  $\mathcal{L}_W$  ▷ Selection rule
4:     Compute  $lb f(X)$  ▷ Bounding rule
5:     if  $X$  cannot be eliminated then ▷ Elimination rule
6:         Divide  $X$  into  $X^j$ ,  $j = 1, \dots, p$ , subintervals ▷ Division rule
7:         for  $j = 1, \dots, p$  do
8:             if  $X^j$  satisfies the termination criterion then ▷ Termination rule
9:                 Store  $X^j$  in  $\mathcal{L}_Q$ 
10:            else
11:                Store  $X^j$  in  $\mathcal{L}_W$ 
12:            end if
13:        end for
14:    end if
15: end while
16: return  $\mathcal{L}_Q$ 

```

Chapter 4

Conclusion

Lorem ipsum dolor sit amet, consectetur adipiscing elit. In eu egestas mauris. Quisque nisl elit, varius in erat eu, dictum commodo lorem. Sed commodo libero et sem laoreet consectetur. Fusce ligula arcu, vestibulum et sodales vel, venenatis at velit. Aliquam erat volutpat. Proin condimentum accumsan velit id hendrerit. Cras egestas arcu quis felis placerat, ut sodales velit malesuada. Maecenas et turpis eu turpis placerat euismod. Maecenas a urna viverra, scelerisque nibh ut, malesuada ex.

Aliquam suscipit dignissim tempor. Praesent tortor libero, feugiat et tellus portitor, malesuada eleifend felis. Orci varius natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Nullam eleifend imperdiet lorem, sit amet imperdiet metus pellentesque vitae. Donec nec ligula urna. Aliquam bibendum tempor diam, sed lacinia eros dapibus id. Donec sed vehicula turpis. Aliquam hendrerit sed nulla vitae convallis. Etiam libero quam, pharetra ac est nec, sodales placerat augue. Praesent eu consequat purus.

Acknowledgements

In case your thesis received financial support from a project or the university, it is usually required to indicate the proper attribution in the thesis itself. Special thanks can also be expressed towards teachers, fellow students and colleagues who helped you in the process of creating your thesis.

Appendix A

Simulation results

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