First year project
Project 99: Who's Julia?

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1 Summary

Julia is a new programming language. Through tests and benchmarking it is found that * *

2 Preface

This report has been written in May 2016 as a first year project in the Bachelor Degree of Computer Science. We thank our supervisor Michal Kotrbčík for his help and time. In this project we have been doing benchmarks to find out if Julia is as good as the developers claim it to be.

Contents

3 Introduction

Java, C, C++, C# and Python are on top ten of the most used programming languages. There are hundreds of languages, but not minding the hard competition new languages are still created with the thought of doing better. Julia is a new programming language, which has been developed to combine other languages best features.
The purpose of this report is to find out if the programming language Julia has a chance in the marked and if it is worth changing to. The languages Java, C++, Python and Julia will be compared on syntax and time performance.

4 Julia

in this section we
Special Features in Julia:

- Dynamic typing and byte-related memory management
- Multiple dispatch
- User defined types
- Garbage Collector
- Built-in package manager
- Lightweight green threading
- Meta-programming and Macros
- Implementing code from other languages
- Designed for parallelism and distributed computation
- Supports Unicode
- Devectorized code is fast
- Others we have not looked into

Julia is a programming language, which has been under development since 2009. First released in 2012 and the newest stable version of Julia is version 0.4.5. The language has been created because the developers wanted a language with all the features they like from different languages. The developers also wanted the language to be open source, which means everybody can read and modify the language. Julia shares many similarities with python. One of the ideas was to make the language as simple, readable and easy to learn as possible. The language is made for high performance and scientific computations while still supporting general purpose programming. Programming in Julia can be done in the terminal like python with interactive mode:

(a) Julia

```
Python 2.7.11+ (default, Apr 17 2016, 14:00:29)
[GCC 5.3.1 20160413] on linux2
Type "help", "copyright", "credits" or "license" for more information
.
>>> 2+2
4
```

(b) Python

Figure 1: Julia and Python in terminal

Writing longer programs in the terminal might not be the preferred method. The text editor Atom supports the Julia language. Atom has a package, **uber-juno**, which sets up Atom to act like an IDE, integrated development environment for Julia.

4.1 Syntax

Make examples of syntax between all the languages here.

```
1   Julia:     Python:     Java:           c++:
2   a = 10     a = 10      int a = 10;     int a = 10;
```

Figure 2: Declaring and assigning variables

```julia
for i = 1 : 10
    println(i)
end
```

(a) Julia

```python
for i in range(1, 11):
    print i
```

(b) Python

```java
for (int i = 1; i <= 10; i++){
    System.out.println(i);
}
```

(c) Java

```cpp
for (int i = 1; i <= 1+; i++){
    std::cout << i << "\n";
}
```

(d) C++

Figure 3: For-loops: Incrementing

```julia
for i = 10 : -1 : 1
    println(i)
end
```

(a) Julia

```python
for i in range(10, 0, -1):
    print i
```

(b) Python

```java
for (int i = 10; i > 0; i--){
    System.out.println(i);
}
```

(c) Java

```cpp
for (int i = 10; i > 0; i--){
    std::cout << i << "\n";
}
```

(d) C++

Figure 4: For-loops: Decrementing

```julia
if i == a
    println(a * b)
end
else if i == b
    println(a / b)
else
    println(a + b)
end
```

(a) Julia

```python
if i == a:
    print a * b
elif i == b:
    print a / b
else:
    print a + b
```

(b) Python

```java
if(i == a){
    System.out.println(a * b);
}
else if(i == b){
    System.out.println(a / b);
}
else{
    System.out.println(a + b);
}
```

(c) Java

```cpp
if(i == a){
    std::cout << a * b << "\n";
}
else if(i == b){
    std::cout << a / b << "\n";
}
else{
    std::cout << a + b << "\n";
}
```

(d) C++

Figure 5: If statements

```
1  int i = 0
2  while i < 10
3  i += 1
4  end
```

(a) Julia

```
1  int i = 0
2  while (i < 10):
3      i += 1
```

(b) Python

```
1  int i = 0;
2  while (i < 10){
3      i++;
4  }
```

(c) Java

```
1  int i = 0;
2  while (a < 10){
3      i++;
4  }
```

(d) C++

Figure 6: while-loop

```julia
function hello(name)
    println("Hello $name")
end
```

(a) Julia

```python
def hello(name):
    print "Hello", name
```

(b) Python

```java
public static void hello(String name){
    System.out.println("Hello " + name);
}
```

(c) Java

```cpp
void hello(std::string name)
{
    std::cout << "Hello " << name << std
        ::endl;
}
```

(d) C++

Figure 7: Declaring functions

```julia
array = fill(0, 100)
```

(a) Julia

```python
array = [0 for col in range(100)]
```

(b) Python

```java
int[] array = new int[100];
Arrays.fill(array, 0);
```

(c) Java

```cpp
std::array<int,100> array;
array.fill(0);
```

(d) C++

Figure 8: Filling array

4.2 Features

* In this section we *

4.2.1 Dynamic typing and byte-related memory management

Dynamic typing is a type management approach where type checks are mostly performed at runtime, as opposed to static typing, where type checks are made at compile time. Dynamic typing allows the programmer to skip the type declaration and let the dynamic type system handle it. In Julia it is possible to specify types, but mostly it is not necessary.

* rephrase * Julia also makes decisions about how much memory to allocate for variables and the assigned memory size will not change later, not even if a big value, that exceeds the memory of the variable, is assigned to it.

The memory size can be decreased and this will be addressed later under the section Garbage Collector. However, there is a range of memory sizes to chose from when initializing a variable. Julia will by default assign 32 bits to an integer or a float if no more memory is needed at initialization, but it is possible to manually chose one of the following:

- Signed/unsigned integer – 8, 16, 32, 64 and 128 bits – Int8, UInt8, Int16, UInt16, Int32, UInt32, Int64, UInt64, Int128 and UInt128
- Floating point – 16, 32 and 64 bits – Float16, Float32 and Float64
- Boolean – 8 bits – Bool
- Character – 32 bits - Char

To initialize a variable with a given memory size:

```
1 x = Int8(10)
```

But if the variable is later assigned a new value, Julia will automatically allocate 32 bits for the variable or more if needed:

```
1 x = Int8(10)
2 typeof(x) #Int8
3 x = 4
4 typeof(x) #Int32
```

If no certain memory size is needed but only a specific type then abstract types will come in handy. An abstract type is just some form of generalization of a concrete type. For example 16, 32 and 64 bit floating points are of type AbstractFloat. This is especially useful when the programmer do not know how much memory a certain variable may need. Too little memory will result

in a bug and too much memory is a waste. * Example *

4.2.2 Multiple dispatch

Multiple dispatch is used to determine which function to call by the type of one or more of the parsed argument(s). This is useful for example when two functions, with the same name, are declared:

```
1 function a(arg1::Int8)
2     println("Int")
3 end
4
5 function a(arg1::Float16)
6     println("Float")
7 end
```

If a variable is declared as an Int8 and used as argument in function a(), then Julia will print "Int". If the variable is declared as a Float16 and used as argument in function a(), then Julia will print "Float". It is also possible to use abstract types here, so arg1::Float16 and arg1::Int8 could be changed to arg1::AbstractFloat and arg1::AbstractInt, which will make the function 'a' accept any type of floating points and integers.

4.2.3 User defined types

User defined types, also known as composite types, give the programmer the option to define new types in Julia. A composite type in Julia could look as the following:

```
1 type person
2     age::Int16
3     name #a variable, which gets the assigned default type ::Any
4 end
```

If a variable in a composite type is not specified with any type, the default is ::Any, which accept any type. To initialize a composite type, think of it like an object. Person = person(21, "Carl"), and the values can be changed with "Person.age = 25". In the example above, the type person can now be used as any other of the built in types in Julia.

```
function a(arg1::person)
    println(arg1.age)
end
Person = person(21, "Carl")
a(Person) #Will print 21
```

The developers of Julia claim that user defined types are as fast and compact as built in types.

4.2.4 Garbage Collector

Julia uses a garbage collector to automatically free the memory when needed. There is no guarantee when the garbage collector will run, but it is possible to force garbage collection with a function call **gc()**. One thing to keep in mind is that once a name is defined in Julia, it will always be present until program termination. The garbage collector does not free the memory of unreachable object, but rather reallocates memory for objects when memory size has changed. Therefore, the only way the garbage collector can free the memory is when an object has been reduced in size, for example:

```
A = rand(float32, 10000, 10000)
A = 0
gc()
```

This code will generate a 10.000×10.000 matrix filled with random 32 bit floating points, which consumes approximately 400MB of memory. When the value **A** is set to 0 the memory allocated will stay the same until the garbage collection is executed as in the example above, or on program termination.

4.2.5 Built-in package manager

Julia comes with a built in package manager, which keeps track of packages that needs to be included in the program to run. It is not necessary to state, which packages needs to be included. For example, when the user calls the sort function, **sort()**, no package include statement or **math.sort()** is needed – this is done automatically by the package manager.

4.2.6 Lightweight green threading

A thread is lightweight when it shares address space with other threads opposed to heavyweight threads, which has its own address space. If threads share the same address space the communication between them is faster and much simpler. The communication between heavyweight threads have to go through pipes or sockets.

Green threads are threads that are scheduled not by the operating system but rather by the runtime library or the virtual machine. Green threads do not have to rely on the operating system and can be controlled much better – which means the threads are in user space and not kernel space. (See section 6.3 for explanation of time measurements) As of Julia 0.4.5 multithreading is not available but in the unstable version 0.5.0 an experimental support of multithreading is available, therefore threading will be addressed no further.

4.2.7 Meta-programming and Macros

Meta-programming is a way to write programs in programs and let them use program code as data. In Julia meta-programming can be done by defining macros. For example, the @time macro was used extensively in the project. The @time macro is a part of the Julia standard library. The @time macro takes a function as an argument and starts a timer bafore the code execution and stops the timer after execution and prints the time passed and memory allocated. Meta-programming and macros are known from Lisp, a programming language, and have been used in early AI research.

4.2.8 Implementing code from other languages

Since Julia is a newer language there are not many written libraries yet. Julia has an import feature for both Python and C libraries to avoid this disadvantage. Import the library PyCall with the "using" operation to use python and import Python libraries via a macro @pyimport. To use C libraries or coding, simply run the function ccall(). The programming language C is a well known and used language. Many systems are based on C, which makes C an advantage for hardware programming. Another feature is to execute shell commands. Execute shell commands using run(“). An example would

be running run(‘echo Hello World‘), which would return the output "Hello World".

```
#Run Pkg.add("PyCall") for the first time.
using PyCall

@pyimport pylab #Import library pylab

x = linspace(0, 4, 100); y = x + 1;
pylab.plot(x, y)
pylab.show() #Shows the graph x + 1

println(pyeval("4*3+1")) #prints 13
```

Figure 9: Import of Python libraries.

4.2.9 Designed for parallelism and distributed computation

Julia claims to be designed for parallelism and distributed computation. Parallel computing is dividing a problem into smaller problems and solve the smaller problems at the same time. Distributed computing is solving a problem using a network of computers working together to get to the solution. Julia have been trying to make this easier to achieve with different macros.

4.2.10 Supports Unicode

The Unicode support globalize the language. Unicode is an encoding system for characters. Unicode supports a large range of characters and is designed to make it easier to read and write non-latin characters.

4.2.11 Devectorized code is fast

Vectorization of code is, for example, when a for loop is rewritten to sequential operations. Figure 10 shows an example of a non-vectorized for loop and the vectorized version. Vectorized code is usually faster. Julia claims that there is no reason to vectorize as the performance stays the same.

```
1  a = 1, 2, 3, 4
2  b = 2, 3, 4, 5
3  c is empty
4  for i = 1 to 4
5  begin
6      c[i] = a[i] + b[i]
7  end
```

(a) Devectorized code

```
1  a = [1, 2, 3, 4]
2  b = [2, 3, 4, 5]
3  c is empty
4  c[1] = a[1] + b[1]
5  c[2] = a[2] + b[2]
6  c[3] = a[3] + b[3]
7  c[4] = a[4] + b[4]
```

(b) Vectorized code

Figure 10: Vectorization

5 Project Euler

Project Euler is a website (`https://projecteuler.net/`) with a huge database of mathematical and programming challenges. In this report Project Euler has been used to find challenges for testing the different programming languages.

6 Theory

6.1 Benchmarking

In computer science, benchmarking is experimental measuring the amount of performance crammed by a particular program. In this report we will be measuring the time it takes for a programming language to execute a set of programs implemented in Julia, Python, C++ and Java. To get an indication of the real CPU time, multiple tests are done and the median is calculated. The median run time is considered since there can be fluctuations in run times for every test.

6.2 Profiling

Profiling is a way to analyse code. For example, the analysis could be measuring the memory usage, time and function calls. The analysis shows, which part of the code took the longest time or used up all memory. Profiling is often used for optimization.

6.3 Time measurements

Looking at the run time the most common terms are wall time (real time) and CPU time. Wall time is the time it took the program to terminate, from start to finish. CPU time is how much time the program used on the CPU. The time difference between wall time and CPU time comes from the fact that the program being benchmarked might get interrupted by the operating system, because other tasks needs to be handled. These tasks could be other programs, or something that the OS needs to get done. The processing time of those tasks will be included in the wall time but excluded in the CPU time. To get the run times in Unix based system, the time command is available from the terminal:

```
1 time <COMMAND>
```

Where <COMMAND> can be any terminal command. The time command will return three different times.

```
real    0m0.627s
user    0m0.462s
sys     0m0.147s
```

Figure 11: Sample output of the time command

.

- Real: This is the wall time mentioned above.
- User: User time is how much CPU time is spent in user mode.
- Sys: System time is how much CPU time is spent in kernel mode.

The difference between user- and kernel mode is the following:
In most memory protected systems there are some locked operations for security reasons. E.g. allocation of memory or accessing hardware requires kernel mode and cannot be done in user mode. Operations as malloc and reading/writing to files will be proccessed in the kernel and this is counted as

system time. This does not necessarily mean that all time is spent in kernel mode operating with file data, since the only time that is spent in kernel mode is writing the data from the file to memory. The rest of the operation is counted towards user time. Therefore to get the amount of time spent by the CPU, User time + system time is a good estimation. Another way to measure time spent on the CPU is to use the built in libraries. For example the ThreadMXBean in Java. This is especially useful for profiling.

7 Materials and methods

7.1 Benchmarking

Materials for benchmarking:
Lenovo W530: Intel Core i5-3320M 2.60GHz x 4, 8GB RAM, Ubuntu 16.04 64-bit
MacBook: Intel Core i5 1,4GHz, 8GB RAM, OSX El Capitan 10.11.5
MacBook:
Julia 0.4.5
Python 2.7.11+
C++11
Java 1.8.0_92

Benchmarking will be done by comparing the run time of the same algorithm in different languages. In this project we measure the run time as the sum of system and user time, because the system and user time are not affected by heavy loads on the machine. All time measurements are measured using the shell 'time' command that returns the three types of time taken for the algorithm to run. The problems will be scaled to have smaller and larger inputs. However, in some situations a large input can cause memory problems, which will be addressed in the specific problem. The memory problems is unfortunately making an upper bound for how large data is possible to pass for certain problems. A tool created for this project gather the data and calculates the median of the run time.

8 Problems

8.1 Projecteuler 11

In the 20x20 grid below, four numbers along a diagonal line have been marked in red. The product of these numbers is 26×63×78×14 = 1788696. What is the greatest product of four adjacent numbers in the same direction (up, down, left, right, or diagonally) in the 20x20 grid?

```
08 02 22 97 38 15 00 40 00 75 04 05 07 78 52 12 50 77 91 08
49 49 99 40 17 81 18 57 60 87 17 40 98 43 69 48 04 56 62 00
81 49 31 73 55 79 14 29 93 71 40 67 53 88 30 03 49 13 36 65
52 70 95 23 04 60 11 42 69 24 68 56 01 32 56 71 37 02 36 91
22 31 16 71 51 67 63 89 41 92 36 54 22 40 40 28 66 33 13 80
24 47 32 60 99 03 45 02 44 75 33 53 78 36 84 20 35 17 12 50
32 98 81 28 64 23 67 10 26 38 40 67 59 54 70 66 18 38 64 70
67 26 20 68 02 62 12 20 95 63 94 39 63 08 40 91 66 49 94 21
24 55 58 05 66 73 99 26 97 17 78 78 96 83 14 88 34 89 63 72
21 36 23 09 75 00 76 44 20 45 35 14 00 61 33 97 34 31 33 95
78 17 53 28 22 75 31 67 15 94 03 80 04 62 16 14 09 53 56 92
16 39 05 42 96 35 31 47 55 58 88 24 00 17 54 24 36 29 85 57
86 56 00 48 35 71 89 07 05 44 44 37 44 60 21 58 51 54 17 58
19 80 81 68 05 94 47 69 28 73 92 13 86 52 17 77 04 89 55 40
04 52 08 83 97 35 99 16 07 97 57 32 16 26 26 79 33 27 98 66
88 36 68 87 57 62 20 72 03 46 33 67 46 55 12 32 63 93 53 69
04 42 16 73 38 25 39 11 24 94 72 18 08 46 29 32 40 62 76 36
20 69 36 41 72 30 23 88 34 62 99 69 82 67 59 85 74 04 36 16
20 73 35 29 78 31 90 01 74 31 49 71 48 86 81 16 23 57 05 54
01 70 54 71 83 51 54 69 16 92 33 48 61 43 52 01 89 19 67 48
```

The program runs from command-line/terminal with command line arguments in order to be able to test on different inputs and amount of adjacent numbers multiplied. To run the Julia version from the terminal:
Julia euler11.jl 100 4.
This would make the program run with a matrix of size 100 and calculating product of 4 adjacent numbers. A matrix generator was created, which can be found in appendix, to produce the matrix data. The matrix generator requires one argument, which is the size of the matrix. So if 500 is passed to the matrix generator, a file named 500mat.txt will be created containing 500x500 digits ranging from 100-9999.

The algorithm first reads through the input file and creates a matrix. To calculate products in all directions needed in the problem, the algorithm goes through the matrix a total of 3 times. A nested for loop is needed to go though a matrix, lines 1-2 at figure 12. The outer loop iterates through the rows, and the inner loop iterates through the columns. Fig-

ure 12 calculates the horizontal and vertical directions, firgure 13 diagonally from left to right(downwards) and figure 14 going diagonally from right to left(downwards). The algorithm starts in the most upper left cell, and iterates through all cells in the matrix. Lets have the first cell as (1,1), first number is row(**i**) and second number is column(**j**). Looking at figure 12, **matLength** is the size of the matrix, size = 100 would mean a matrix of size $100 \cdot 100$. **numProd** is the number of adjacent numbers multiplied together. For matrix with size 100, and multiplying four adjacent numbers, the algorithm would do the following in figure 12:

Starting at cell (1,1) to the end, which is cell (100, 100 - 4).

Line 5-7: Loops over the adjacent cells and multiplies the numbers.

Line 8-10: Sets current product to max product, if current is larger than previously max product.

```
1  for i = 1 : matLength
2    for j = 1 : matLength - numProd
3      #right/left
4      prod = Int64(1)
5      for k = 0 : numProd - 1
6        prod *= mat[i, j + k]
7      end
8      if prod > maxProd
9        maxProd = prod
10     end
11     #up/down
12     prod = Int64(1)
13     for k = 0 : numProd - 1
14       prod *= mat[j + k, i]
15     end
16     if prod > maxProd
17       maxProd = prod
```

Figure 12: Horizontal and vertical

Figure 13 shows the loop that iterates over the matrix and calculating the product of the diagonal going downwards from left to right. Figure 14 shows

the diagonal product going upwards from left to right. The loop starts in the first row, and starting column is the last, not the first like the previously loops.

```
#diagonal left->right
for i = 1 : matLength - numProd
  for j = 1 : matLength - numProd
    prod = Int64(1)
    for k = 0 : numProd - 1
      prod *= mat[i + k, j + k]
    end
    if prod > maxProd
      maxProd = prod
```

Figure 13: Diagonal downwards left to right

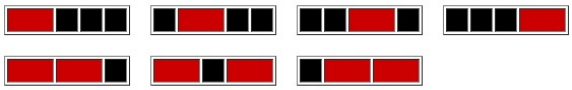
```
#diagonal right->left
for i = 1 : matLength - numProd
  for j = matLength : -1 : numProd
    prod = Int64(1)
    for k = 0 : numProd - 1
      prod *= mat[i + k, j - k]
    end
    if prod > maxProd
      maxProd = prod
```

Figure 14: Diagonal upwards left to right

8.2 Projecteuler 116

Description: A row of five black square tiles is to have a number of its tiles replaced with coloured oblong tiles from red(length two), green(length three), or blue(length four). If red tiles are chosen there are exactly seven ways. If green tiles are chosen there are three ways. And if blue tiles are chosen there are two ways. Figure 15 is a visualization of how the tiles can be lain. Assuming that colours cannot be mixed there are $7 + 3 + 2 = 12$ ways of replacing the black tiles in a row measuring five units in length.

How many different ways can the black tiles in a row measuring fifty units in length be replaced if colours cannot be mixed and at least one coloured tile must be used?



(a) Red tiles

(b) Green tiles

(c) Blue tiles

Figure 15: Projecteuler: 116

8.3 Quicksort

Quicksort applies the divide-and-conquer paradigm to sort numbers. Divide-and-conquer has three steps. **Divide** the problem into a number of subproblems that are smaller instances of the same problem. **Conquer** the subproblems by solving them recursively. If the subproblems sizes are small enough, however, just solve the subproblems in a straightforward manner. **Combine** the solutions to the subproblems into the solution for the original problem [1, chapter 4, page 65]. Description of quicksort: [1, chapter 7, page 170-171]

> **Divide**: Partition (rearrange) the array A[p..r] into two (possible empty) subarrays A[p..q-1] and A[q+1..r] such that each element of A[p–q1] is less than or equal to A[q], which is, in turn, less than or equal to each element of A[q+1..r]. Compute the index q as part of this partitioning procedure.
>
> **Conquer**: Sort the two subarrays A[p..q-1] and A[q+1..r] by recursive calls to quicksort.
>
> **Combine**: Because the subarrays are already sorted, no work is needed to combine them: the entire array A[p..r] is now sorted.

Figure 16 shows a visualization of quicksort.

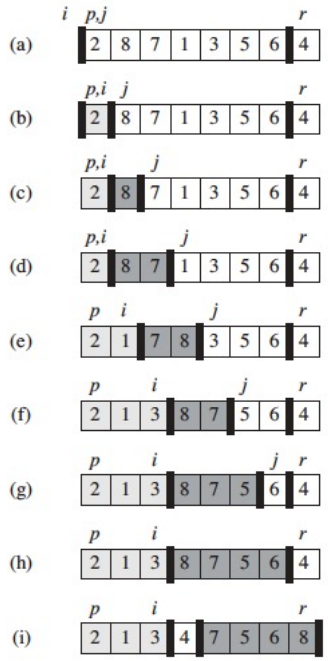


Figure 16: Quicksort

9 Results

9.1 Benchmarking

10 Personal experience with Julia

10.1 Sonni

Some of the design choices, in Julia, can be really frustrating for someone who is adapting to Julia. The indices starts at 1 - this could be debatable because of the statement that Julia is used in a lot of scientific computations and many programming languages made for scientific computations use 1-based indexing. But as a programmer who is used to indices starting at 0, this can cause a lot of unnecessary bugs. The developers of Julia also made unusual design choice with the for-loop syntax. A incrementing for loop looks like:

```
1 Julia:
2 for i = 1 : n
3     Some code ...
```

```
4 end
5
6 General languages:
7 for i = 1; i < n; i++
8     Some code ...
```

This is straightforward many other languages, but take a look at the decrementing for-loop:

```
1 Julia:
2 for i = n : -1 : 0
3     Some code ...
4 end
5
6 General languages:
7 for i = n; i > 0; i--
8     Some code
```

In Julia the exit condition and incrementation / decrementation are swapped and there is no consistency. The decrementing for-loops both start at n, and stops at 0. This kind of syntax can again cause bugs, and is not that easy to get eyes on.

The documentation of Julia is far from being great, which is a huge bump on the road to learn Julia. It feels far from complete. The documentation do not explain much but instead gives some examples. Essential information are often lacking, e.g. what types is needed to parse for a given function. It might point out that these arguments are needed, but lacking to describe those arguments. An example from the documentation is the function **rand()**, which is used to generate random numbers:

```
1 rand( [ rng ] [ ,S ] [ , dims... ] )
```

"Pick a random element or array of random elements from the set of values specified by S; S can be:
- an indexable collection (for example 1:n or ['x','y','z']), or
- a type: the set of values to pick from is then equivalent to typemin(S):typemax(S) for integers (this is not applicable to BigInt), and to [0,1) for floating point

numbers;
S defaults to Float64."
The argument **S** is explained, but does not mention anything about **rng** or **dims**.
Another example is how to access data within an array at a specific index. This should be one of the first things in the Array section, but is first described after about two pages of text. A person with experience in programming might know that to access an element in an array with an index is this simple line of code:

```
1 a[index]
```

But this isn't so obvious for new programmers. It is clear that something has to be done with the documentation.

Another downside to Julia is its consistency. The developers has tried to remove some of the burden from the programmer with dynamic typing, package manager system etc., but with memory allocation and garbage collection it does not make much sense. The garbage collector does not free memory from unreachable object. Sizes of variables cannot be changed after declaration, and is not automatically increased if needed. If the programmer assign for example 8 bit memory to a variable and later change the value of that variable, then julia automatically assigns 32 bit or more if needed to that variable even if the 8 bits were enough.

10.2 Simon

I personally see my self the one in the group with the least programming experience, and might needed more time learning Julia. I was not learning as fast as the others. I only know a few languages, and as many knows, the more languages you know, the easier it gets learning a new language. The documentation of Julia was not satisfying enough to me. I learn faster if I can visually see how a function is used, rather than reading a wall of text. The visualizations on the current documentation was not fulfilling my needs. The documentation also misses to explain crucial information to a function, like what a given argument is presenting. For that reason I often found myself looking through the documentation of Python, to read about a

function, since the syntax is so similar. Nevertheless, for programming I keep finding Julia more satisfying as I learn more, and for future programming I will definitely use Julia over Python.

10.3 Asbjørn

I found the syntax a bit confusing at first. I am not used to Python and I missed code structure and forced typing, in Julia and Python it looks like the code is hovering. After some time I got used to it and I found it very easy to learn. It makes it a little hard to find answers with the documentation and community being a bit thinner than with other languages. I think the 1-indexing is a bit complicated because I had never thought any language would use this, but I found that a lot of languages actually use this, they just are not that popular.

11 Discussion

Pros and Cons with good arguments http://www.evanmiller.org/why-im-betting-on-julia.html
High-Performance JIT Compiler chart at http://julialang.org/
http://www.nowozin.net/sebastian/blog/the-julia-language-for-scientific-computing.html
http://radar.oreilly.com/2013/10/julias-role-in-data-science.html

12 Conclusion

Is Julia a worthy competitor? Is it worth switching to Julia? Would we recommend Julia to anyone?

It can be difficult to make any conclusions by the benchmarking but it may give an idea of how Julia performs, compared to Java, Python and C++. One thing to keep in mind is that as of writing this report, Julia is in version 0.4.5 - it has yet to reach version 1.0.0 while the other languages are much older than Julia. This could mean that Julia might get even faster in the future.

13 Appendix

13.1 Process analysis

13.1.1 Projectmanagement, organizing workflow and organizing process of learning

The first thing we agreed doing was getting to know Julia for the research. We used a lot of time solving problems in Julia and trying to figure out how to get a view of what was to be done and how to organize it. We mostly communicated through facebook and created a repository on github to share project files. We gathered our solutions to Project Euler and made comparisons. Gathering information about benchmarking we mostly ran into walls of text on how to do it properly, and did not know where to start. Every time we thought we were understanding benchmarking, our supervisor taught us something new. We created a board on Trello. We made a to-do list of cards so we knew what had to be done and started handing out tasks. We communicated more with our supervisor via email as we started writing the report. The group was really good at getting the tasks, we agreed on doing, done. We should have been using more tools for organizing and we did not set any deadlines for anything. Scrum is a tool, which would have helped us a lot, but it is not that easy to learn. We should have met and worked together, several times a week, discussing our problems and goals.

13.1.2 Process of learning

We learn by both direct and indirect learning process. We learned Julia indirectly by solving Project Euler. We pretty much read about every topic, which is direct learning. We cannot think of another way to learn programming than reading, trying it out and reading to get a result. Project Euler was a good support for learning, since learning something new, is much easier, when there's a purpose or a goal. Programming is not as fun if there's no end goal in mind.

13.1.3 Cooperation, difficulties in group and with supervisor

We actually had a good idea about who was good at what and splitting the tasks between us with this in mind. The communication could have been better. It seemed that we worked on different times of the day, which made

communication difficult. Our supervisor did his best and we think he did a good job.

13.1.4 Conclusion

Trello is a very good tool for organizing and we should have been using it from the beginning. Looking beyond the fact that some data was lost using Git, the tool is perfect for team programming. We have payed the price not making any deadlines. Deadlines seems useless when the focus is just on the project, but when the workload gets more intense, it can be very good to have smaller deadlines or milestones during a project. Meetings should have occured more often, and syncing the current progress. Overall collaboration was very well, taken into account what could have been improved.

13.2 Copy of poster in A4

References

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[2] `http://www.tiobe.com/tiobe_index`

[3] `http://julialang.org/blog/2012/02/why-we-created-julia`

[4] `http://docs.julialang.org/en/latest/manual/parallel-computing/`

[5] `http://unicode.org/standard/WhatIsUnicode.html`

[6] `http://www.cs.cornell.edu/courses/cs1112/2013fa/Exams/exam2/vectorizedCode.pdf`