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Titel

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professionele bachelor in de toegepaste informatica

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Instelling: —

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Institution: —

Academic year: 2018-2019

Second examination period

Preface

Samenvatting

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Abstract

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1. Introduction

De inleiding moet de lezer net genoeg informatie verschaffen om het onderwerp te begrijpen en in te zien waarom de onderzoeksvraag de moeite waard is om te onderzoeken. In de inleiding ga je literatuurverwijzingen beperken, zodat de tekst vlot leesbaar blijft. Je kan de inleiding verder onderverdelen in secties als dit de tekst verduidelijkt. Zaken die aan bod kunnen komen in de inleiding (**Polleffiet2011**):

- context, achtergrond
- afbakenen van het onderwerp
- verantwoording van het onderwerp, methodologie
- probleemstelling
- onderzoeksdoelstelling
- onderzoeksvraag
- ...

1.1 Problem Statement

Uit je probleemstelling moet duidelijk zijn dat je onderzoek een meerwaarde heeft voor een concrete doelgroep. De doelgroep moet goed gedefinieerd en afgeleid zijn. Doelgroepen als “bedrijven,” “KMO’s,” systeembeheerders, enz. zijn nog te vaag. Als je een lijstje kan maken van de personen/organisaties die een meerwaarde zullen vinden in deze bachelorproef (dit is eigenlijk je steekproefkader), dan is dat een indicatie dat de doelgroep goed gedefinieerd is. Dit kan een enkel bedrijf zijn of zelfs één persoon (je co-promotor/opdrachtgever).

1.2 Research question

Wees zo concreet mogelijk bij het formuleren van je onderzoeksvraag. Een onderzoeksvraag is trouwens iets waar nog niemand op dit moment een antwoord heeft (voor zover je kan nagaan). Het opzoeken van bestaande informatie (bv. “welke tools bestaan er voor deze toepassing?”) is dus geen onderzoeksvraag. Je kan de onderzoeksvraag verder specificeren in deelvragen. Bv. als je onderzoek gaat over performantiemetingen, dan

1.3 Research objective

Wat is het beoogde resultaat van je bachelorproef? Wat zijn de criteria voor succes? Beschrijf die zo concreet mogelijk. Gaat het bv. om een proof-of-concept, een prototype, een verslag met aanbevelingen, een vergelijkende studie, enz.

1.4 Structure of this bachelor thesis

De rest van deze bachelorproef is als volgt opgebouwd:

In Hoofdstuk 2 wordt een overzicht gegeven van de stand van zaken binnen het onderzoeksdomein, op basis van een literatuurstudie.

In Hoofdstuk 3 wordt de methodologie toegelicht en worden de gebruikte onderzoekstechnieken besproken om een antwoord te kunnen formuleren op de onderzoeksvragen.

In Hoofdstuk 4, tenslotte, wordt de conclusie gegeven en een antwoord geformuleerd op de onderzoeksvragen. Daarbij wordt ook een aanzet gegeven voor toekomstig onderzoek binnen dit domein.

2. State of the art

2.0.1 General explication of quantum computing

There are a few advantages that quantum computers have over any classical machine, to understand them we will have to introduce a couple of explanations.

The first is *superposition*, it is the term used to explain how a quantum bit (Qubit) can be in multiple states at once. In classical computing we are able to represent 1 state at a time with the use of a normal bit, 0 or 1. In quantum computing this is different through the use of superposition, a qubit can be in both states at one point in computation. (Shor2000) Effectively this means that quantum computers can exponentially gain computational space through only the addition of 1 qubit, while a classical computer would add bits to only linearly gain computational space. But this only counts inside the computation, because as we know a qubit will 'fall' in a single state as soon as it is observed/ measured. (Rieffel1998)

A practical example for a clearer understanding of the term. Suppose that we have a classical system where we have access to 4 bits of processing space, this would effectively mean that we are able to represent 16 different states. If we compare it now we suppose a quantum system that utilizes 4 qubits of processing space, if we take in accounts the use of superposition 1 qubit is able to represent 2 classical bits. Meaning that we now have access to 16 computational space in classical bits, which also means that we have 65536 different states to represent.

$$\text{Classical : } 4 \text{ bits} \Rightarrow 2^4 \text{ states} \quad (2.1)$$

$$\text{Quantum : } 4 \text{ qubits} \Rightarrow 16^4 \text{ states} \quad (2.2)$$

Another really powerful tool for quantum computations is called *entanglement*. It describes the physical phenomenon that 2 particles can become entangled, meaning that one's state can directly influence the state of the other over an infinite distance. In our case, the particles represent the qubits that can become entangled which could mean that if 1 qubit is measured in a specific state and it is entangled with another qubit, it means that we are able to know the state of the other qubit *without* measuring it. Think of the possible utilisation in communication in between devices and/ or networks that this physical phenomenon could introduce.

Decoherence is also a term that forms a big issue right now for further advancements in quantum computing. Decoherence is the term that describes how a qubit can lose its quantum capabilities over time or due to interference from the outside world, currently to achieve quantum aspects we need to cool down the quantum devices to around 0 Kelvin or -273.15 degrees Celsius. Only slight fluctuations of the near perfect conditions can mean that the qubits lose their quantum capabilities, which would mean that the eventual computation becomes useless. As of now the Sycamore processor from Google has achieved the largest amount of qubits (53) to be used for a computation with 'fighting off' the decoherence. With 'fighting off' we are referring towards the process of Quantum Error Correction (QEC), this is a process that tries to prevent the decoherence and interference between the qubits. This is as of now the main restriction on just expanding the number of qubits, because the more qubits are used in the system the more the system will be susceptible for decoherence and interference. (Cory1998)

2.0.2 Practical fields of study using quantum

Security

A great concern with the rise of quantum computing has come up, people are believing that our current encryption system is easily breached by quantum computation. But indeed everyone was shocked when Peter Shor released his paper **Shor1994**, which described a way to resolve prime factorization on quantum computers. A classical computer can easily find the result of a multiplication but finding the factors of a large number is an exponential computation for a normal computer. Shor's algorithm uses superposition and quantum Fourier transform to resolve this exponential issue, meaning that it would suddenly become really easy to brute-force encryptions of data (e.g. RSA). (Rivest1978) This could possibly mean that the praised mainframe environment would become a lot less secure. In reality however factorization of large numbers is not the only way that we encrypt our data. For example the AES algorithm uses multiple partitions of a key to encrypt its data, which would re-introduce the issue of exponential computation even when using a quantum computer.

(Daemen2000) (IBM2019)

In effect the introduction of quantum computing will most likely result in a much safer environment, because through the utilization of quantum encryption our data could even become impenetrable for quantum computers. When quantum computing will be imple-

mented alongside the already existing mainframe applications, it will only strengthen its safety aspects and also the speed of these encryptions in mass.

Data

Physics and chemistry

Open source software

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3. Methodology

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A. Onderzoeksvoorstel

Het onderwerp van deze bachelorproef is gebaseerd op een onderzoeksvoorstel dat vooraf werd beoordeeld door de promotor. Dat voorstel is opgenomen in deze bijlage.

B. Table of contents

B.1 Introduction

B.1.1 Situating the subject

There has been a strong believe in the last 30 years that quantum computing can and will influence our environment more than we think. In case of the mainframe environment it will maybe be the most influential sector in *computer science*, because of its immense creation of data. Data will become or has already been the driving factor inside our societies, think of how much our daily lives are already controlled by data (e.g. online shopping, social media etc.). With the usage of mainframes we are able to create a sense of logic in this almost infinite pile of data. Now with *theoretical* utilisation of quantum computing, data can become much more important and meaningful for business applications.

The main driving factors for technological breakthroughs have always been wars and economics (e.g. Atomic energy, commercial aircraft, radio etc.). If we are able to find and explore quantum applications for our current high-transactional business applications, a new wave of investment in research will open up. Which would obviously boost both fields at once. In this paper we will try and find these general applications that can prevail through the use of quantum technology.

B.1.2 Topics

- Security implications with the rise of quantum computing
- Efficiently exploring mainframe data using quantum computing
- Advantages and disadvantages of combining classical computing with quantum

computing

- Building quantum software before the creation of the hardware

B.2 State-of-the-art

B.2.1 Prior knowledge

Inside the paper a couple of physics associated terms will be utilised. If you are not familiar with basic quantum physics notations, it would be highly recommended to read one or both of the following papers, **Rieffel1998** or **Shor2000**. For the general quantum notation that are used throughout the field, we refer towards **Dirac1939**. It is also possible to read this paper as an informational piece without the implications of the mathematics and physics surrounding the subject. As previously stated the paper will not be going in depth technologically, because the scope is more focused on exposing the practical usages of quantum computing compared to classical computing or the combination of both.

B.2.2 Recent developments

As of now Google has claimed to have won the *Quantum Supremacy race* (**Google2019**) against IBM. They have realised this through the creation of their 54-Qubit quantum computer (53 functional qubits), that is able to perform a calculation exponentially faster than an classical system could ever hope to perform. In this case the *Sycamore* (Quantum processor) was able to perform a calculation within 200 seconds that could only be performed by a classical computer over 10.000 years. Although it most definitely was an experimental calculation that has no real value in the business world, it does prove the potential of quantum computing. IBM, Google's main rival in quantum computing, has expressed concerns regarding the claim of Google that the task would take 10.000 years on a classical machine. Despite this, Google has still achieved the status of releasing the first paper proving the viability of quantum computing in the real world. It has been rumoured that IBM will release its counterpart of its research in 2020. The fact that these 2 conglomerates are competing so fiercely will only further the technological developments in the realm of quantum mechanics. IBM has not been sitting idly either they have released algorithms applications with quantum. (**IBM2019**)

B.3 Methodology

While the field of practical quantum computing is still in its infancy, there are a lot of different angles to approach the subject with. First of all we will be introducing the guiding principles of quantum computing, as to all start on the same footing. Then we will explore the realistic potential that quantum computing can offer for economic gain. This will mainly be comprised by an extensive literature study that will set its focus mainly on economic applications of quantum computation. Finally there will be a demonstration of

quantum computation software development through the use of the open-source framework called Qiskit. (**Qiskit**) Qiskit is an IBM Python framework that allows its users to simulate quantum circuits to build software, but what makes it really interesting is the fact that IBM allows its users to effectively perform these quantum circuits on existing quantum computers! (with limited qubits)

B.4 Expected results

As to be expected with every new field of study, this one will not be different. Meaning that there will be a lot of diverse opinions throughout the literature. Having this fierce arguments between papers only helps the subject further, because it challenges everyone to be critical of all the source material. The paper will create a more concrete point of view on the possible features quantum computation can offer. As said before, if we are able to create these business opportunities general interest will only increase. And with the demonstration of quantum computation we are hoping that readers are going to be inspired to be creative with the new technology and start developing their first 'Hello World' with Qiskit.

B.5 Expected conclusions

We are expecting to *debunk* the more absurd ideas of quantum computing. (e.g. destroying all our encryptions and our society) Also with software being so readily available for the general public, we expect that quantum computing applications will be created exponentially faster than with the dawn of classical computing 70 years ago. With this train of thought, we are hoping that real economical value can be available within the next decade. Frameworks like Qiskit will be developed further and more powerful quantum computers will be made available towards the public to boost the research in the subject.