Universiteit Leiden

# Master Computer Science

Title :Discovering quantum communication strategies with multi-agent reinforcement learning


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Master's Thesis in Computer Science


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# Abstract

Communication channel systems are easy to use; however, they are vulnerable to attacks by a third person. The third person can easily penetrate the channel and read or manipulate messages before reaching the receiver from the sender. For this purpose a number of protocols are recommended that can secure the communication between the two parties. Nowadays, quantum computing has been shown to get benefit from such scenarios and introduces protocols that can encrypt and decrypt a message. One of those protocols is the protocol of Bemett and Brassard. The purpose of this Master thesis is to present a simulation of a quantum communication channel using reinforcement learning algorithms. In more details it describes in details how the sender and the receiver exchange messages and how they verify the security of the channel with a secret key.

The main goal of this Master thesis is to simulate a Quantum key distribution process using artificial intelligence environment. In each episode the two agents are using a communication channel. The first agent reads a message and then sends it to second agent , the receiver verify the message correctness. In case the message has been transferred successful, the episode ends with the maximum reward in the other cases the reward is negative.

A number of reinforcement learning algorithms are implemented during the Master thesis project. Namely a Q-learning, deep q learning approach that solves artificial environment with optimal solutions. As a result the agent performs that actions that is required to communicate with each other avoiding any mistakes.

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# Chapter 1

# Introduction

The current project has as a main goal to simulate an artificial environment of quantum key distribution. The process that describes an communication between two artificial agents that takes place in a quantum channel. For reasons of security the channel uses a protocol that encrypts and decrypts the messages with some error. Next the sender and the receiver communicate with a classical to channel to compare the message and to evaluate the protocol keys. The quantum channel use quantum gates as key that produces a small amount of error.
In the artificial environment each of the two agent can make at least ten actions until the episode to finish and the communication to end. In case each of the agents make the require actions the episode finish earlier and gives a positive reward to the agent. The communication channel generates a message that the sender with read it, next will send it to receiver that he will compare both message and save the key.
To solve the environment it is a proposed reinforcement learning algorithms. Algorithms can explore the environment until to find an optimal solution playing a large number of episodes.
The project concentrate on the following research question:
Does the reinforcement learning environment simulate a Quantum key distribution?
Is the communication of a quantum channel that implements the BB84 protocol secure?
Is the protocol efficient?
To sum the project deploys an artificial environment that represents as states the encryption/decryption between messages of two parties. The implementation of a software that takes as an input a plain text(cipher-text) encrypts the message and decrypts it. The implementation includes the quantum polarization base of each bit. An error analysis and the parameters that have been used during the simulation such as the bistream length, error correction, number of iterations will determine the key quality.

# Chapter 2

# Background

## 2.1 Example

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