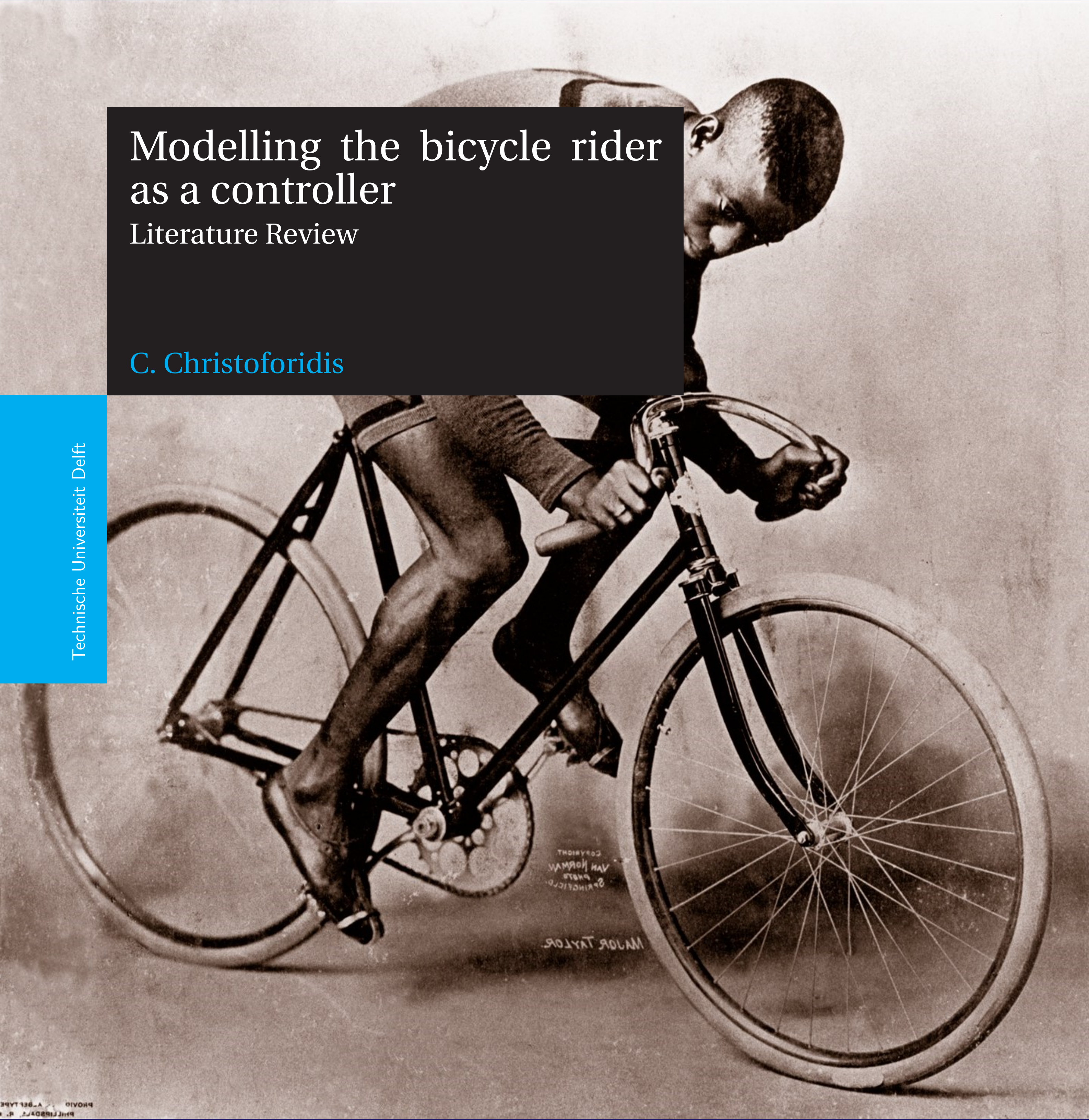

Modelling the bicycle rider as a controller

Literature Review

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Challenge the future

MODELLING THE BICYCLE RIDER AS A CONTROLLER

LITERATURE REVIEW

by

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ABSTRACT

Bicycle riding is a fundamental part of everyday transportation in many countries around the world. Ever since the development of the safety bicycle, the bicycle remains one of the most prominent means of transport. Despite cycling's prominence in every day life for almost two centuries we still do not fully understand how the rider controls the bike in a more systematic way.

The purpose of this literature study is to explore and evaluate models of the single track vehicle rider found in the researched bibliography. Firstly a brief analysis of bicycle stability and its dynamics is presented as explored by Meijaard et al.[8]. In Chapter 3models which were classified on their control theory approach are presented. In section **??**, models using the classical control approach are described. Following the steps of early cybernetics research in which airplane pilot modelling was pioneered by McRuer[5–7], a plethora of authors attempted adapting McRuers crossover model in order to model the rider of a seemingly much more complex task, motorcycle and bicycle riding. However some argued that such an approach will not work since cycling is not just a compensatory task. These spawned a new wave of research focusing in optimal control which is described in section **??**. This approach has its roots in early motor control research in which the human brain is believed to work as a constrained optimal controller. In the final section of Chapter 3, all models that do not fall under the two approaches described above are reviewed. These include fuzzy logic controllers which have the advantage of incorporating heuristic findings that are impossible to formulate using systematic mathematical approaches. Also intermittent control is briefly explored as a solution.

Based on this literature review the graduation project will try to model the human controller for bicycles, while focusing on the roll stabilization task. Open road experiments will be conducted in effort to estimate the controller's parameters and indirectly validate it with real cycling data.

C. Christoforidis
Delft, April 2018

CONTENTS

1
INTRODUCTION

Bicycle riding is a fundamental part of everyday transportation in many countries around the world. Ever since the development of the safety bicycle(two equal sized wheels, pneumatic tires, chain drive, rear wheel propulsion and a bent front fork), almost 130 years ago, the bicycle remains one of the most prominent means of transport [3]. With the growing concerns of sedentary lifestyles many choose the bicycle as their primary commute vehicle with the hopes of maintaining some levels of fitness. Additionally the bicycle is the preferred means of physical exercise for the elderly especially in the Netherlands and Denmark. Despite the fact that riding a bicycle is one of the first skills we acquire as kids and is used throughout the adult life, the fundamental way humans control the bicycle and ,generally single track vehicles, is yet to be understood.

In a recent study examining the entries of patients to the emergency department due to traffic related accidents in the Netherlands (see Fig. 1.1), it was found that bicycle related accidents were the most prevalent. With over 60,000 reported cases bicycle accidents outnumber automobile accidents more than 4 to 1. It therefore becomes clear that a lot could be done to improve cycling safety. Further look at the figure will reveal that most of those accidents did not involve a second party. There was just a rider that fell off his bike. Although there are several potential reasons that riders lose control of the bicycle, formulating a general model of how humans control single track vehicles could prove invaluable in understanding the causes behind the above numbers.

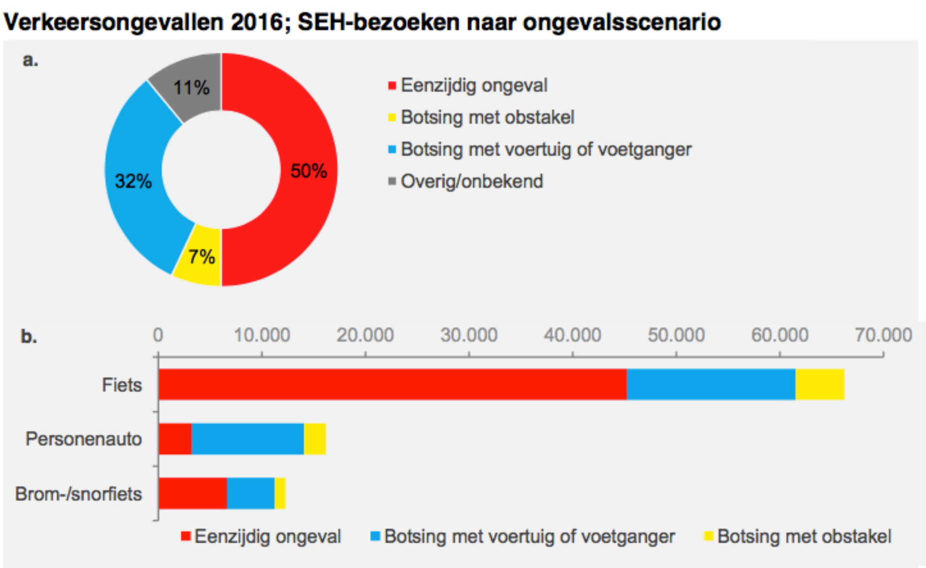

Figure 1.1: The number of road users that visit the emergency department at a hospital after a traffic accident in the Netherlands in 2016. Red indicates single vehicle accidents, yellow indicates a collision with an obstacle, blue indicates multi-vehicle accident and grey indicates other type of accidents[4].

Every human-machine system requires an understanding of how the plant operates. In the case of the bicycle multiple efforts have been made in capturing the dynamics of the bicycle and its self-stabilizing behavior. These have resulted in a set of linearized equations of motion, now commonly referred to as the Whipple Carvalho model [8], which is going to be discussed further in chapter 3.

As it is known single track vehicles are not stable at low speeds. This is why a controller (like the human rider) is required to close the loop and create a stable system. There are two ways with which the human affects the dynamics of the plant. The first is with its passive interactions with the plant as a physical multi-body system. Most passive models model the rider as a point mass rigidly attached to the rear frame, or as a pendulum connected to the rear frame [1], although recent efforts have been made to extend this further with more complex passive rider models which include modeling of neuromuscular dynamics with spring-damper systems at various interfaces between rider and the bicycle frame[2]. The second is with its active control behavior. This involves the active control motion, such as steering, leaning or pedaling, applied by the rider to control and balance the bicycle. In most such cases, the passive behavior of the rider is simplified by only accounting for a fixed mass on the seat post, but when lean torque needs to be examined more complex modeling is required. The focus of the study is to explore the available models that best express the human rider as a controller in the bicycle-rider closed loop system.

The literature review presented herein gives an overview of research done in the field of active rider modelling concerning single-track vehicles, while discussing with which methods and to what extent have these models been validated. This extensive overview is given in section **??** of chapter 3, which is structured in three sections: **??** Classical control system design, **??** Optimal control system design and **??** Other control system design. Chapter 4 concludes on the results from Chapter 3 having as a final goal to answer the research question:

- **What is the controller that best simulates the behavior of the human in the control of single track vehicles?**

2

METHODS

3

RESULTS

4

CONCLUSIONS

Bibliography

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