



Mobile Robot Self-Driving Through Image Classification Using Discriminative Learning of Sum-Product Networks

Undergraduate Thesis

Student: Renato Lui Geh

Advisor: Prof. Denis Deratani Mauá

**INSTITUTE OF MATHEMATICS AND STATISTICS
UNIVERSITY OF SÃO PAULO**

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Abstract

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Driving has proven to be a very difficult task for machines to emulate, not only due to the inherent complexity of the problem but also because of the need for accurate real-time predictions. Nonetheless, recent advances in computer vision and machine learning have shown promising results in the real-world. Mobile robots are low-cost miniature computers with limited processing power and memory. The problem of self-driving can be similarly applied to the mobile robot domain as a down-scaled version of the same task, with an additional hardware constraint. Sum-product networks are probabilistic graphical models capable of representing tractable probability distributions containing a great number of variables. Exact inference is asymptotically linear to the number of edges in the network's graph, and its deep architecture is capable of representing a wide range of distributions. In this work, we attempt to model autonomous driving by using sum-product networks on a small mobile robot. We model this task as an imitation learning problem through image classification. We present accuracy results on an artificial self-driving dataset for different sum-product network learning algorithms, providing a comparative study not only for different network architectures, but also discriminative and generative models. Finally, we provide a real-world mobile robot implementation on a miniature computer.

Keywords: sum-product networks, probabilistic graphical models, machine learning, robotics

Abbreviations

DAG	Directed acyclic graph
EM	Expectation-maximization
GD	Gradient descent
IV	Indicator variable
MAP	Maximum a posteriori probability
MPE	Most probable explanation
MPN	Max-product network
PGM	Probabilistic graphical model
RV	Random variable
SGD	Stochastic gradient descent
SPN	Sum-product network
SPT	Sum-product tree

Symbols

μ	Gaussian distribution mean
σ	Gaussian distribution standard deviation

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Chapter 1

Introduction

In this chapter we first describe the motivations and objectives of this thesis. Next, we describe the structure of this document.

1.1 Motivation and objectives

Self-driving is a challenging computer vision task, mainly due to its inherent complexity and the necessity for real-time decision making. Although there have been many promising results the past few years on autonomous driving, the task still relies on the underlying problem of following a pathway through visual cues (usually road markings). A possible approach to this task is through imitation learning by means of image classification. That is, the agent tasked with driving should be able to reliably mimic human behavior by correctly classifying whether to turn, stop or go straight given an image captured in front of the car.

Mobile robots are low cost machines capable of movement. These robots are usually small, and because of their size and cost, often don't have the same performance capabilities as a desktop computer. However, these domain traits make mobile robot self-driving a very similar analogue to real-world autonomous cars. Processing power and memory constraints play a big role in this case, and translate well to embedded systems present in a self-driving car.

Sum-product networks (SPNs) are probabilistic graphical models that are able to represent a wide range of tractable probability distributions of many variables. SPNs have shown impressive results in several domains, and particularly that of image classification. Their deep architecture seems to capture features and contexts well, and since inference is computed in time linear to the network's edges, SPNs are promising models for fast inference in self-driving.

In this work, we attempt to model self-driving of mobile robots through image classification. For the task of classification our objective is to use sum-product networks learned discriminatively, though we also give results for generative SPNs, comparing not only generative and discriminative learning, but also different SPN architectures.

1.2 Thesis structure

This thesis is structured as follows. In [chapter 2](#), we first provide background on sum-product networks, where we formally define an SPN, present key properties on their structure, explain how to compute exact inference and find an approximation of the maximum a posteriori probability (MAP).

In ??, we show how to compute the partial derivatives with respect to a sub-SPN and to its weights, leading on how to perform gradient descent and then on learning the weights of the network through gradient descent both generatively and discriminatively.

?? is dedicated to algorithms for learning the structure of an SPN. We explain the two structural learning algorithms that were used in the experiments.

For ??, we first show how we model self-driving as an image classification problem. We then specify the architecture of the robot used in the experiments, giving specifications on the hardware and software used. Furthermore, we describe some concepts of control we use for navigation.

In ??, we provide classification results on many image classification datasets from various domains with different learning algorithms. We then describe the self-driving dataset used for training, and give in-dataset accuracies as well as real-world empirical results on the mobile robot itself.

Finally, in ?? we give our conclusions and provide some discussion of the results.

There is an additional section of this thesis in which we give a brief subjective insight on the work done for this thesis. We also list subjects we deemed important for the work done in this thesis.

Furthermore, ?? contains all proofs done in this thesis.

Chapter 2

Sum-product networks

Hello

