Undergraduate Thesis

CurbNet: Semantic segmentation of curbs and curb cuts from street imagery

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July 22nd, 2019

Writing Period

04. 20. 2019 – 07. 22. 2019

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Declaration

I hereby declare, that I am the sole author and composer of my thesis and that no other sources or learning aids, other than those listed, have been used. Furthermore, I declare that I have acknowledged the work of others by providing detailed references of said work.
I also hereby declare, that my thesis has not been prepared for another examination or assignment, either in its entirety or excerpts thereof.

Place, Date

Signature

Abstract

(TODO: Write this.)

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1 Introduction

Semantic scene segmentation is a popular research topic in the field of computer vision, and especially important for autonomous vehicles. The ability to semantically understand a scene is especially important for autonomous vehicles and robots to safely navigate an environment. Generally, most implementations attempt to segment road surfaces but in this thesis, we propose the segmentation of curbs and curb cuts to allow safer sidewalk navigation.

The Europa project has resulted in the Obelix robotic platform, which has already been demoed to successfully perform pedestrian navigation [1][2]. We propose to add to this platform the ability to detect curbs and curb cuts using semantic segmentation. The Obelix platform is **(TODO: Add short description)**.

(TODO: Full description of what obelix is not capable of doing yet.)

Our goal is thus to implement a computer vision algorithm capable of the semantic segmentation of curbs and curb cuts using a single camera image. To do so, we will implement a convolutional neural network with a traditional encoder-decoder architecture. We will also include prior knowledge to the training, since we can assume that the camera setup for the Obelix robot will remain relatively similar throughout its lifespan.

We will begin by discussing the motivation behind this thesis, followed by a disucssion of related works and the background. Then the approach will be discussed in detail along with the experiments and results. Finally, a discussion of potential future research will be presented followed by the conclusion.

1.1 Motivation

(TODO: Do this.)

2 Related Work

There are many works in the field of semantic segmentation in recent years, both discussing object scene segmentation and road segmentation. The field of semantic segmentation using trainable neural network models started in 1989 with the work of Eckhorn et al. and their paper describing how the visual cortex of a cat functions and its implications for network models [3]. This early method used a pulse coupled neural network, which produced synchronous bursts of pulses, effectively grouping the neurons by phase and pulse frequency, which can then be analyzed for feature extraction. In recent years, models using convolutional neural networks have become more common.

3 Background

Explain the math and notation.

$$\text{a} \longrightarrow \text{b}$$

Figure 1: Use tikz to draw nice graphs!

Algorithm 1 Stochastic Gradient Descent: Neural Network

Create a mini batch of m samples $\mathbf{x}_0 \dots \mathbf{x}_{m-1}$
foreach sample $\mathbf{x}$ **do**
    $\mathbf{a}^{\mathbf{x},0} \leftarrow \mathbf{x}$ $\triangleright$ Set input activation
    foreach Layer $l \in \{1 \dots L-1\}$ **do** $\triangleright$ Forward pass
        $\mathbf{z}^{\mathbf{x},l} \leftarrow \mathbf{W}^l \mathbf{a}^{\mathbf{x},l-1} + \mathbf{b}^l$
        $\mathbf{a}^{\mathbf{x},l} \leftarrow \varphi(\mathbf{z}^{\mathbf{x},l})$
    end for
    $\boldsymbol{\delta}^{\mathbf{x},L} \leftarrow \nabla_{\mathbf{a}} C_{\mathbf{x}} \odot \varphi'(\mathbf{z}^{\mathbf{x},L})$ $\triangleright$ Compute error
    foreach Layer $l \in L-1, L-2 \dots 2$ **do** $\triangleright$ Backpropagate error
        $\boldsymbol{\delta}^{\mathbf{x},l} \leftarrow ((\mathbf{W}^{l+1})^T \boldsymbol{\delta}^{\mathbf{x},l+1}) \odot \varphi'(\mathbf{z}^{\mathbf{x},l})$
    end for
end for
foreach $l \in L, L-1 \dots 2$ **do** $\triangleright$ $\triangleright$ Gradient descent
    $\mathbf{W}^l \leftarrow \mathbf{W}^l - \frac{\eta}{m} \sum_{\mathbf{x}} \boldsymbol{\delta}^{\mathbf{x},l} (\mathbf{a}^{\mathbf{x},l-1})^T$
    $\mathbf{b}^l \leftarrow \mathbf{b}^l - \frac{\eta}{m} \sum_{\mathbf{x}} \boldsymbol{\delta}^{\mathbf{x},l}$
end for

---

4 Approach

The approach usually starts with the problem definition and continues with what you have done. Try to give an intuition first and describe everything with words and then be more formal like ‘Let g be ...’.

4.1 Problem Definition

Start with a very short motivation why this is important. Then, as stated above, describe the problem with words before getting formal.

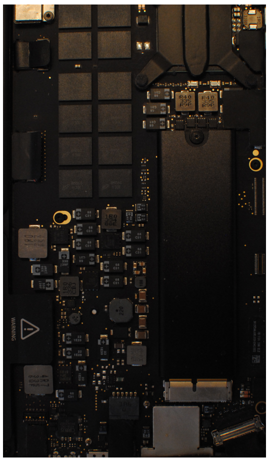
4.2 First Part of the Approach

4.3 N-th Part of the Approach

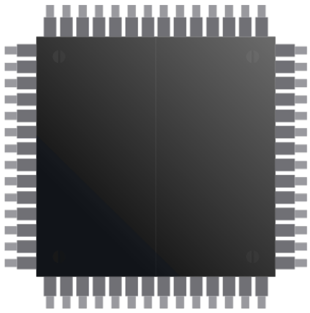
5 Experiments

Type	Accuracy
A	82.47 ± 3.21
B	78.47 ± 2.43
C	84.30 ± 2.35
D	86.81 ± 3.01

Table 1: Table caption. foo bar...



(a) Some cool graphic



(b) Some cool related graphic

Figure 2: Caption that appears under the fig Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, nonummy eget, consectetuer id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.

6 Conclusion

7 Acknowledgments

First and foremost, I would like to thank...

- advisers
- examiner
- person1 for the dataset
- person2 for the great suggestion
- proofreaders

Bibliography

[1] "The european pedestrian assistant."

[2] R. Kümmerle, M. Ruhnke, B. Steder, C. Stachniss, and W. Burgard, "A navigation system for robots operating in crowded environments," in *2013 IEEE International Conference on Robotics and Automation*, IEEE, May 2013.

[3] R. Eckhorn, H. J. Reitboeck, M. Arndt, and P. Dicke, "Feature linking via stimulus - evoked oscillations: Experimental results from cat visual cortex and functional implications from a network model," in *International 1989 Joint Conference on Neural Networks*, IEEE, 1989.