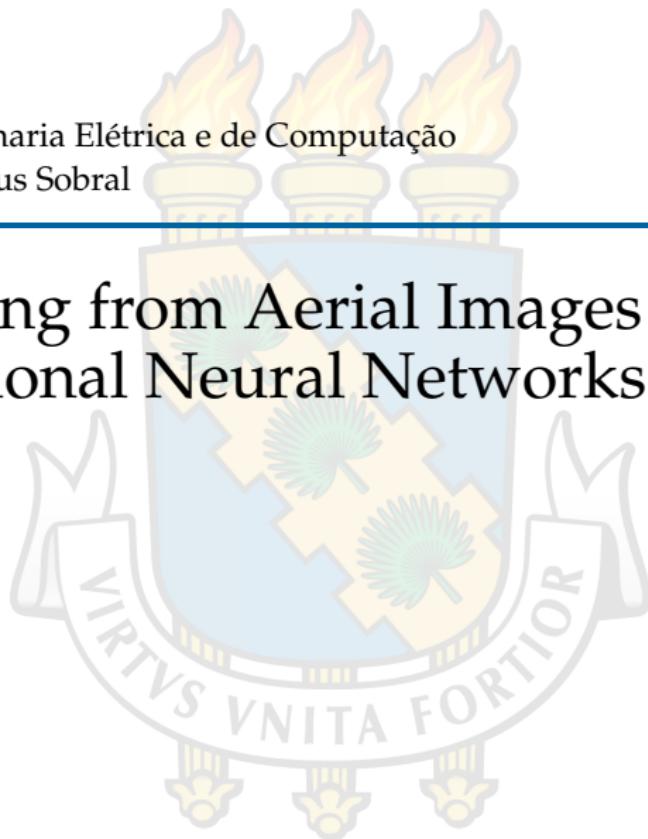


Programa de Pós-Graduação em Engenharia Elétrica e de Computação
Universidade Federal do Ceará – Campus Sobral

Traversability Learning from Aerial Images with Fully Convolutional Neural Networks

David Borges
davidborges@protonmail.com

26 June, 2019



Introduction

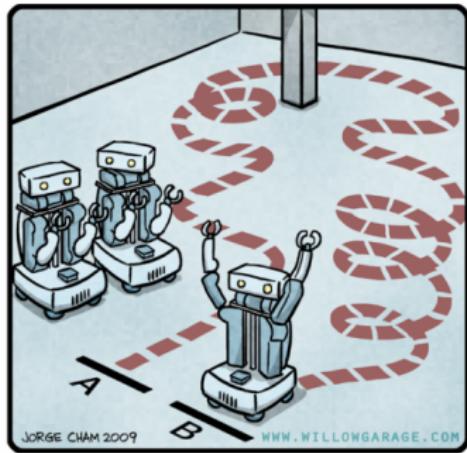
Guide a robot through the environment.

Mapping.

Localization.

Goal recognition.

Path planning.



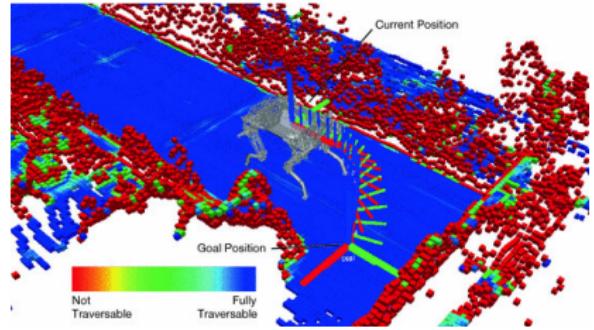
"HIS PATH-PLANNING MAY BE
SUB-OPTIMAL, BUT IT'S GOT FLAIR."

Source: [http://www.willowgarage.com/blog/2009/09/04/
robot-comics-path-planning](http://www.willowgarage.com/blog/2009/09/04/robot-comics-path-planning)

Introduction

Guide a robot through the environment.

**Mapping.
Traversability.**

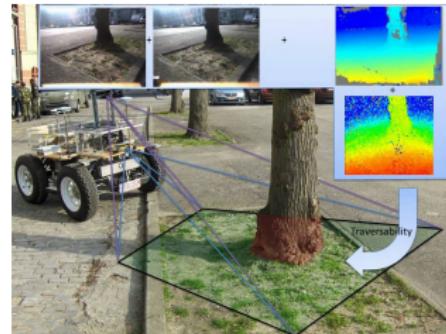


Source: Fankhauser and Hutter (2016)

Introduction

Guide a robot through the environment.

Mapping.
Traversability.
Aerial data.



Source: <https://www.youtube.com/watch?v=CNFc5qPvnB0>



Source: <https://www.directionsmag.com/pressrelease/6225>

Goal

Main goal

Compute traversability maps from aerial data.



Source: Borges et al. (2019)



Source: Borges et al. (2019)

Previous work

Image input



Source: <https://en.wikipedia.org/wiki/Hampshire>

Hudjakov and Tamre (2011)
Hudjakov and Tamre (2013)
Delmerico (2017)
Borges et al. (2019)

Depth input

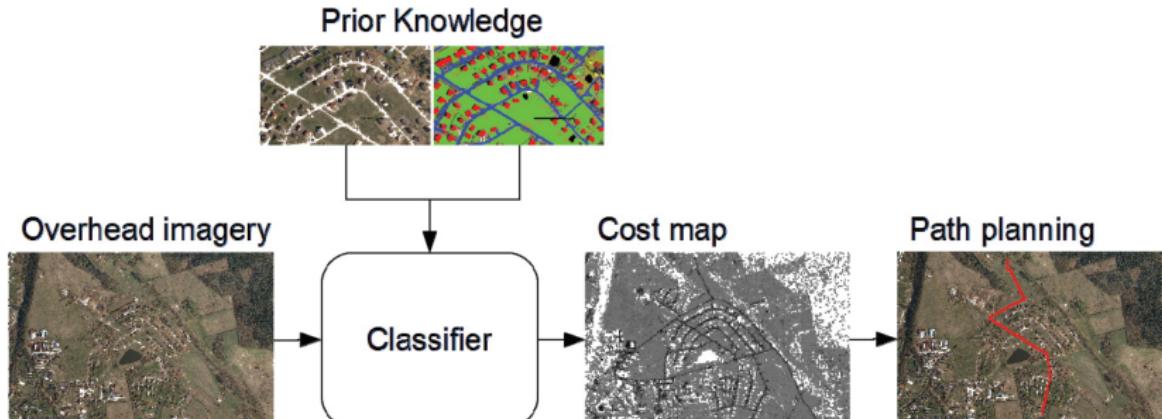


Source: <https://www.directionsmag.com/pressrelease/6225>

Vandapel et al. (2006)
Silver et al. (2006)
Sofman et al. (2006)
Shneier et al. (2008)
Chavez-Garcia et al. (2018)

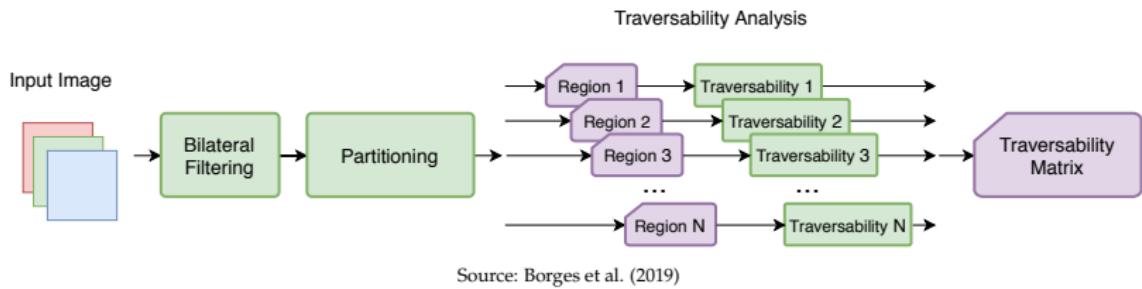
Previous work

Traversability maps from image classification



Previous work

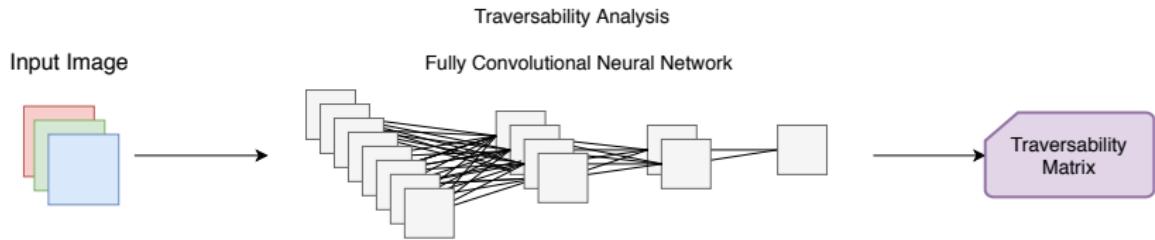
Traversability maps from heuristics



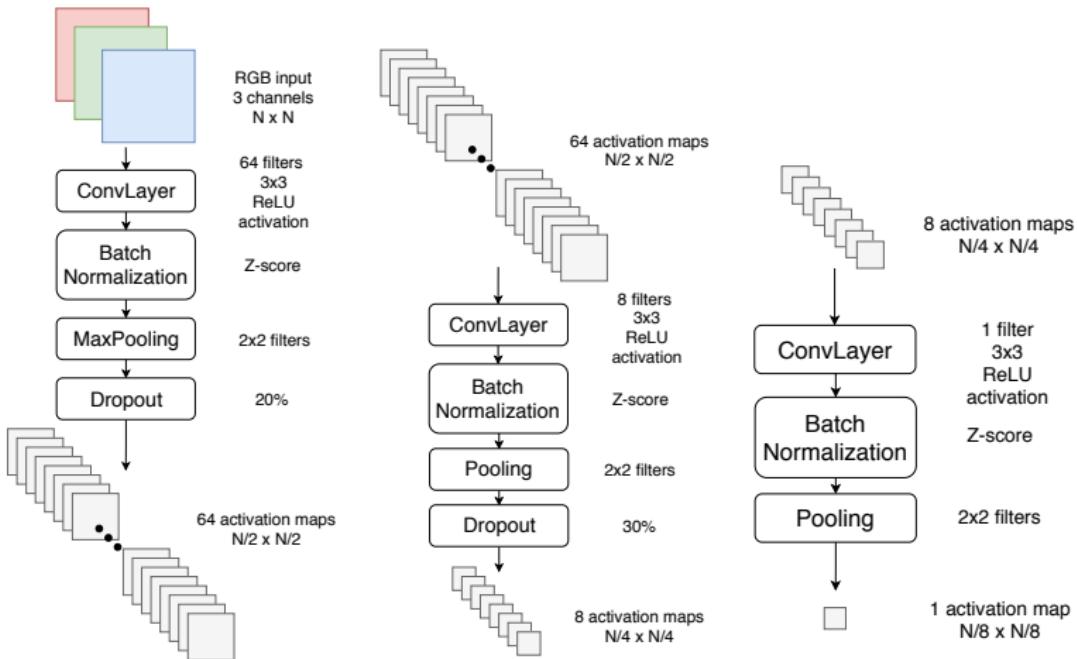
Source: Borges et al. (2019)

Proposal

Traversability maps from fully convolutional neural networks



TFCN architecture



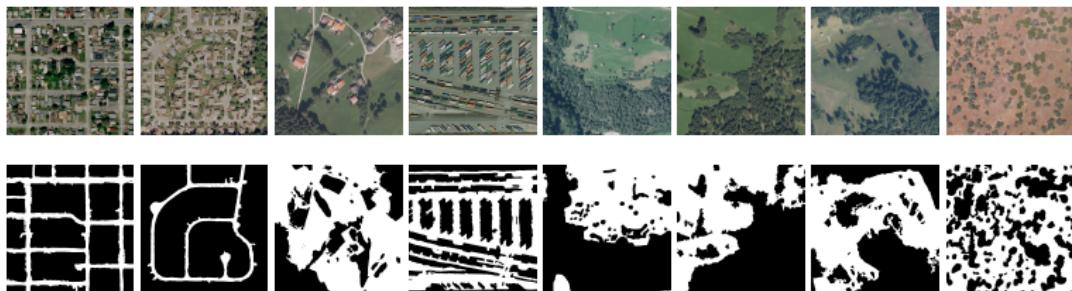
Dataset

ATPD Aerial Traversability and Planning Dataset.

Data 8 aerial images and their traversability labels.

Image size 1000×1000 pixels.

Resolution $0.3\text{ m} \times 0.3\text{ m/p.}$



Source: Borges et al. (2019)

Data augmentation

Rotations Random angles from 0° to 360° .

Shifts Max 30% vertical and horizontal.

Flips Vertical and horizontal.

Shear Max 30° distortion.

Zoom Max 20% amplification.

Training

Optimizer Adam.

Loss function Mean Squared Error.

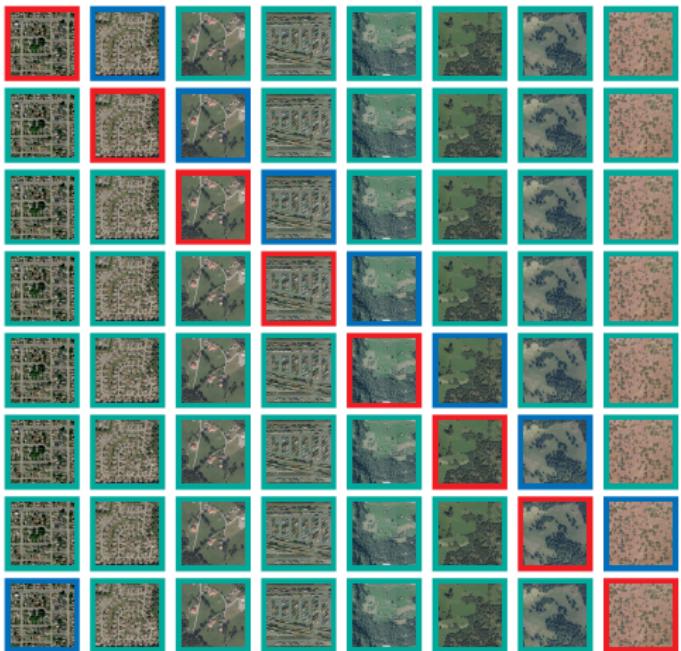
Max epochs 100.

Early stopping if validation loss does not improve after 20 epochs.

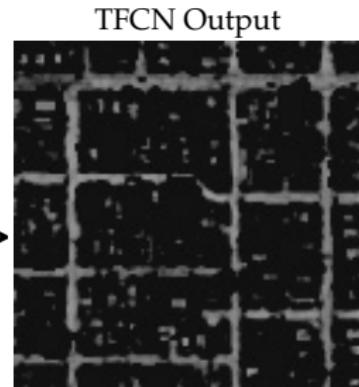
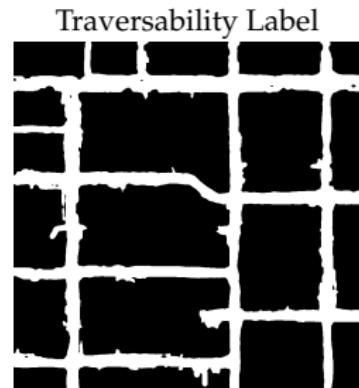
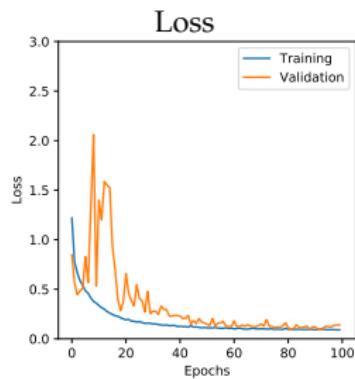
Cross-validation

Leave-one-out

- 1 test image
- 1 validation image
- 6 training images

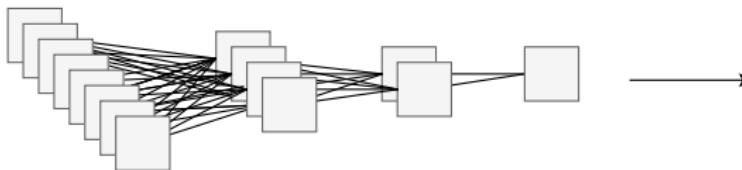


Results

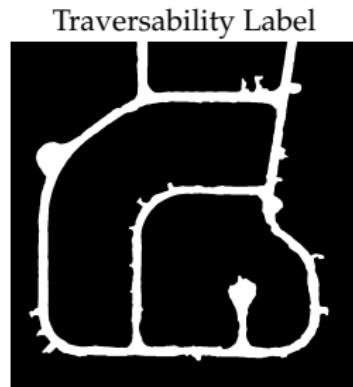
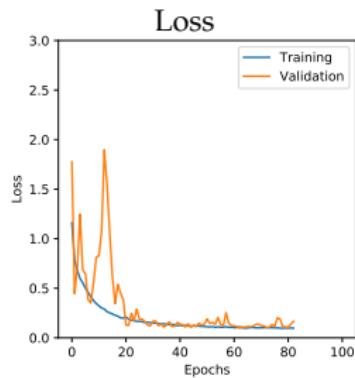


Traversability Analysis

Fully Convolutional Neural Network

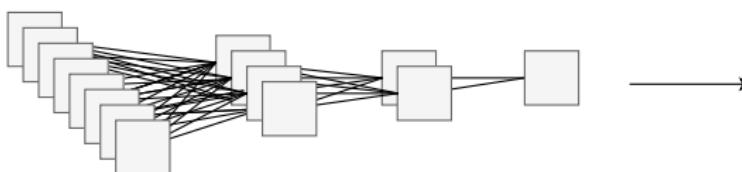


Results

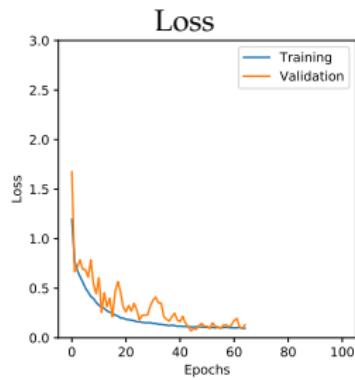


Traversability Analysis

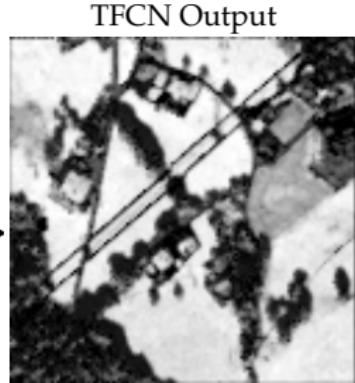
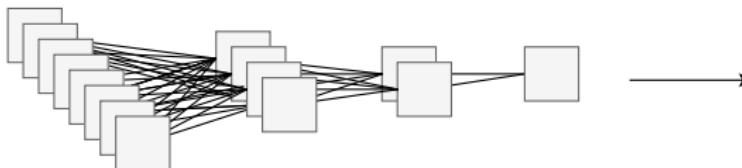
Fully Convolutional Neural Network



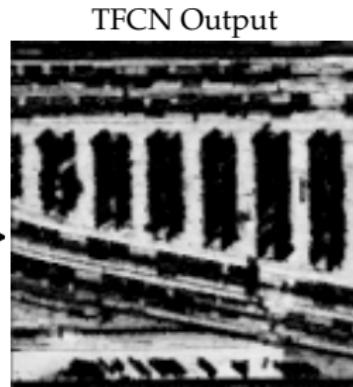
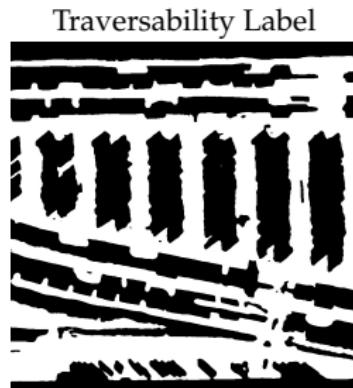
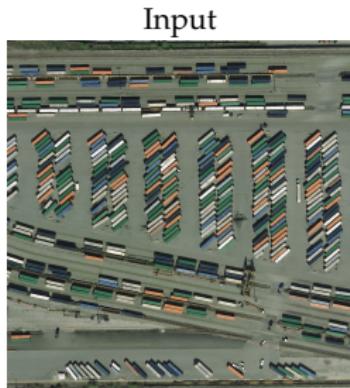
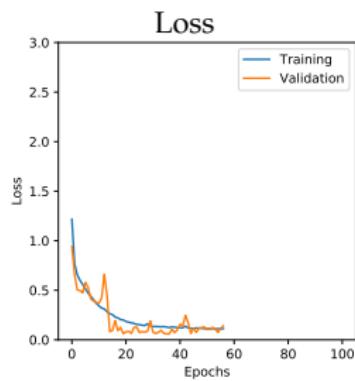
Results



Traversability Analysis
Fully Convolutional Neural Network

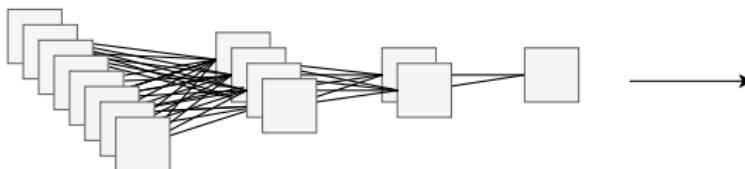


Results

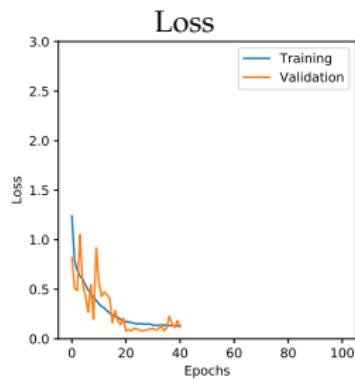


Traversability Analysis

Fully Convolutional Neural Network

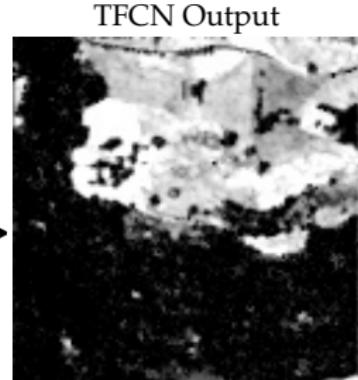
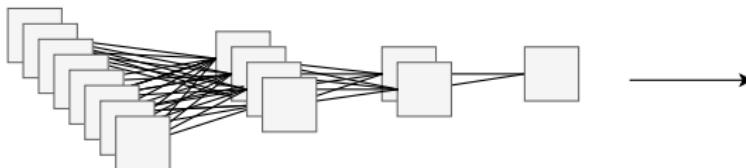


Results

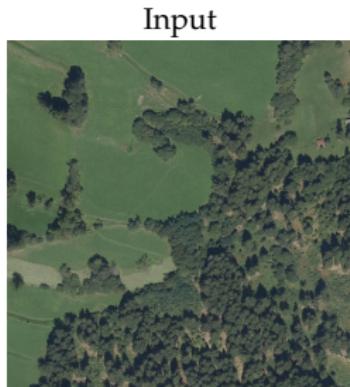
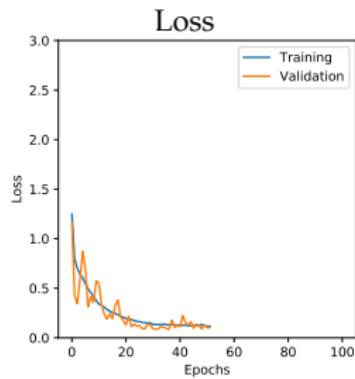


Traversability Analysis

Fully Convolutional Neural Network

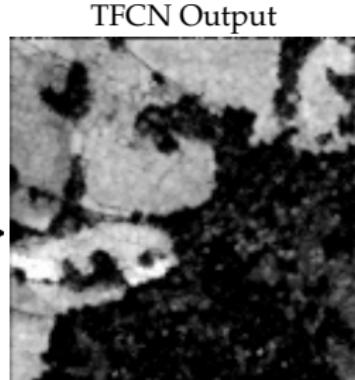
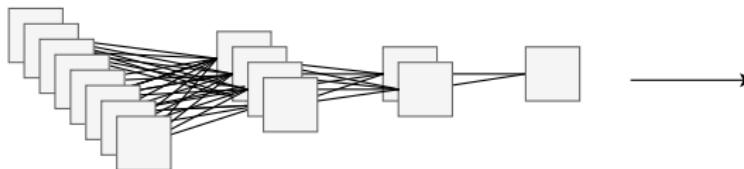


Results

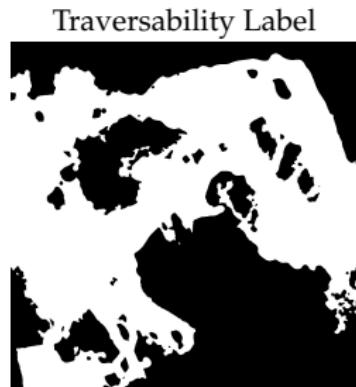
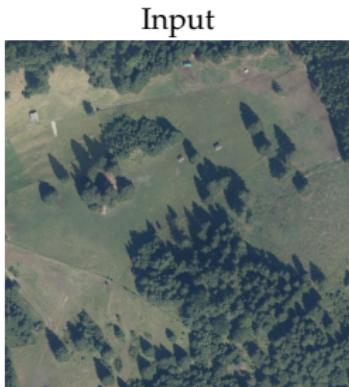
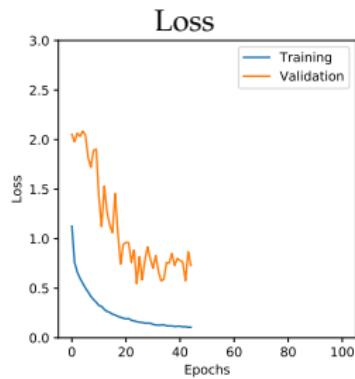


Traversability Analysis

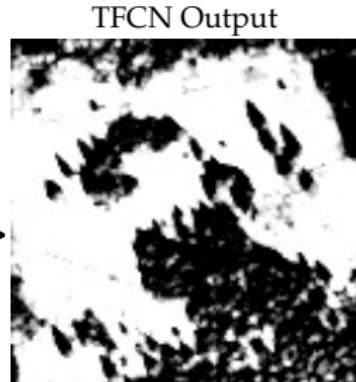
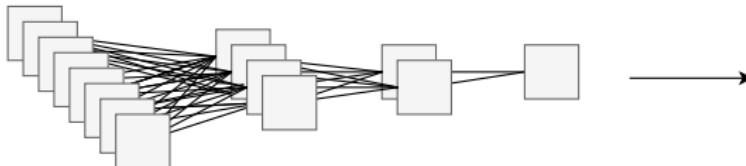
Fully Convolutional Neural Network



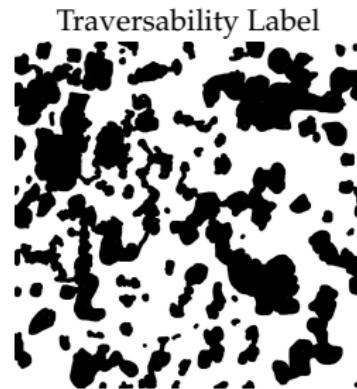
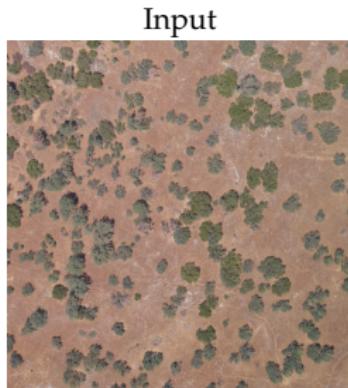
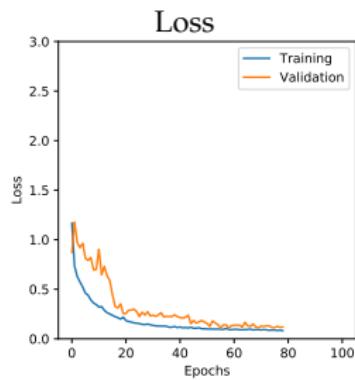
Results



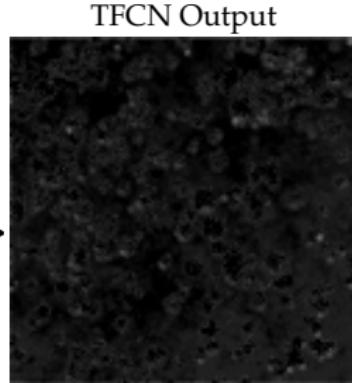
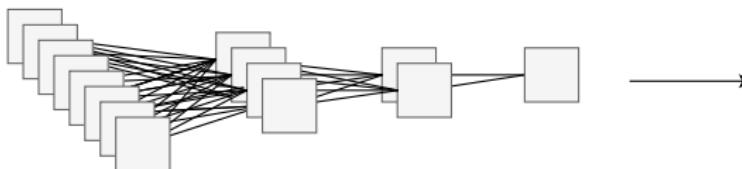
Traversability Analysis
Fully Convolutional Neural Network



Results



Traversability Analysis
Fully Convolutional Neural Network



Results

TABLE I
CROSS-VALIDATION RESULTS

Leave-one-out Step	Total Epochs	Best Epoch	Training Loss	Validation Loss	Test Loss
1	100	93	0.0974	0.0949	0.1265
2	83	63	0.1106	0.0951	0.1199
3	65	45	0.1103	0.0701	0.1161
4	57	37	0.1232	0.0589	0.1011
5	41	23	0.1643	0.0784	0.0712
6	52	32	0.1336	0.0869	0.0820
7	45	25	0.1627	0.5474	0.2302
8	79	59	0.0950	0.1093	0.5137

TABLE II
MSE COMPARISON

Input Image ATPD ID	Borges et al. [11] MSE	TFCN MSE
1	0.1566	0.1245
2	0.2066	0.1177
3	0.1714	0.1137
4	0.1265	0.0986
5	0.1394	0.0688
6	0.1420	0.0796
7	0.1756	0.2279
8	0.1488	0.5114

TABLE III
TIME COMPARISON

Input Image Size	H. & T. [9] Time (s)	Borges et al. [11] Time (s)	TFCN Time (s)
1000 × 1000	1250 ^{b*}	11 ^{c*}	0.834 ^a
2000 × 2000	5000 ^b	44 ^c	3.336 ^{a*}
			2.583 ^a

a. Intel Core i5 650 CPU

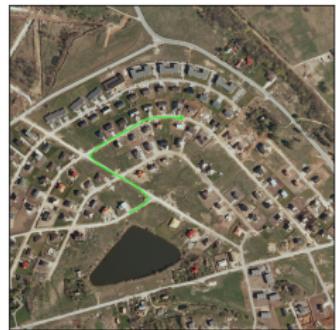
b. Intel Core i7 920 CPU

c. 2x Nvidia GTX 570 GPUs

* Estimate based on number of patterns per image and processing speed

Results

Preview



Questions

