

Street Infrastructure: urban area crosswalks localization via Google satellite imagery using a deep learning model

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Outline

Introduction

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Pedestrian Crosswalk



- ▶ Pedestrian crosswalk plays an important role as urban infrastructure.
- ▶ Pedestrian crosswalk is primarily designed to have a zebra-crossing stripes at the road/intersection.



Typical pedestrian crossings in urban area:

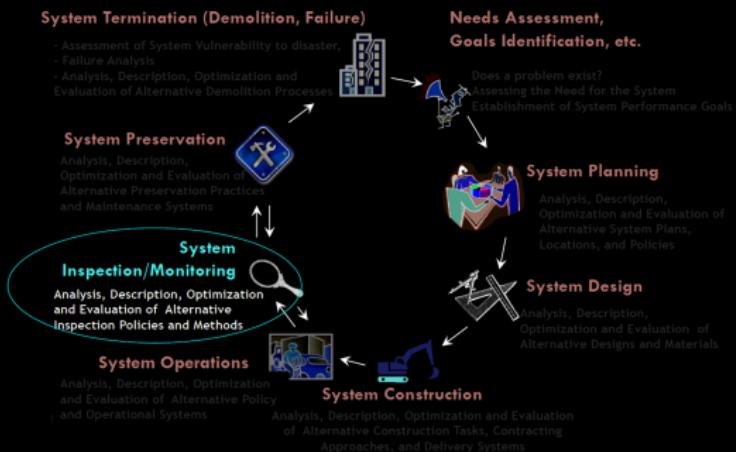
https://en.wikipedia.org/wiki/Zebra_crossing

What is missing?

- ▶ A complete data inventory of crosswalks
 - ▶ The City of Dallas do not provide any data regarding the location of crosswalks.
 - ▶ Collecting crosswalks is time-consuming and not cost-effective.
 - ▶ Interested but no action due to the budget limitation.
- ▶ It becomes interested if crosswalk localization can be automated.
 - ▶ Let the computer do the work ⇒ Save time.
 - ▶ Does not extensively rely on hardware. ⇒ Efficient tool.
 - ▶ Incentive to include crosswalks ⇒ Big picture.

What is in this project?

- ▶ A automatic framework to retrieve street satellite images using Google Map API given street info.
- ▶ A decent crosswalk recognition model.
- ▶ A labeling process to assign crosswalk's geo-coordinates from the model.



CEE 7356 Civil Infrastructure System Course slides

Google Map API



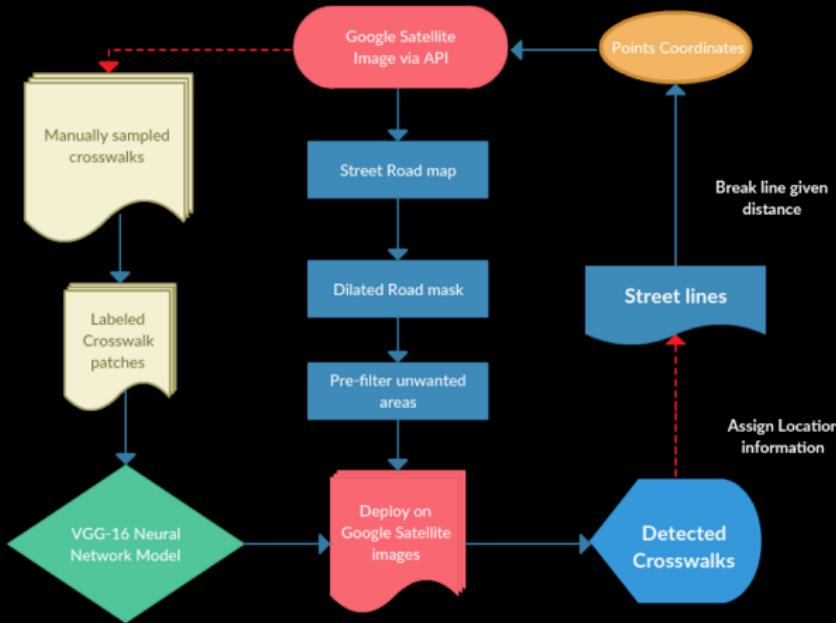
- ▶ Application Program Interface
- ▶ Allows us to communicate with Google via program languages.
 - ▶ Request a web-page.
 - ▶ Download an image (satellite, streetview).
 - ▶ Request a route from place to place.

Overview

Related work

- ▶ Ghilardi et al.[2] developed a support vector machine model(SVM) to detect crosswalks with low resolution Google satellite images.
- ▶ Sun et al.[3] applied two filters to enhance image features and developed a machine learning model to sucessfully detect crosswalks using high resolution satellite imagery.
- ▶ Berriel et al.[1] took the architecture of popular neural network model and showed a deep learning approach to detect crosswalks from streetview image obtained from camera-mounted vehicles.

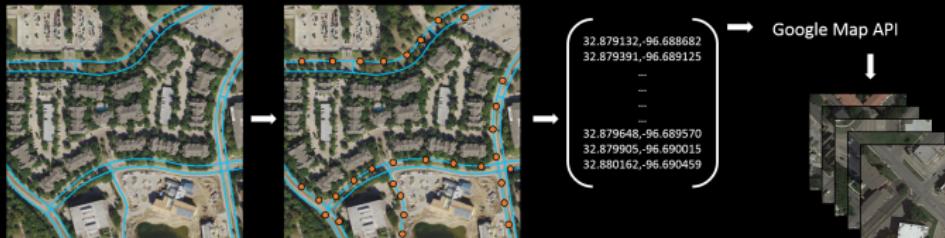
Project Flow Chart



Project workflow. (Starts at Street lines)

Data Acquisition

- ArcGIS street shapefile ⇒ Street locations ⇒ Satellite Images.



Acquiring Satellite images given ArcGIS Shapefile using Google Map API service

Image Processing Intro in 1 minute

Image Representation

- need a compact representation

- grayscale

$$0.3*R + 0.59*G + 0.11*B,$$

"luminance"

gray

1	4	2	5	6	9
1	4	2	5	5	9
1	4	2	8	8	7
3	4	3	9	9	8
1	0	2	7	7	9
1	4	3	9	8	6
2	4	2	8	7	9

Numpy Matrix

image[rows, cols]

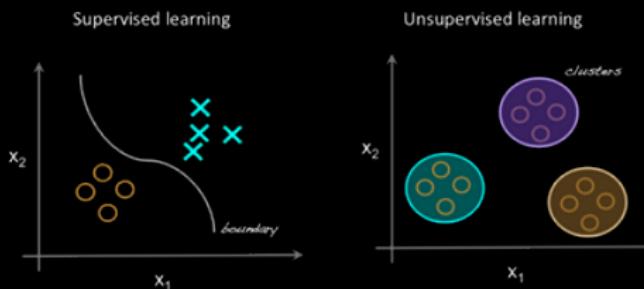
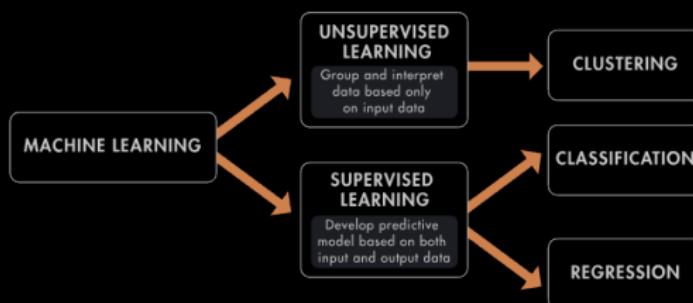
R							
G	1	4	2	5	6	9	
B	1	4	2	5	6	9	9
	1	4	2	5	6	9	7
	1	4	2	5	5	9	7
	1	4	2	8	8	7	8
	3	4	3	9	9	8	9
	1	0	2	7	7	9	6
	1	4	3	9	8	6	9
	2	4	2	8	7	9	

Numpy Matrix

image[rows, cols, channels]

15

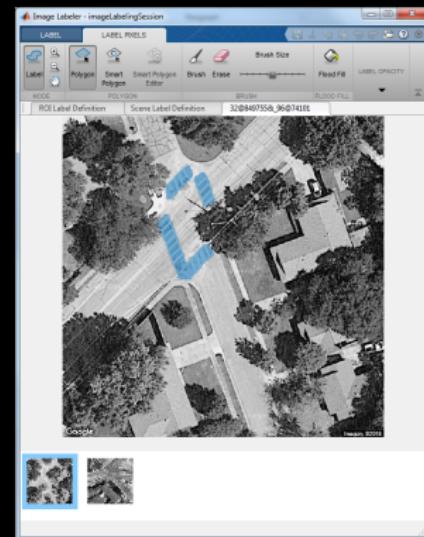
Machine Learning Intro in 1 minute



<https://www.mathworks.com/discovery/machine-learning.html>

Labeling process

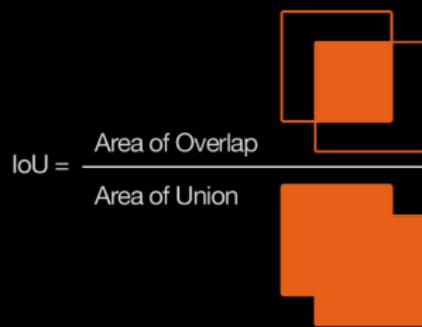
- ▶ To train a crosswalk recognition model:
 - ▶ Manually sample crosswalks satellite images via Google map.
 - ▶ Require large training samples ($\approx 10k$ samples).
 - ▶ Only have ≈ 100 satellite images.
- ▶ Semi-supervised label generating mechanism
 - ▶ Interested in 80x80 (pixels) window
 - ▶ Matlab computer vision Image Labeler



Semi-supervised labels generation

► Intersection over Union (IoU)

- Dividing the area of overlap between the bounding boxes by the area of union



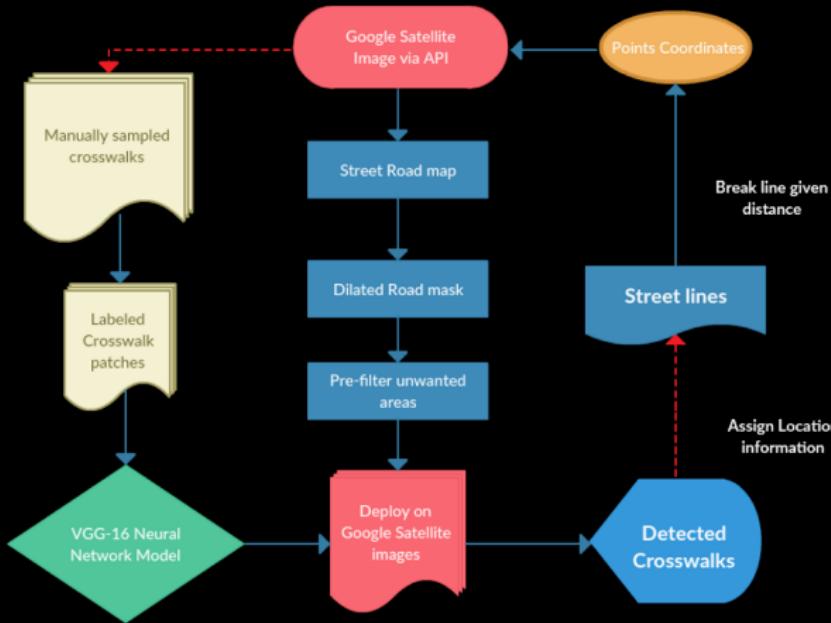
Example Labels

≈ 5000 True Label samples



≈ 5000 False Label samples

Project Flow Chart recap



Project workflow. (Starts at Street lines)

Imagery Preprocess

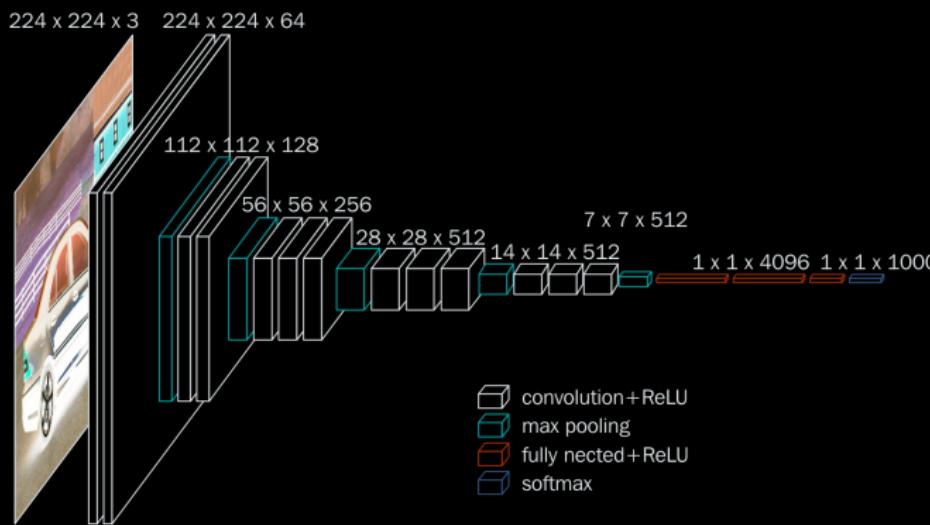
- ▶ The usage of street roadmap mask.
- ▶ To reduce computational cost.



Satellite image \Rightarrow Roadmap \Rightarrow Roadmask \Rightarrow Dilated roadmask \Rightarrow Masked streets

Street segments extraction process

VGG16 Pre-Trained Model



VGG-16 structure

<https://www.oreilly.com/library/view/machine-learning-with/9781786462961/21266fa5-9e3b-43d6-8f8c-2ca27a8f8c12.xhtml>



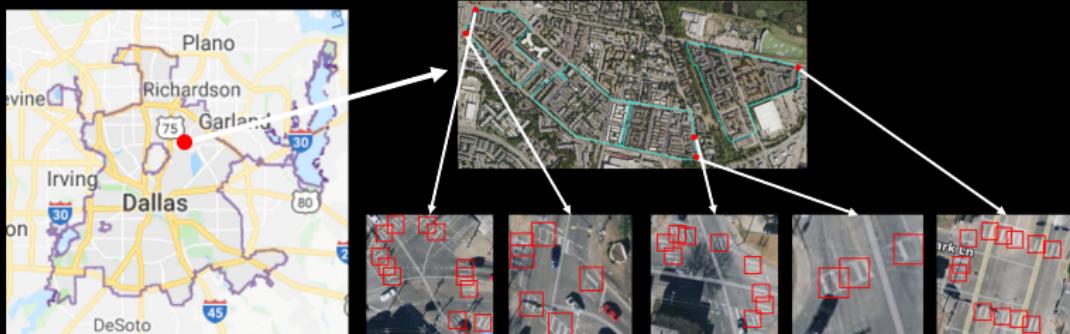
SMU

Deep Learning Model

- ▶ **VGG-16**: A very popular & powerful neural network model.
 - ▶ Consists 16 layers
 - ▶ Won ImageNet competition.
- ▶ Model input: **80x80** pixels image patch
- ▶ Model training & testing: **10k patches** (1:1) & **1k unseen patches**.
- ▶ Model output: Binary response {**Crosswalk, Not crosswalk**}

Preliminary Results

- ▶ Apply the framework to a local neighborhood - Vickery Meadow.



Recognized crosswalks in Vickery Meadow: 16/17 crosswalks detected.
5/5 crosswalk road intersection detected.

Preliminary Conclusion

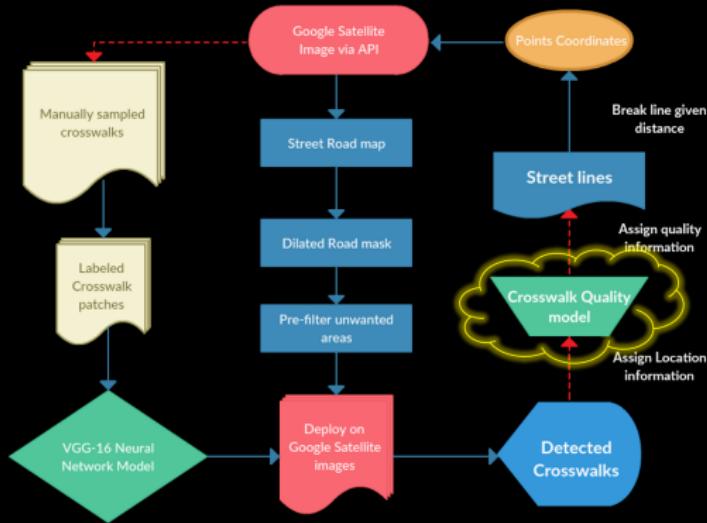
- ▶ The model performs at an acceptable accuracy, therefore it is reliable to extend the current framework to more neighborhoods.

Future Work

- ▶ A citywide crosswalks map.
- ▶ Interested in crosswalks quality (No existing literature!).
 - ▶ How to define crosswalks quality.
 - ▶ How to let computer know.
 - ▶ How to construct training data.

Future Work Cont.

- ▶ Coupled with condition assessment model (if developed).



A complete crosswalks localization and quality assessment framework

Thank you!

References:

-  Rodrigo F Berriel, Franco Schmidt Rossi, Alberto F de Souza, and Thiago Oliveira-Santos.
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