Trash Classification on Water Channels

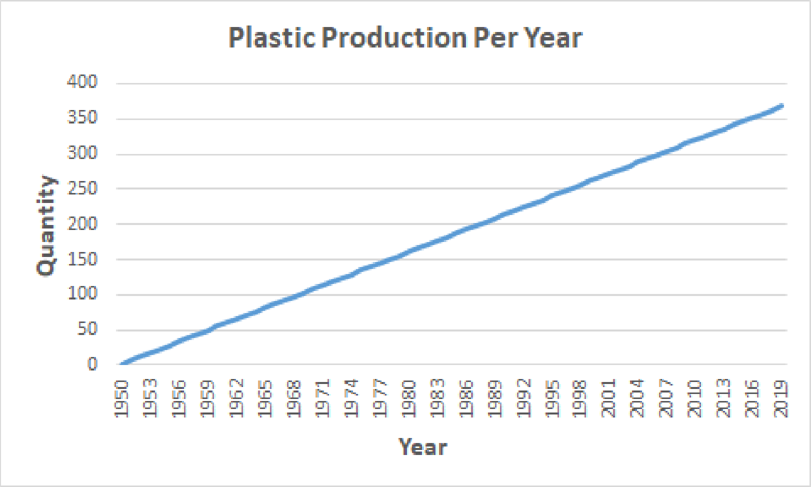
Thesis – MS Computer Science

Abdul Wahab Amin

20030052

Motivation

- 2 million tonnes of plastic produced in 1950
- 368 million tonnes of plastic produced in 2019
- 18,400% increase in plastic production
- 75% plastic ever produced is not recycled
- ~9704 tonnes of plastic



Where does the plastic go?




Sharaqpur
Ghareeb Abad
Umar Di Jhuggi
Dhana
Ravi River
New Cattle Market
Shahpur Kanjra
HOMES
Khanpur KHANPUR
PARK VIEW
TOPAZ BLOCK
RIVER EDGE HOUSING SCHEME
Kot Gujra
KOT GUJRA
EDEN CANAL VILLAS
LAHORE CANAL BANK PHASE 1
BLOCK A
BLOCK B
MUHAFIZ TOWN
SHABBIR TOWN
SHEIKH ZAYED PALACE
TRADE CENTRE
BellBird Health Care
AITCHISON SOCIETY
PCSIR PHASE 2
Manhattan Bites
HIGHCOURT SOCIETY
REVENUE EMPLOYEES COOPERATIVE HOUSING SOCIETY
AL-HAMRA TOWN
ARCHITECTS ENGINEERS HOUSING SOCIETY
IQBAL AVENUE HOUSING SOCIETY
PGECHS
RAHIMABAD
ABPARA HOUSING SOCIETY
AGRICS TOWN
EDEN PALACE VILLAS
BARKATPURA
DHA EME SECTOR
Manowal
MANOWAL
SATLUJ BLOCK
GREEN FORTS 2
Jhok Reserve Forest
NESPAK SOCIETY
WAPDA TOWN
PCSIR STAFF COLONY
NASHEMAN-E-IQBAL HOUSING SOCIETY
Ali Raza Abad
ALI RAZA ABAD
AL JANNAT
PUNJAB UNIVERSITY EMPLOYEES CHS
JUDICIAL HOUSING SOCIETY - PHASE 3
Chung
CHUNG
BARKAT COLONY
IQBAL AVENUE - PHASE 3
FATEH ABAD
OPF HOUSING SCHEME
DREAM VILLAS
PUNJAB GOVERNMENT EMPLOYEES COOPERATIVE HOUSING SOCIETY PHASE 2
TARIQ GARDEN
NFC SOCIETY
EDEN RESIDENCIA
PUBLIC HEALTH SOCIETY
IZMIR
IZMIR EXTENSION
TRICON VILLAGE
PAKH PURA
EDEN LANE VILLAS
DUBAI TOWN
KHARIYAN
COMMERCIAL AREA
COMSATS University Lahore Campus
GREEN ACRES HOUSING SOCIETY
UET HOUSING SOCIETY
AMIR PUR
Mohlanwal
MOHLANWAL SCHEME
BHOBTIAN
AWT HOUSING SCHEME
GUL AFSHAN SOCIETY
VALENCIA
EXTENSION
NAZ TOWN
ENGINEERS TOWN
DREAM AVENUE LAHORE
WOCLAND VILLAS
VALANCIA HOMES
YOUSUF TOWN
MUHAFIZ TOWN
BLOCK AA
BLOCK C
BHATTI WAAL
DREAM GARDENS
SUKH CHAYN GARDENS
TAKBEER BLOCK
JULLIANA
CANAL GARDENS
WOMEN HOUSING SOCIETY
SHAHEEN BLOCK
KOT BAGH
TIP BLOCK
CANAL VIEW RESIDENCY
UMER BLOCK
USMAN BLOCK
OVERSEAS ENCLAVE
EDEN LANE VILLAS 2
HALLOKI GARDENS
KEMC HOUSING SOCIETY
Defence Road

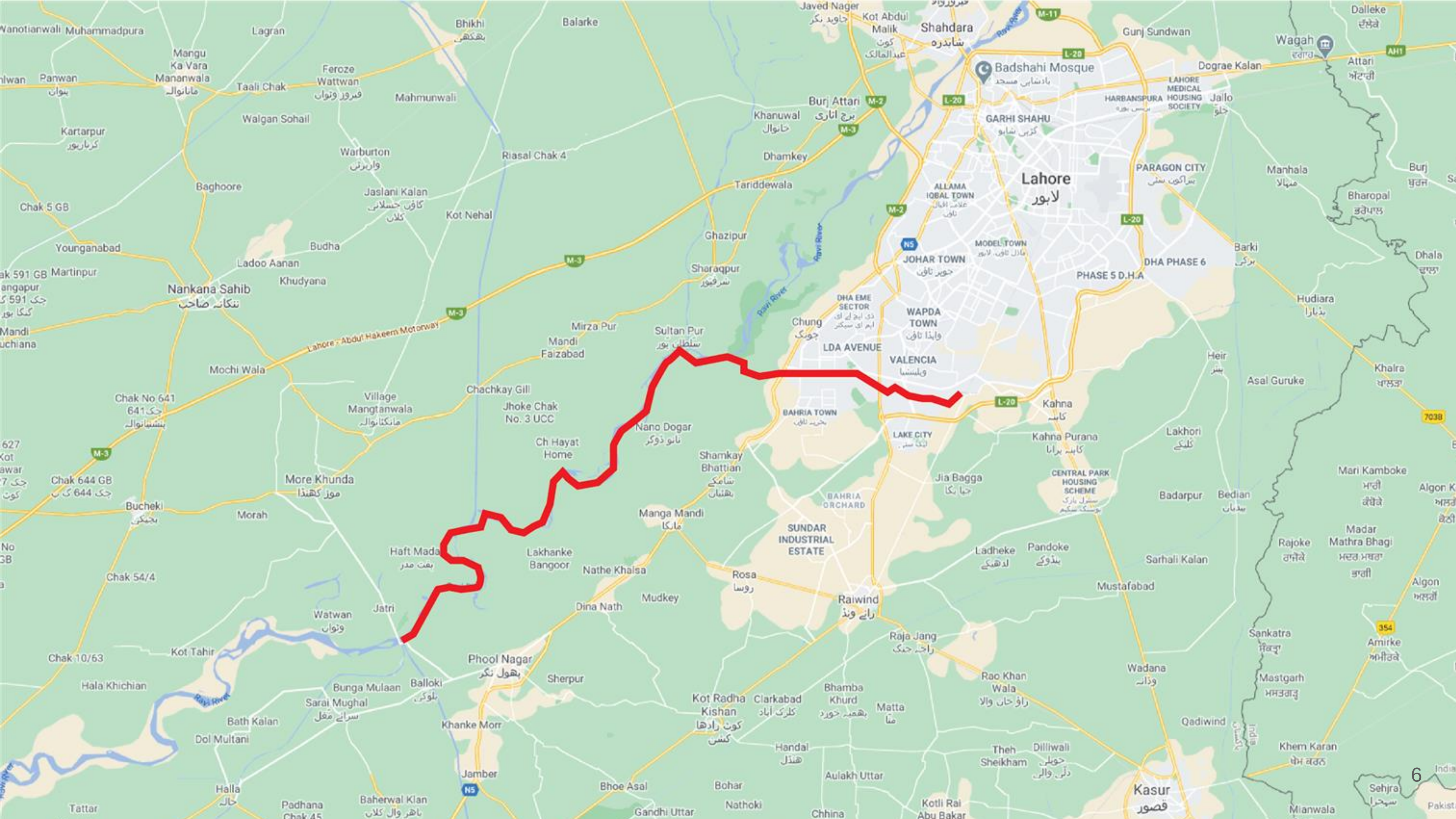

Javed Nager
Kot Abdul Malik
Shahdara
Badshahi Mosque
Gunj Sundwan
Wagah
Dalleke
Attari
Dograe Kalan
LAHORE MEDICAL HOUSING SOCIETY
HARBANSPURA
Jallo
GARHI SHAHU
Lahore
PARAGON CITY
Manhala
Bharopal
ALLAMA IQBAL TOWN
MODEL TOWN
JOHAR TOWN
DHA PHASE 6
PHASE 5 D.H.A
Barki
Dhala
Hudiara
DHA EME SECTOR
WAPDA TOWN
Chung
LDA AVENUE
VALENCIA
Heir
Khalra
Asal Guruke
BAHRIA TOWN
Kahna
LAKE CITY
Kahna Purana
Lakhori
Jia Bagga
CENTRAL PARK HOUSING SCHEME
Mari Kamboke
Badarpur
Bedian
BAHRIA ORCHARD
SUNDAR INDUSTRIAL ESTATE
Ladheke
Pandoke
Sarhali Kalan
Rajoke
Madar Mathra Bhagi
Mustafabad
Raiwind
Rosa
Raja Jang
Sankatra
Amirke
Rao Khan Wala
Wadana
Mastgarh
Qadiwind
Khem Karan
Kasur
Theh Sheikham
Dilliwali
Matta
Bhamba Khurd
Handal
Aulakh Uttar
Kotli Rai Abu Bakar
Chhina
Clarkabad
Kot Radha Kishan
Bohar
Nathoki
Gandhi Uttar
Bhoe Asal
Mudkey
Dina Nath
Nathe Khalsa
Manga Mandi
Shamkay Bhattian
Nano Dogar
Sultan Pur
Mandi Faizabad
Mirza Pur
Sharaqpur
Ghazipur
Khanuwal
Burj Attari
Dhamkey
Tariddewala
Kot Nehal
Riasal Chak 4
Balarke
Bhikhi
Lagran
Feroze Wattwan
Mahmunwali
Taali Chak
Mangu Ka Vara Mananwala
Muhammadpura
Panwan
Kartarpur
Walgan Sohail
Warburton
Jaslani Kalan
Baghoore
Chak 5 GB
Budha
Younganabad
Ladoo Aanan
Khudyana
Martinpur
Nankana Sahib
Lahore - Abdul Hakeem Motorway
Mochi Wala
Chachkay Gill
Jhoke Chak No. 3 UCC
Village Mangtanwala
Chak No 641
Ch Hayat Home
More Khunda
Chak 644 GB
Bucheki
Morah
Lakhanke Bangoor
Haft Mada
Chak 54/4
Watwan
Jatri
Kot Tahir
Chak 10/63
Phool Nagar
Sherpur
Balloki
Bunga Mulaan
Sarai Mughal
Hala Khichian
Bath Kalan
Dol Multani
Khanke Morr
Jamber
Halla
Padhana
Baherwal Klan
Tattar
Ravi River
M-11
M-2
M-3
L-20
N5
AH1
7038
354

Image from Google Maps

Microplastics

- Decomposed form of plastic
- Can be less than 100 nm in size
- Size of covid-19 is 60–140 nm
- Effect soil fertility by damaging the soil flora and fauna [1]
- Soil flora and fauna are responsible for nutrient recycling and organic matter Decomposition [2]

[1]Kumar, Manish, et al. "Microplastics as pollutants in agricultural soils." Environmental Pollution

[2]Sharma, Kavita, "Solid-state fermentation for vermicomposting: a step toward sustainable and healthy soil."

Thesis Aims

Thesis Aims

- Trash classification and localisation system based on deep learning

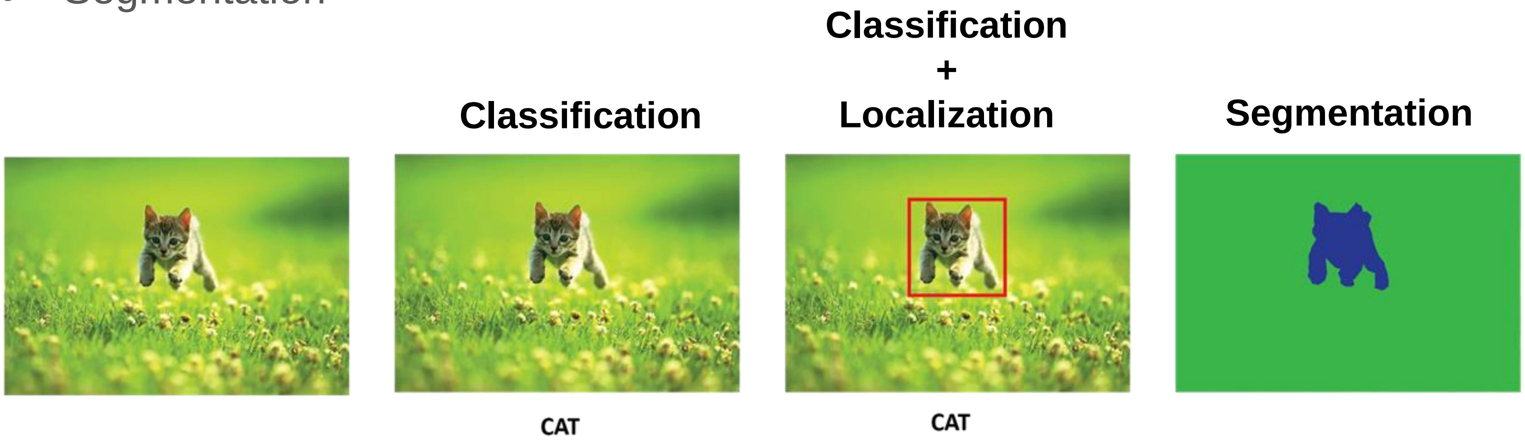
- Trash data analysis for identifying major pollutants

- Water flow measurement through visual sensor based on trash detection

Prior Work

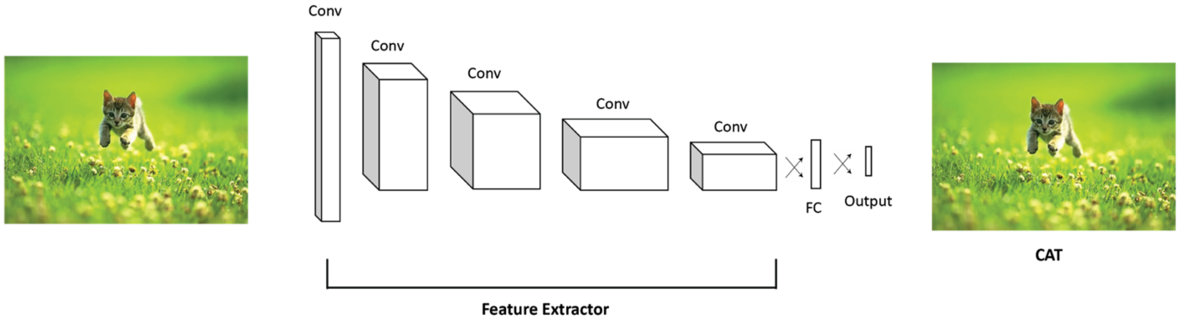
Prior Work

- Trash identification
  - Classification
  - Object Detection
  - Segmentation

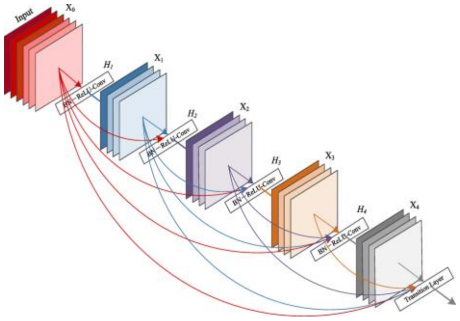


Prior Work: Classification

- Classify if an object is present in the image



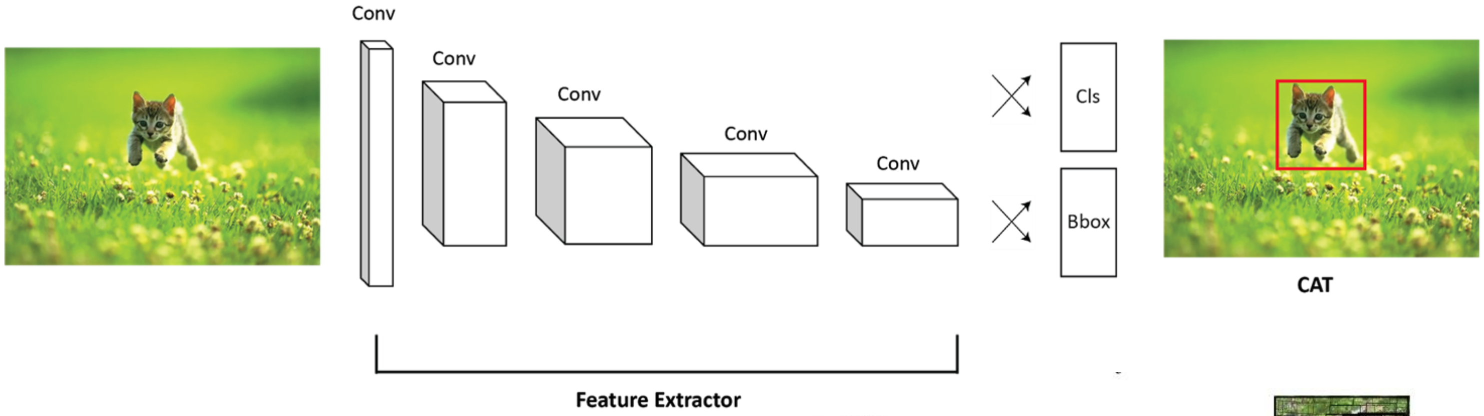
- Standard Architectures
  - DenseNet [1]
  - MobileNet [2]
  - Inception-v4 [3]
  - GoogLeNet [3]



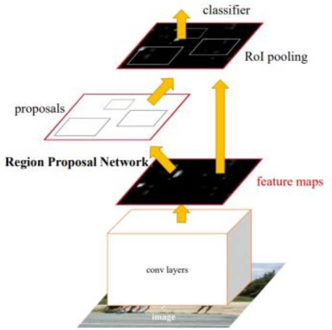
[1]Huang, Gao, et al. [2]Howard, Andrew G., et al. [3]Szegedy et al.

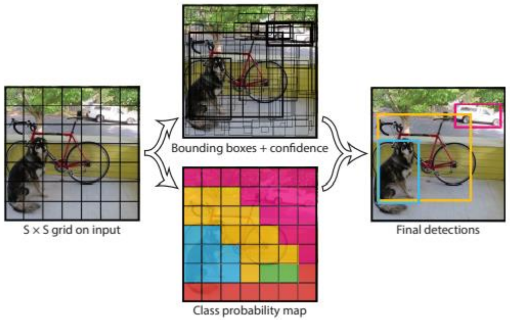
Prior Work: Object Detection

- Simultaneous localization and classification



- Standard Architectures
  - Faster RCNN [1]
  - YOLO [2]
  - Overfeat [3]

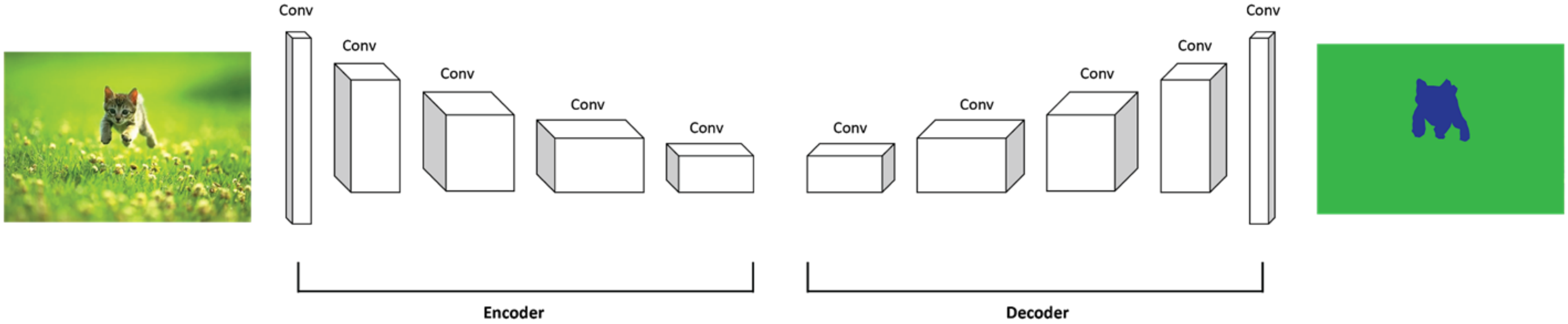




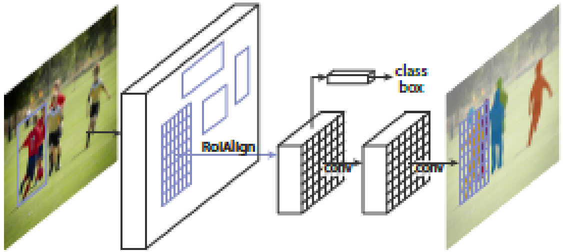
[1]Ren et al. [2]Redmon. et al. [3]Sermanet et al.

Prior Work: Segmentation

- Pixel-wise classification



- Standard architectures
  - Mask R-CNN [1]

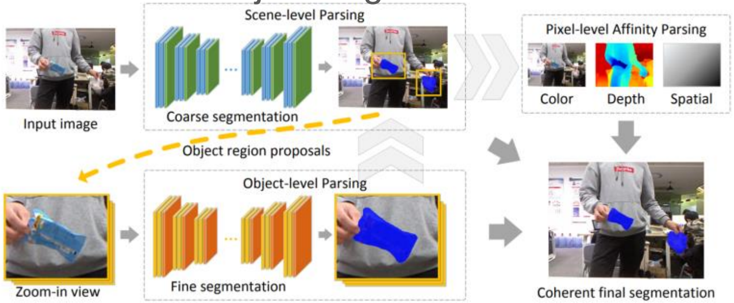


[1]He, Kaiming, et al.

Prior Work: Trash Analysis

- Indoor Trash
  - TrashNet [1]
    - Classification of 6 trash categories
    - Inception-v4, DenseNet, MobileNet

  - MJU-Waste [2]
    - RGBD waste object segmentation



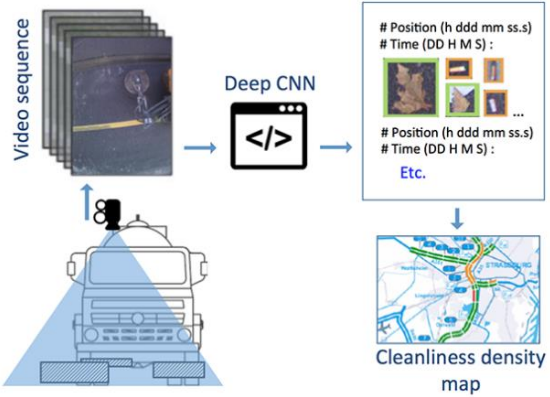
[1]Classification of TrashNet Dataset Based on Deep Learning Models

[2]Tao Wang, A Multi-Level Approach to Waste Object

Prior Work: Trash Analysis

- Outdoor Trash
    - TACO [1]
        - Dataset the with the most diverse amount of backgrounds
        - Water Trash accounts for only 3% of the whole dataset
        - Annotated for segmentation
        - Mask R-CNN

    - Street [2]
        - Camera mounted on a sweeper truck
        - Uses a combination of GoogleNet and OverFeat
        - Cleanliness density map creation based on detected trash



[1]Pedro F Proenca,TACO: Trash Annotations in Context for Litter Detection, 2020 [2]Mohammad Saeed Rad, A computer vision system to localize and classify wastes on the streets, 2017

Prior Work: Trash Analysis

- Ocean Trash
  - Trash-det [1]
    - Autonomous underwater vehicles (AUVs)
    - Detection of plastic objects on ocean floor
    - YOLOv2, SSD etc.

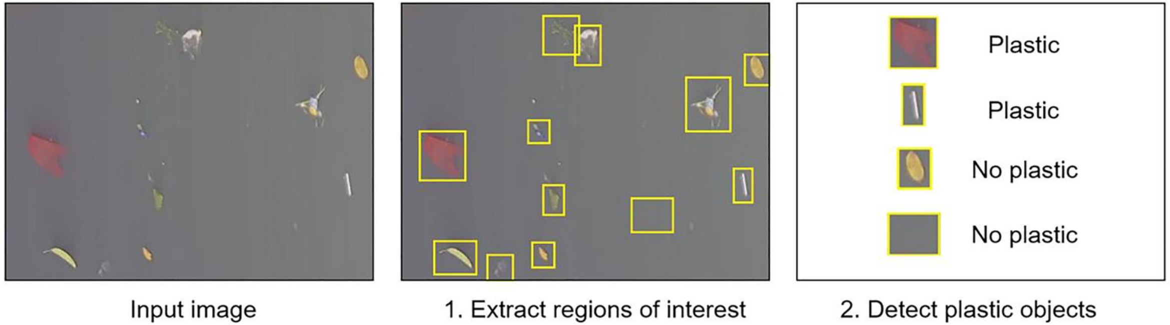
  - Trashcan [2]
    - Autonomous underwater vehicles (AUVs)
    - Segmentation of floating and ocean floor plastics
    - Faster R-CNN, Mask R-CNN

[1]Robotic Detection of Marine Litter Using Deep Visual Detection Models 2019

[2]Jungseok Hong, Trashcan: A semantically-segmented dataset towards visual detection of marine debris, 2020

Prior Work: Trash Analysis

- River Trash
  - River Plastics [1]
    - Plastics and non-plastics
    - Detection using Inception v2
    - Segmentation using Faster R-CNN
    - Only contains top-view of trash objects



[1] Colin van Lieshout, Automated river plastic monitoring using deep learning and cameras 2020

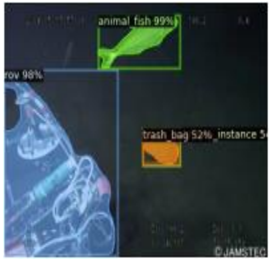
Prior Work: Dataset Comparison

Dataset	Type	# images	# classes	# instances	annot. type	Availability
TrashNet	Indoor	2500	6	2500	Classification	Public
VN-trash	Indoor	5904	3	5904	Classification	Public
MJU-Waste	Indoor	2475	1	2475	Mask	Public
Street	Road	469	6	1421	BBox	Private
TACO	Multi	1500	60	4784	Mask	Public
YOLOTrash	Multi	3974	4	5535	BBox	Private
Trash-det	Marine	5720	3	-	BBox	Private
TrashCan	Marine	7212	22	12480	Mask	Private
River Plastic	Rivers	1272	1	14892	Mask	Private

Summary of Prior Work: Trash Analysis

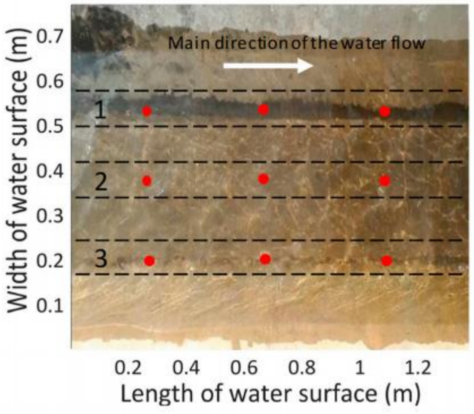
- Majority of the work has been done on street trash
- River channels have been explored for plastic/non-plastic detection
- Hardly no work has been done on water channels
- No public data available on water trash





Prior Work: Water Flow Analysis

- Water flow measure through dense optical flow [1]
  - Camera placement is parallel to water stream
  - Used rectangular box for mapping pixel coordinates to real world dimensions
  - Divided whole area into multiple regions and applied optical flow to get displacement of particles
- Real-Time, Inexpensive, and Portable Measurement of Water Surface Velocity through Smartphone [2]
  - Measurement of water flow through objects
  - Detecting objects through rgb color variation
  - Works at a specific phone height and velocity limits
  - Not deployable



[1] Wu, Heng, et al. 2019 [2]Yang, Tong, et al. 2020

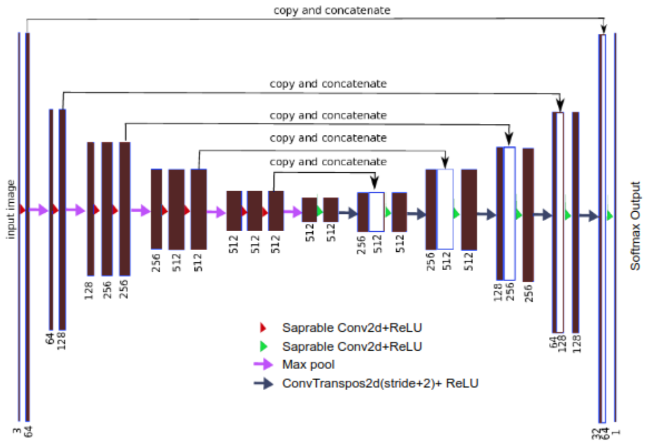
Our Prior Work

- Segmentation
- Separable Convolution in U-Net
- Novel Loss function for Water and Trash Imbalance problem

$$CB_{ipw}(p,y) = \frac{\sum_{i=1}^{C} n_i}{n_c} (\sum_{j=1}^{C} (1-p_i) log(p_i)),$$

- 2x improvement in processing time with 10x reduction in model parameters

Model	Parameters (Millions)	Accuracy	F1-Score	FPS
UNet	31	0.99	0.99	8
UNET+Sep	3.9	0.986	0.987	14



Problem Formulation/Statement

Problem Formulation/Statement

The problem can be formulated as:

- Dataset Collection & Annotation
  - Data collection from multiple sites
  - Class-wise annotation of trash objects
- Automatic Quantification - Fine Grained Detection & Classification
  - Deep learning system for trash detection and classification
- Trash Class Distribution Analysis
  - Detailed analysis on major water channel pollution contributors
- Water Flow Measurement
  - Measuring water flow through trash detection

Dataset Collection & Annotation

Dataset Collection

- Two datasets collected

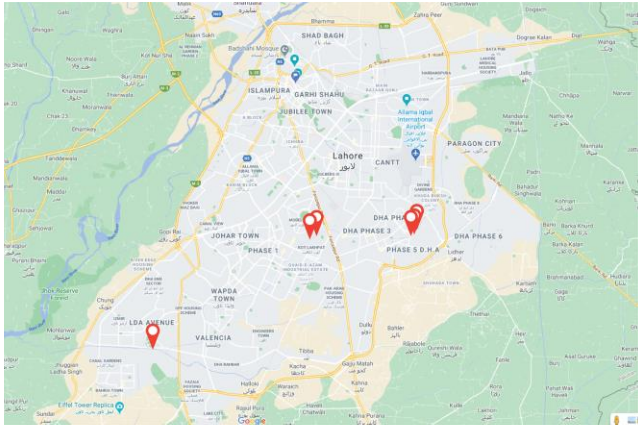
- Trash Classification Dataset (TCD)
  - Image dataset
  - Deep Learning system for trash detection

- Trash Flow Rate Dataset (TFD)
  - Video Dataset
  - Trash Class Distribution Analysis
  - Water Flow Analysis

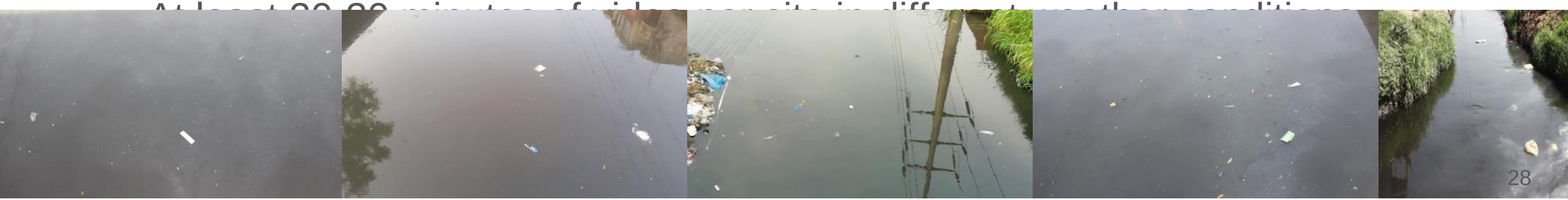
Dataset Collection (TCD)

- 7 Sites

City	Location	Water Channel	GPS Coordinates	
			Latitude	Longitude
Lahore	LUMS	Rohi Nala	31.478224	74.413272
Lahore	Alfalah Town	Rohi Nala	31.472700	74.409738
Lahore	Alfalah Town	Rohi Nala	31.480270	74.414445
Lahore	Liaquatabad	Rohi Nala	31.470839	74.332759
Lahore	Liaquatabad	Rohi Nala	31.473074	74.337413
Lahore	Defence Raod	Hudiara Nala	31.397972	74.211921
Sheikhupura	Shah Khalid Town	SKP Drain	31.667509	74.265385



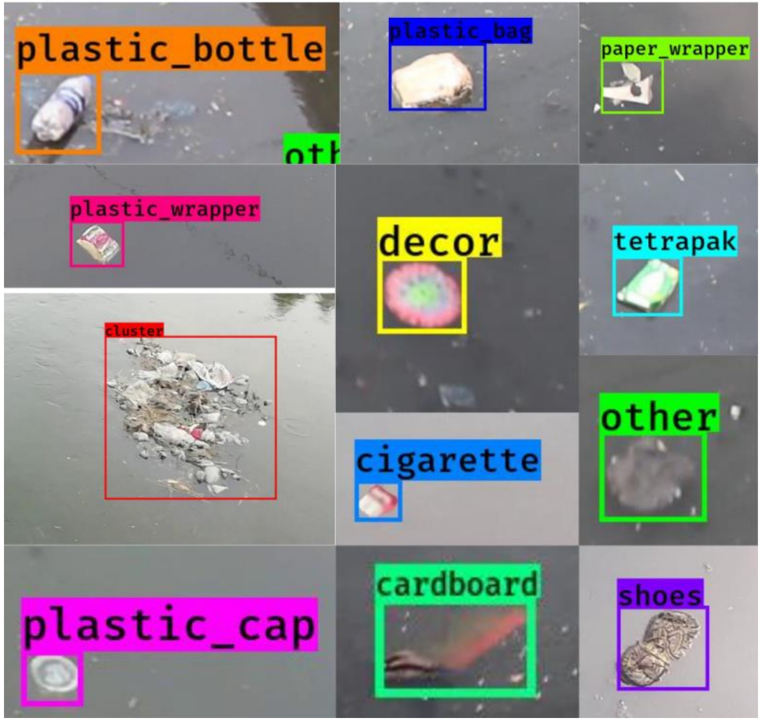
At least 20-30 minutes of video per site in different weather conditions



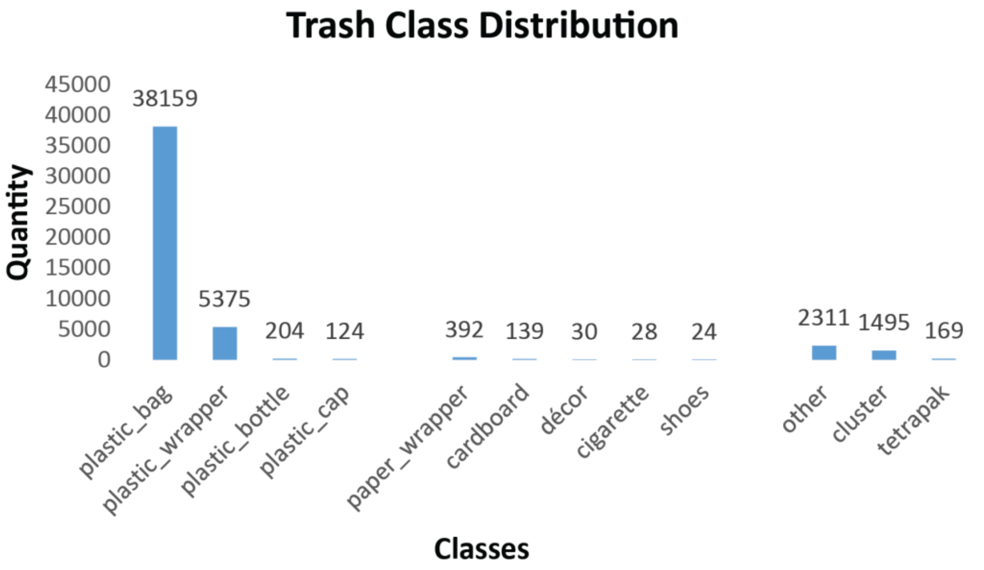
Dataset Annotation (TCD)

- Trash/Non-Trash
  - Single Class, 13,500 Images, 48,450 instances
- Trash
  - 3 Super-classes, 12 classes,
    13,500 images, 48,450 instances

Plastic	Non-plastic	Hybrid
Plastic Bag	Shoes	Tetrapak
Plastic Wrapper	Decor	Cluster
Plastic Bottle	Cigarette	Other
Plastic Cap	Paper Wrapper	
	Cardboard	



Data Distribution (TCD)



Dataset Collection (TFD)

- 2 Sites

City	Location	Water Channel	GPS Coordinates	
			Latitude	Longitude
Lahore	Liaquatabad	Cantonment Drain	31.470839	74.332759
Lahore	Defence Raod	Hudiara Drain	31.397972	74.211921

- ~49 hours of video data collected
  - Liaquatabad - 24 hours
  - Defence Road - 25 hours

Location	Water Channel	Date	Starting Time	Video Time
Liaquatabad	Cantonment Drain	03-17-21	15:00	1 hr 47 min
Liaquatabad	Cantonment Drain	03-18-21	15:00	2 hr 6 min
Liaquatabad	Cantonment Drain	03-20-21	15:00	2 hr 8 min
Liaquatabad	Cantonment Drain	03-31-21	07:00	7 hr 57 min
Liaquatabad	Cantonment Drain	04-01-21	07:00	4 hr 57 min
Liaquatabad	Cantonment Drain	04-03-21	07:00	4 hr 51 min
Defence Raod	Hudiara Drain	03-17-21	11:00	2 hr 24 min
Defence Raod	Hudiara Drain	03-18-21	11:00	2 hr 54 min
Defence Raod	Hudiara Drain	03-20-21	11:00	2 hr 56 min
Defence Raod	Hudiara Drain	03-24-21	07:00	4 hr 1 min
Defence Raod	Hudiara Drain	03-25-21	07:00	3 hr 55 min
Defence Raod	Hudiara Drain	03-27-21	07:00	3 hr 37 min
Defence Raod	Hudiara Drain	03-31-21	15:00	2 hr 47 min
Defence Raod	Hudiara Drain	04-01-21	15:00	2 hr 54 min

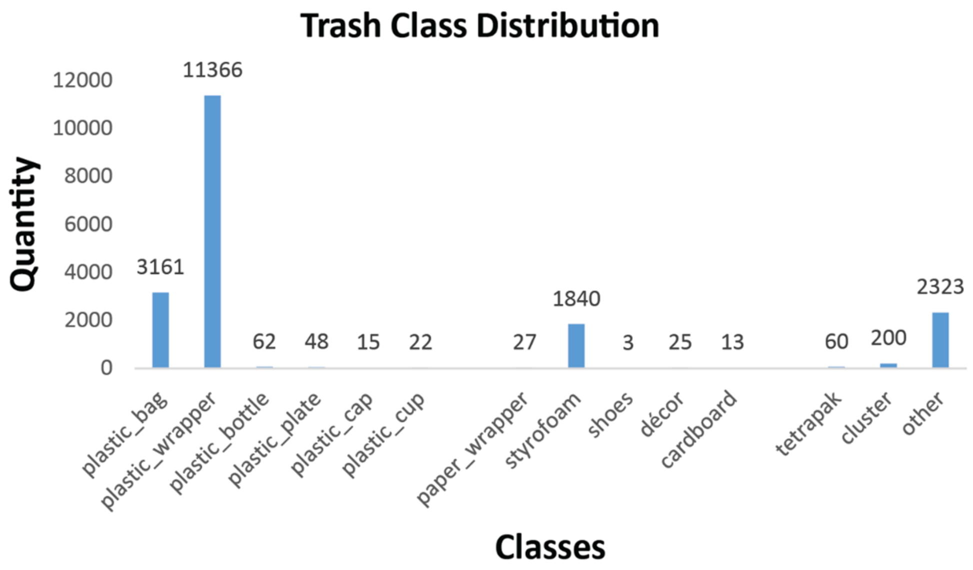



Dataset Annotation (TFD)

- Camera calibration data for trash flow rate
- Trash
  - 3 Super-classes, 14 classes
  - 19,165 unique instances

Plastic	Non-plastic	Hybrid
Plastic Bag	Shoes	Tetrapak
Plastic Wrapper	Decor	Cluster
Plastic Bottle	Styrofoam	Other
Plastic Plate	Paper Wrapper	
Plastic Cap	Cardboard	
Plastic Cup		

Data Distribution (TFD)



Automatic Quantification

Fine Grained Detection & Classification

Trash/Non-Trash Detection Challenges

Trash/Non-Trash Detection Challenges

- Variable Object Sizes (COCO Standard)
  - Deformed objects cause intra-class variance

Size	No. of Objects	Area (pixels)
Small	11,214	$\text{area} \leq 32^2$
Medium	32,078	$32^2 < \text{area} \leq 96^2$
Large	5,158	$\text{area} > 96^2$
Total	48,450	$\text{area} > 7^2$

Fine-grained Detection & Classification Challenges

- Texture and Geometrical similarity

Existing object detectors fail to localize and classify in these challengings cases

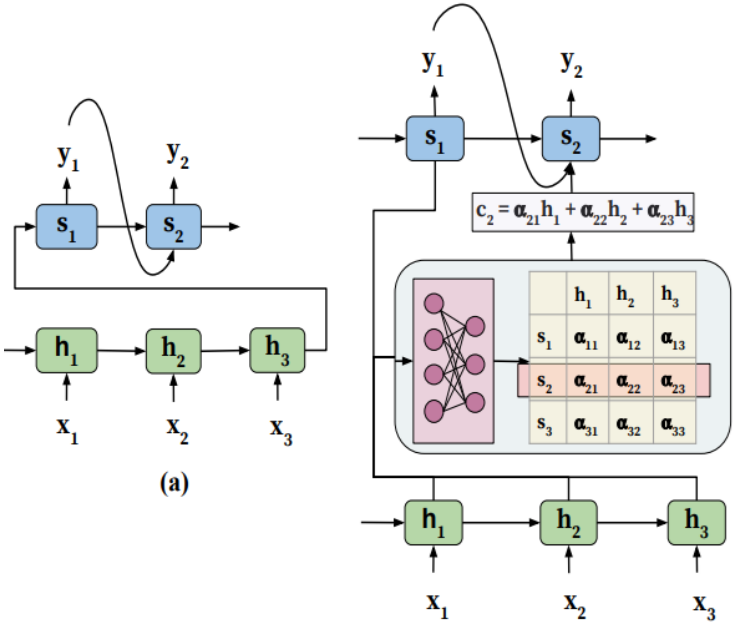
Methodology

- What is attention?
  - How does the human visual system work?

Methodology

- Improving simultaneous localization and classification via Attention

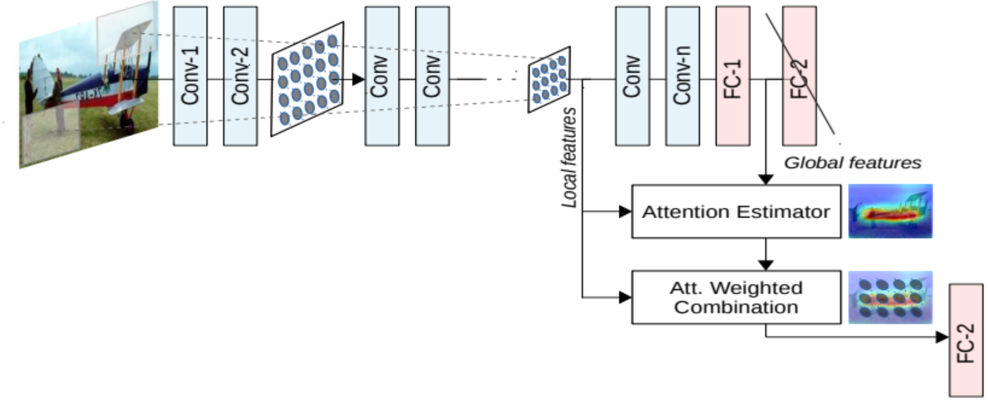
- Attention for machine translation*
  - Encoder-Decoder network
  - Attention as relative importance



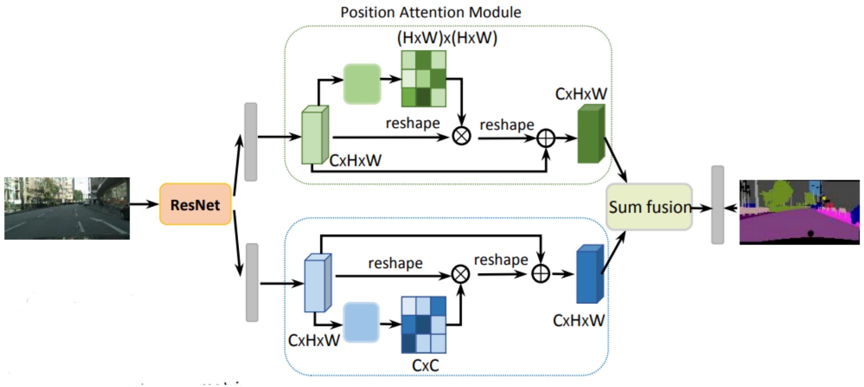
*Chaudhari, Sneha, et al. "An attentive survey of attention models."

Methodology

- Attention for image classification*



- Attention for image segmentation**

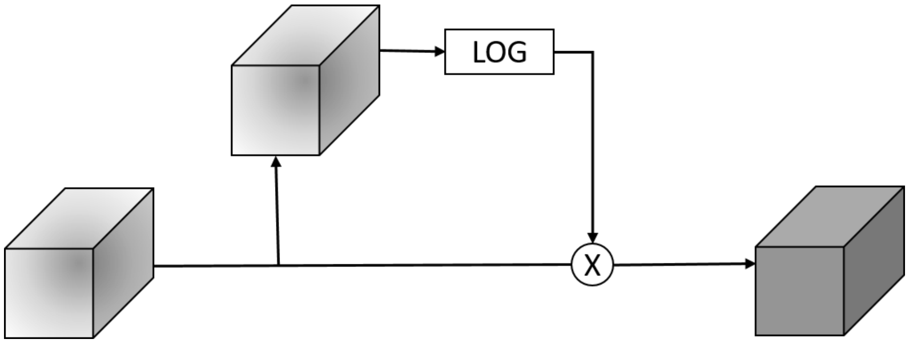


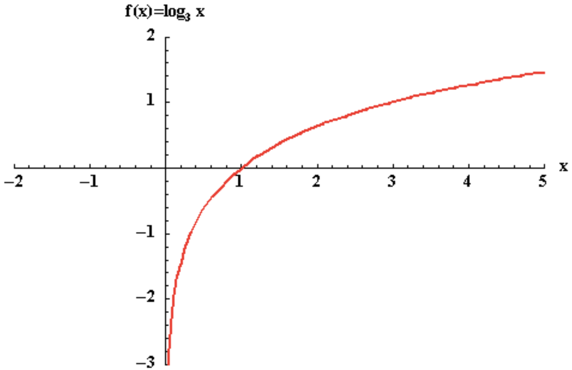
*Jetley, Saumya, et al. "Learn to pay attention." **Fu, Jun, et al. "Dual attention network for scene segmentation."

Methodology

- Log Attention Module (LAM)

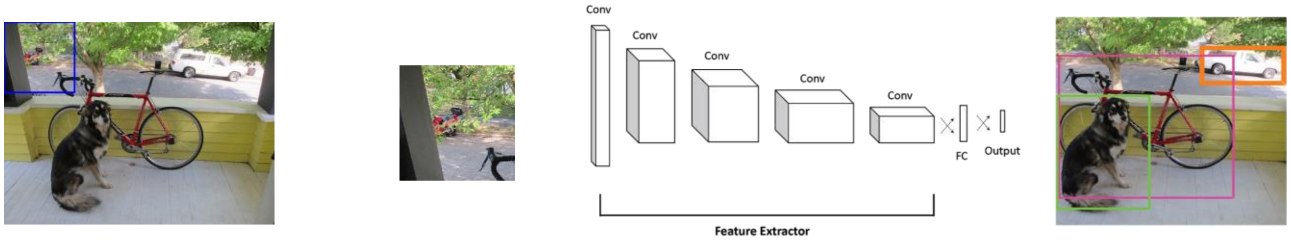
$$f_{i+1} = f_i \times log(ReLU(f_i) + 1)$$



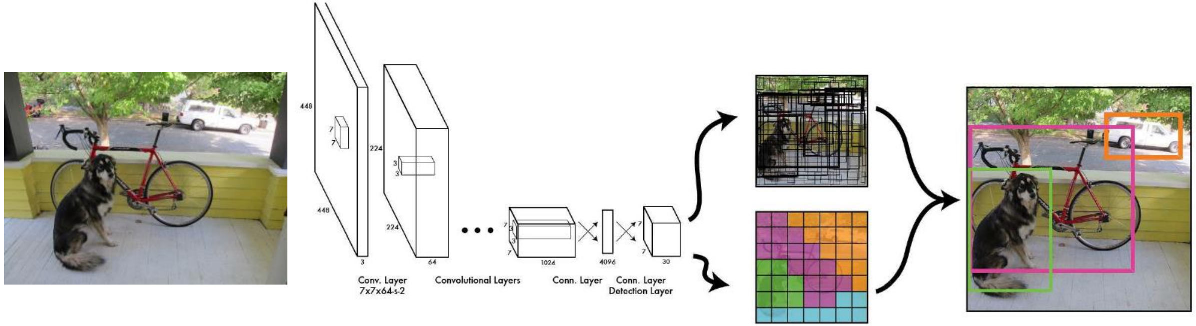


Methodology: Introducing Attention in Yolo-v3

- Sliding Window Detection



- YOLO: You Only Look Once



Methodology: Introducing Attention in Yolo-v3

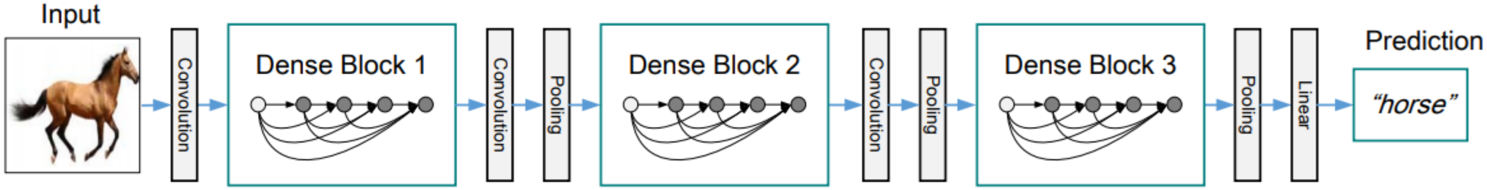
- 4 Log Attention Modules (LAM)

Type	Size	Times	Output
Convolutional	3 x 3		256x256
Convolutional	3 x 3		128x128
Convolutional	1 x 1		128 x 128
Convolutional	3 x 3	1x	128 x 128
Residual			128 x 128
Convolutional	3 x 3		64 x 64
Convolutional	1 x 1		64 x 64
Convolutional	3 x 3	2x	64 x 64
Residual			64 x 64
Convolutional	3 x 3		32 x 32
Convolutional	1 x 1		32 x 32
Convolutional	3 x 3	8x	32 x 32
Residual			32 x 32
Convolutional	3 x 3		16 x 16
Convolutional	1 x 1		16 x 16
Convolutional	3 x 3	8x	16 x 16
Residual			16 x 16
Convolutional	3 x 3		8 x 8
Convolutional	1 x 1		8 x 8
Convolutional	3 x 3	4x	8 x 8
Residual			8 x 8

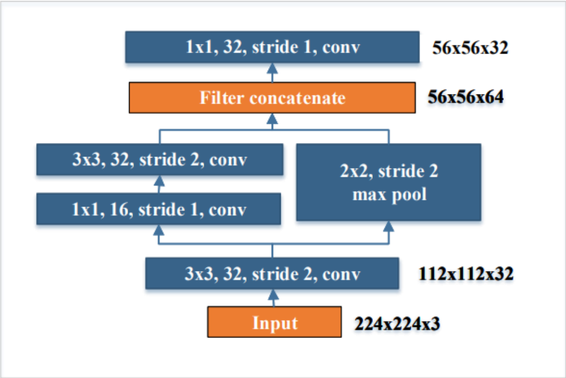
Type	Size	Times	Output
Convolutional	3 x 3		256x256
Convolutional	3 x 3		128x128
Convolutional	1 x 1		128 x 128
Convolutional	3 x 3	1x	128 x 128
Residual			128 x 128
LAM			128 x 128
Convolutional	3 x 3		64 x 64
Convolutional	1 x 1		64 x 64
Convolutional	3 x 3	2x	64 x 64
Residual			64 x 64
LAM			64 x 64
Convolutional	3 x 3		32 x 32
Convolutional	1 x 1		32 x 32
Convolutional	3 x 3	8x	32 x 32
Residual			32 x 32
LAM			32 x 32
Convolutional	3 x 3		16 x 16
Convolutional	1 x 1		16 x 16
Convolutional	3 x 3	8x	16 x 16
Residual			16 x 16
LAM			16 x 16
Convolutional	3 x 3		8 x 8
Convolutional	1 x 1		8 x 8
Convolutional	3 x 3	4x	8 x 8
Residual			8 x 8

Methodology: Introducing Attention in PeleeNet

- PeleeNet
  - A variant of densenet*



  - Densenet41
  - Stem Block for better feature expression
  - Dynamic Number of Channels in BottleNeck Layer
  - Residual Connections for fine-grained features



*Gao Huang, Densely Connected Convolutional Networks

Methodology: Introducing Attention in PeleeNet

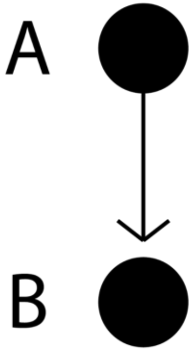
- 2 Log Attention Modules (LAM)

Type	Size	Times	Output
Stem Block			56 x 56 x 32
Dense Layer		3x	56 x 56 x 128
Convolutional	1 x 1		56 x 56 x 128
Average Pool	2 x 2		28 x 28 x 128
Dense Layer		4x	28 x 28 x 256
Convolutional	1 x 1		28 x 28 x 256
Average Pool	2 x 2		14 x 14 x 128
Dense Layer		8x	14 x 14 x 512
Convolutional	1 x 1		14 x 14 x 512
Average Pool	2 x 2		7 x 7 x 512
Dense Layer		6x	7 x 7 x 704
Convolutional	1 x 1		7 x 7 x 128

Type	Size	Times	Output
Stem Block			56 x 56 x 32
Dense Layer		3x	56 x 56 x 128
LAM			56 x 56 x 128
Convolutional	1 x 1		56 x 56 x 128
Average Pool	2 x 2		28 x 28 x 128
Dense Layer		4x	28 x 28 x 256
LAM			28 x 28 x 256
Convolutional	1 x 1		28 x 28 x 256
Average Pool	2 x 2		14 x 14 x 128
Dense Layer		8x	14 x 14 x 512
Convolutional	1 x 1		14 x 14 x 512
Average Pool	2 x 2		7 x 7 x 512
Dense Layer		6x	7 x 7 x 704
Convolutional	1 x 1		7 x 7 x 128

Methodology: Water Flow Calculation

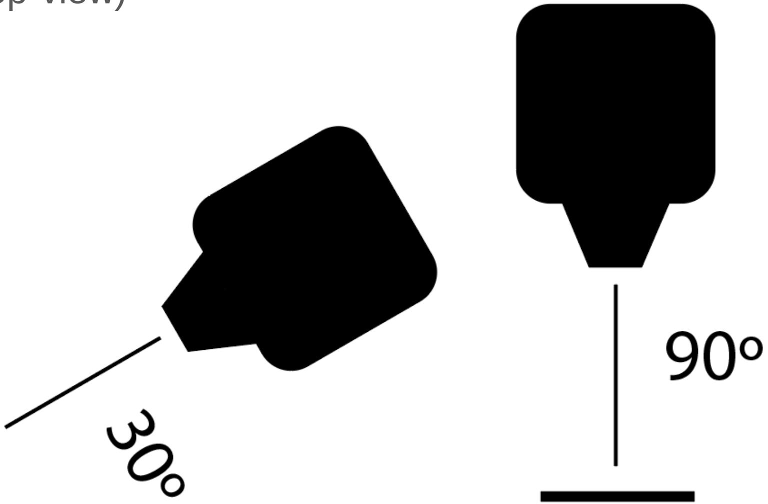
- Water flow measurement through object detection
- Steps:
  - Calculating vertical distance travelled by trash object
  - Divide vertical distance by time taken to travel between point A and B to get water flow



Methodology: Water Flow Calculation

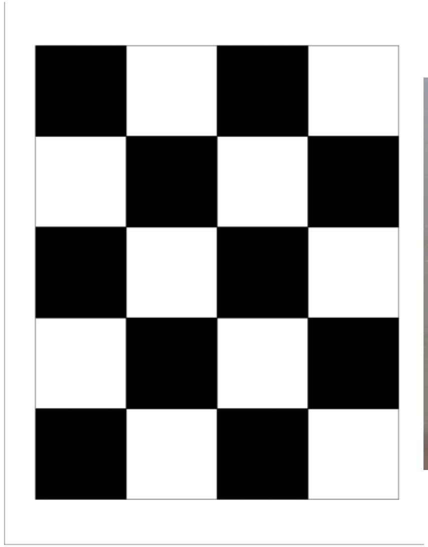
- Pixel to Pixel real world distance?
  - Take image of an object with known dimension (top-view)
  - Map pixel dimensions to real world dimensions

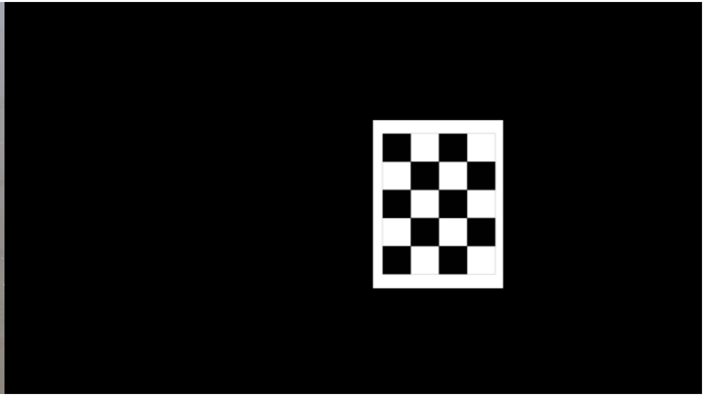
- Dataset does not contain top-view
- Videos with slight tilt or perspective



Methodology: Water Flow Calculation

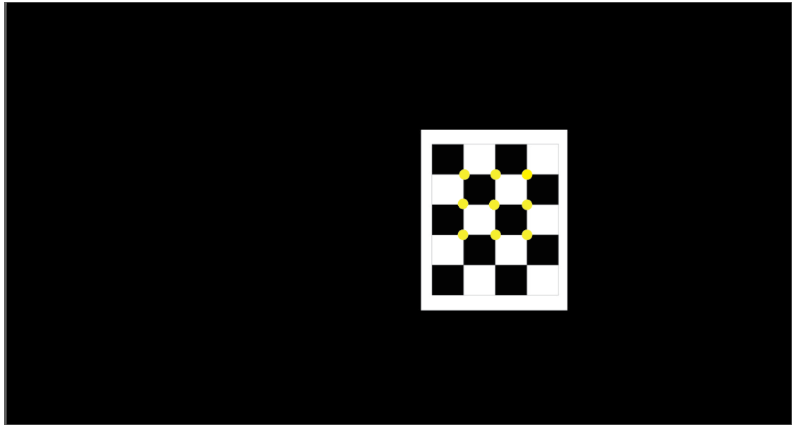
- Orthogonal projection of tilted image through Homography
  - Checkerboard Pattern Used (Checker dimensions = 4 inches)
  - Orthogonal image creation for calculating transformation





Methodology: Water Flow Calculation

- Orthogonal projection of tilted image through Homography
  - 9 corresponding points from both images



Methodology: Water Flow Calculation

- Orthogonal projection of tilted image through Homography

$$\begin{bmatrix} x_2 \\ y_2 \\ z_2 \end{bmatrix} = \begin{bmatrix} H_{11} & H_{12} & H_{13} \\ H_{21} & H_{22} & H_{23} \\ H_{31} & H_{32} & H_{33} \end{bmatrix} \begin{bmatrix} x_1 \\ y_1 \\ z_1 \end{bmatrix} \Leftrightarrow \mathbf{x}_2 = H\mathbf{x}_1$$

In inhomogenous coordina $(x'_2 = x_2/z_2 \text{ and } y'_2 = y_2/z_2)$,

$$x'_2 = \frac{H_{11}x_1 + H_{12}y_1 + H_{13}z_1}{H_{31}x_1 + H_{32}y_1 + H_{33}z_1}$$

$$y'_2 = \frac{H_{21}x_1 + H_{22}y_1 + H_{23}z_1}{H_{31}x_1 + H_{32}y_1 + H_{33}z_1}$$

Methodology: Water Flow Calculation

- Orthogonal projection of tilted image through Homography

$$z_1 = 1$$

$$x_2'(H_{31}x_1 + H_{32}y_1 + H_{33}) = H_{11}x_1 + H_{12}y_1 + H_{13}$$
$$y_2'(H_{31}x_1 + H_{32}y_1 + H_{33}) = H_{21}x_1 + H_{22}y_1 + H_{23}$$

$$\mathbf{a}_x^T \mathbf{h} = \mathbf{0}$$
$$\mathbf{a}_y^T \mathbf{h} = \mathbf{0}$$

Methodology: Water Flow Calculation

- Orthogonal projection of tilted image through Homography

$$
\begin{aligned}
\mathbf{h} &= (H_{11}, H_{12}, H_{13}, H_{21}, H_{22}, H_{23}, H_{31}, H_{32}, H_{33})^T \\
\mathbf{a}_x &= (-x_1, -y_1, -1, 0, 0, 0, x_2' x_1, x_2' y_1, x_2')^T \\
\mathbf{a}_y &= (0, 0, 0, -x_1, -y_1, -1, y_2' x_1, y_2' y_1, y_2')^T .
\end{aligned}
$$

Methodology: Water Flow Calculation

- Orthogonal projection of tilted image through Homography

$$A\mathbf{h} = \mathbf{0}$$

2Nx9 9x1

$$A = \begin{pmatrix} \mathbf{a}_{x1}^T \\ \mathbf{a}_{y1}^T \\ \vdots \\ \mathbf{a}_{xN}^T \\ \mathbf{a}_{yN}^T \end{pmatrix}.$$

Results & Analysis

Experimental Setup

Dataset

- Split (TCD)
  - Training - 12500 samples
  - Testing - 1000 samples

Algorithms

- Yolo-v3*
- Yolo-v3-Tiny*
- PeeleNet**
- Yolo-v3+Attn
- PeeleNet+Attn

* Redmon, Joseph, et al. "You only look once: Unified, real-time object detection." **Wang,"Pelee: A real-time object detection system on mobile devices."

Evaluation Metrics

- Precision

$$Precision = \frac{TP}{TP + FP}$$

- Recall

$$Recall = \frac{TP}{TP + FN}$$

- Intersection over union (IoU)

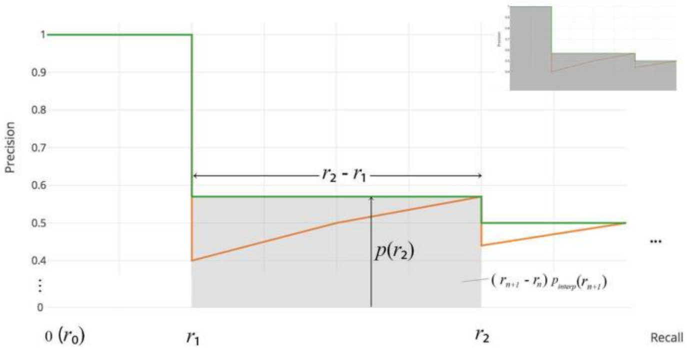
$$IoU = \frac{Area(P \cap G)}{Area(P \cup G)}$$

	Class A	Class B
Class A	TN	FP
Class B	FN	TP

Evaluation Metrics

- Average Precision (AP)

$$\mathrm{AP} = \int_0^1 p(r)dr$$



- Three different object sizes
  - Small
  - Medium
  - Large

Qualitative Results

(a) YOLO-v3

(b) YOLO-v3+Attn

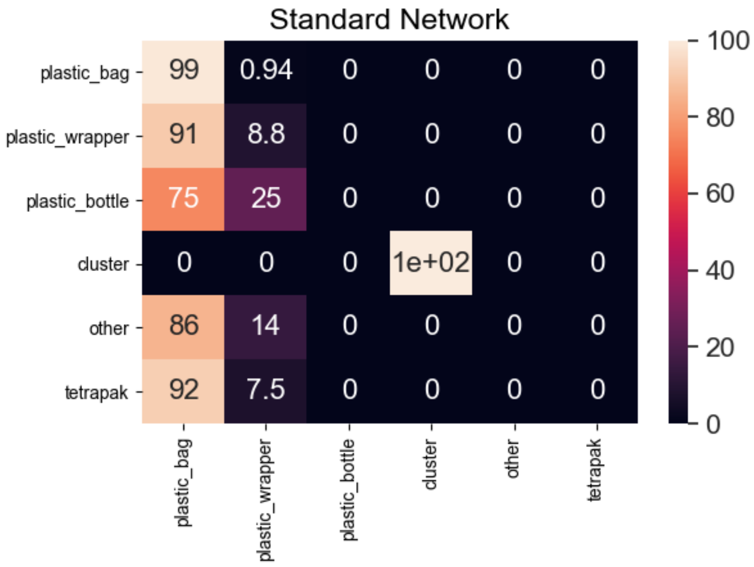
Object Detection Analysis

Size	No. of Objects	Area (pixels)
Small	11,214	area $\leq 32^2$
Medium	32,078	$32^2 <$ area $\leq 96^2$
Large	5,158	area $> 96^2$
Total	48,450	area $> 7^2$

Model	#Param	AP^S	AP^M	AP^L	mAP
YOLO-v3 [20]	61.5M	3.4	7.4	10.5	21.7
YOLO-v3-Tiny	8.6M	0.7	2.4	7.4	7.8
PeleeNet [25]	4.8M	3.0	10.3	21.0	26.0
YOLO-v3+Attn	61.5M	**3.6**	**21.4**	10.8	**31.5**
PeleeNet+Attn	4.8M	3.4	10.4	**26.6**	26.5

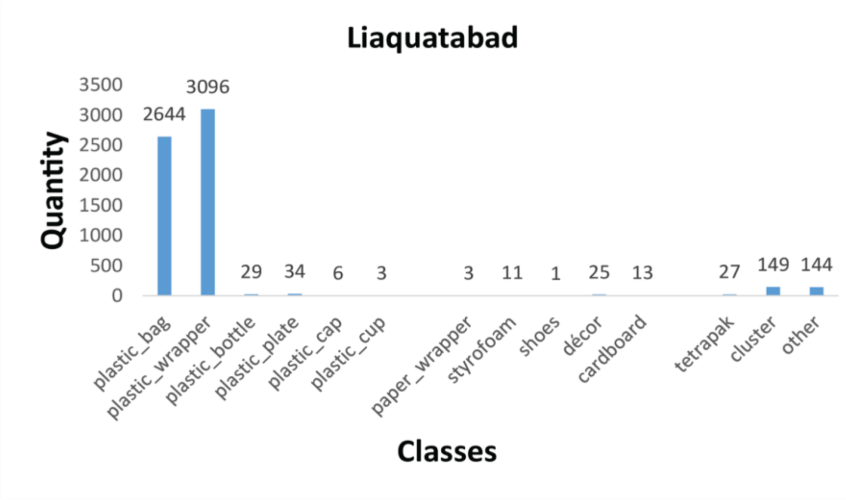
Object Detection Analysis

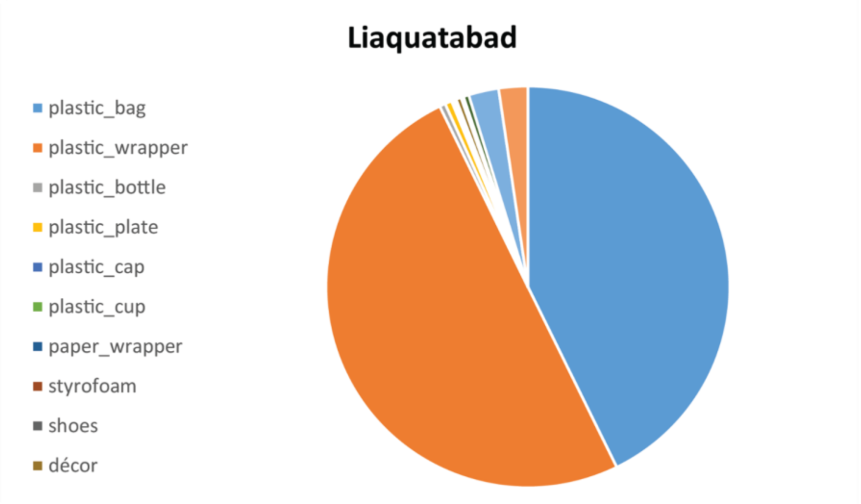
- Plastic bag occupies most of the predictions.



Trash Class Distribution Analysis (TFD)

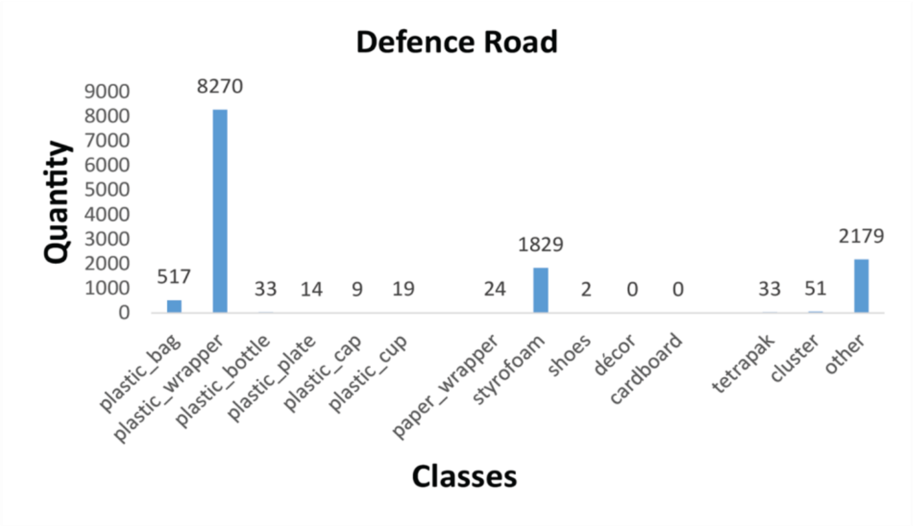
- Liaquatabad (Cantonment Drain)

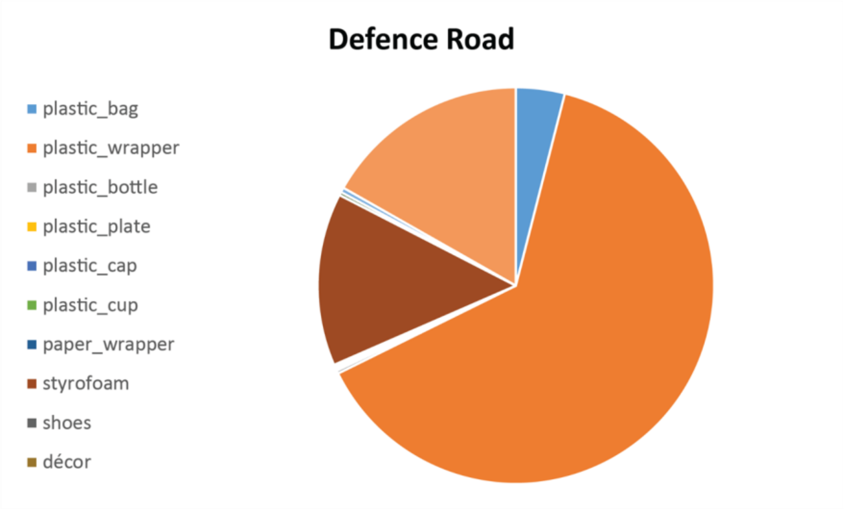




Trash Class Distribution Analysis (TFD)

- Defence Road (Hudiara Drain)





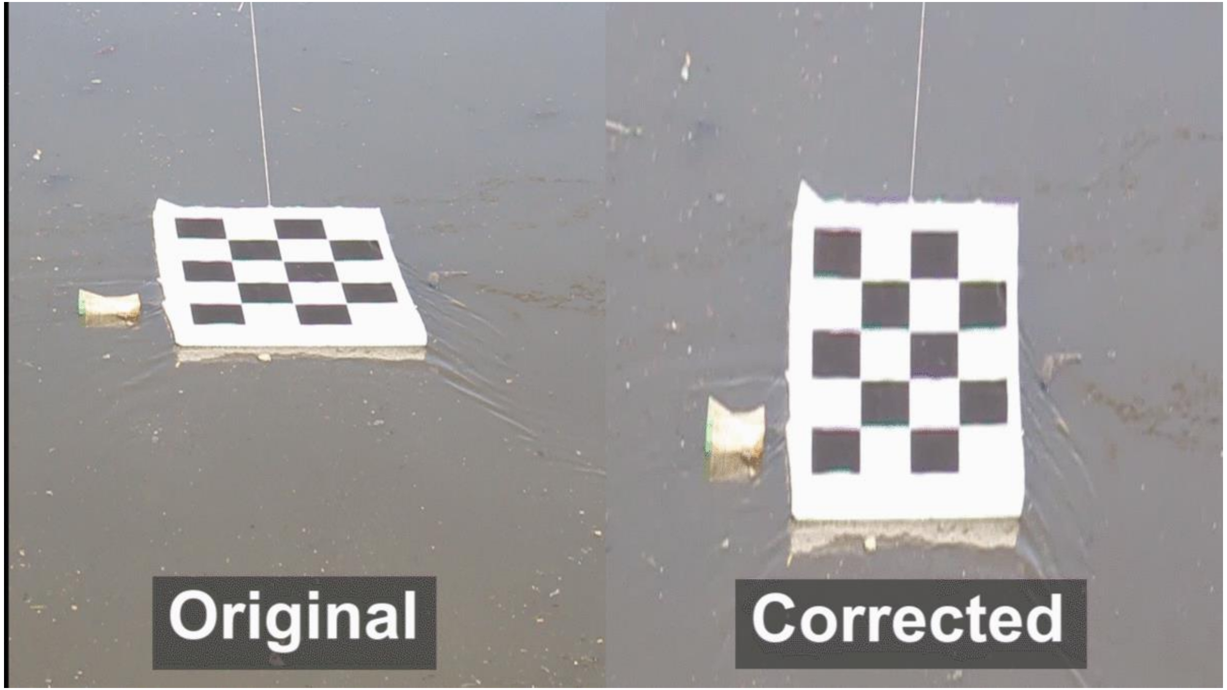
Trash Class Distribution Analysis (TFD)

- ATOPH (Average Trash Objects Per Hour)

Site	Drain	ATOPH
Liaquatabad	Cantonment Drain	260
Defence Road	Hudiara Drain	508

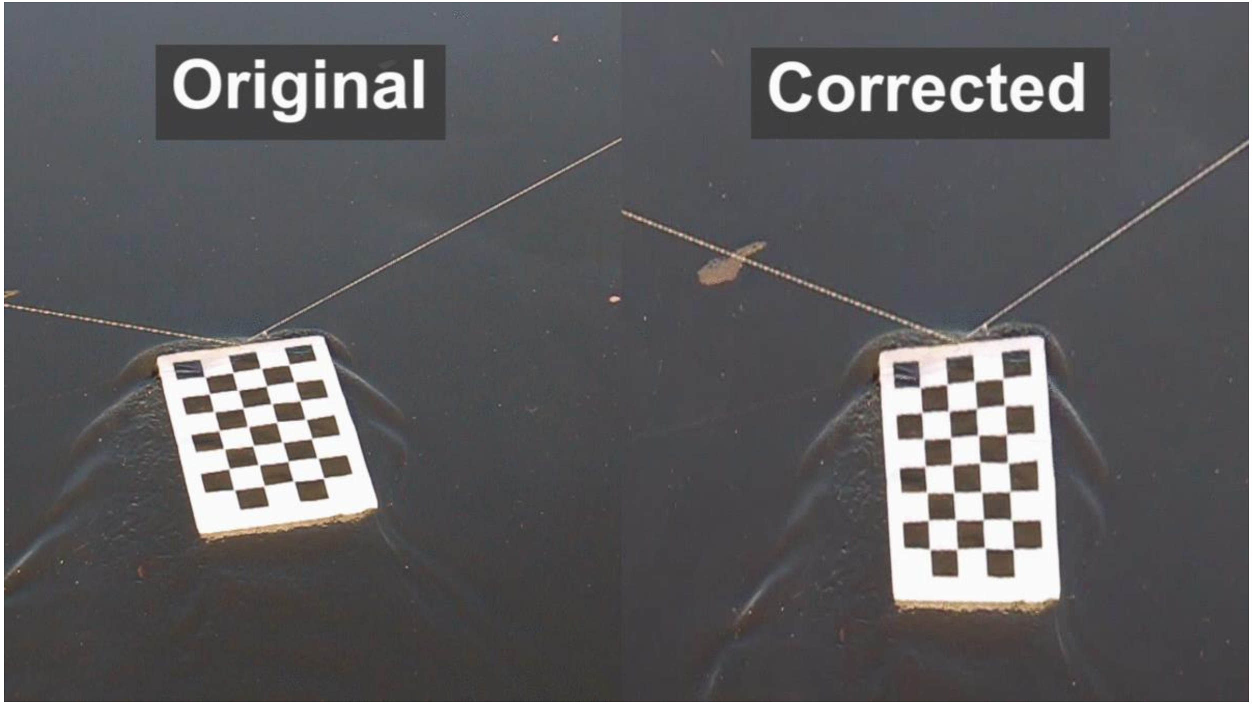
Water Flow Calculation

- Liaquatabad site (Cantonment Drain) after applying Homography



Water Flow Calculation

- Defence Road site (Hudiara Drain) after applying homography



Water Flow Calculation

- Water Flow Calculation For Liaquatabad

  Checker dimension = 4 inches = 0.1016 m

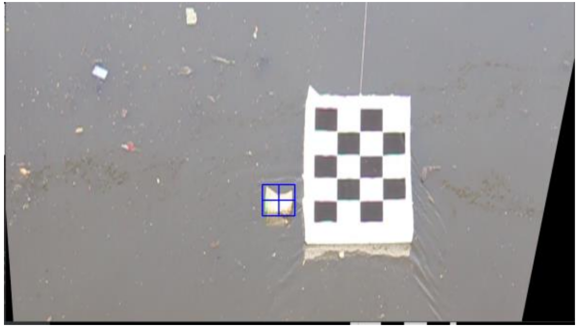
  Checker Pixels = 52 **(After applying Homography)**

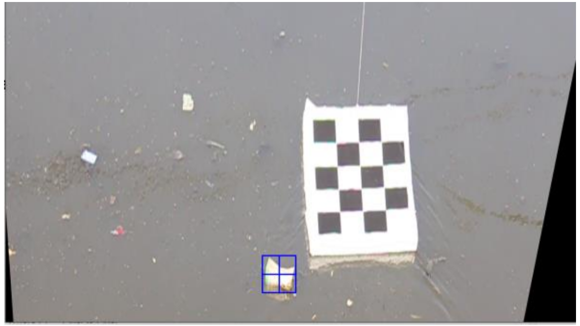
  Pixel Distance = 0.1016/52 = 0.0019538 m

  Y1 = 445 pixel **(Image at t = 0 sec)**

  Y2 = 611 pixel **(Image at t = 1 sec)**

  Water Flow = (Y2 - Y1) * Pixel Distance = 0.32 m/s





Water Flow Calculation

- Water Flow Calculation For Defence Road

Checker dimension = 4 inches = 0.1016 m

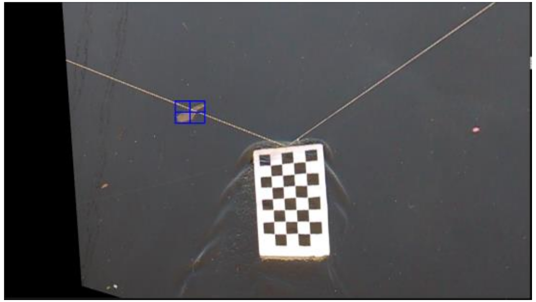
Checker Pixels = 27 **(After applying Homography)**

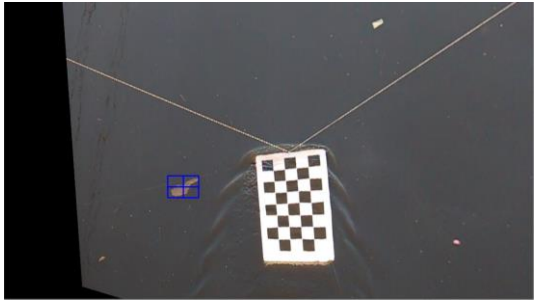
Pixel Distance = 0.1016/27 = 0.0037629 m

Y1 = 266 pixel **(Image at t = 0 sec)**

Y2 = 447 pixel **(Image at t = 1 sec)**

Water Flow = (Y2 - Y1) * Pixel Distance = 0.67 m/s





Water Flow Calculation

Liaquatabad (Cantonment Drain) **10.96m**

Water Flow: 0.32 m/s

Defence Road (Hudiara Drain) **30.18m**

Water Flow: 0.67 m/s

Summary

Achieved

- Dataset for fine-grained trash detection and classification (TCD)
- Improvement in localisation, detection and classification
- Dataset for trash class distribution (TFD)
- Trash class distribution analysis
- Water flow measurement

Future Work

- Solve data imbalance
- Validity of water flow measurement through flow meters

References

1. Kumar, Manish, et al. "Microplastics as pollutants in agricultural soils." Environmental Pollution (2020): 114980.
2. Sharma, Kavita, and Vinod Kumar Garg. "Solid-state fermentation for vermicomposting: a step toward sustainable and healthy soil." Current Developments in Biotechnology and Bioengineering. Elsevier, 2018. 373-413.
3. Proença, Pedro F., and Pedro Simões. "TACO: Trash Annotations in Context for Litter Detection." arXiv preprint arXiv:2003.06975 (2020).
4. Rad, Mohammad Saeed, et al. "A computer vision system to localize and classify wastes on the streets." International Conference on computer vision systems. Springer, Cham, 2017.
5. Fulton, Michael, et al. "Robotic detection of marine litter using deep visual detection models." 2019 International Conference on Robotics and Automation (ICRA). IEEE, 2019.
6. Hong, Jungseok, Michael Fulton, and Junaed Sattar. "TrashCan: A Semantically-Segmented Dataset towards Visual Detection of Marine Debris." arXiv preprint arXiv:2007.08097 (2020).

References

7. van Lieshout, Colin, et al. "Automated river plastic monitoring using deep learning and cameras." Earth and space science 7.8 (2020): e2019EA000960.
8. Lee, Hansang, Minseok Park, and Junmo Kim. "Plankton classification on imbalanced large scale database via convolutional neural networks with transfer learning." 2016 IEEE international conference on image processing (ICIP). IEEE, 2016.
9. Pouyanfar, Samira, et al. "Dynamic sampling in convolutional neural networks for imbalanced data classification." 2018 IEEE conference on multimedia information processing and retrieval (MIPR). IEEE, 2018.
10. Wang, Shoujin, et al. "Training deep neural networks on imbalanced data sets." 2016 international joint conference on neural networks (IJCNN). IEEE, 2016.
11. Lin, Tsung-Yi, et al. "Focal loss for dense object detection." Proceedings of the IEEE international conference on computer vision. 2017.
12. Wu, Heng, et al. "Measuring Surface Velocity of Water Flow by Dense Optical Flow Method." Water 11.11 (2019): 2320.

Thank You!