Segmentation of Water Channels to Measure Water Contamination Due to Trash

QR Scan

Thesis – MS Computer Science

Fezan Rasool

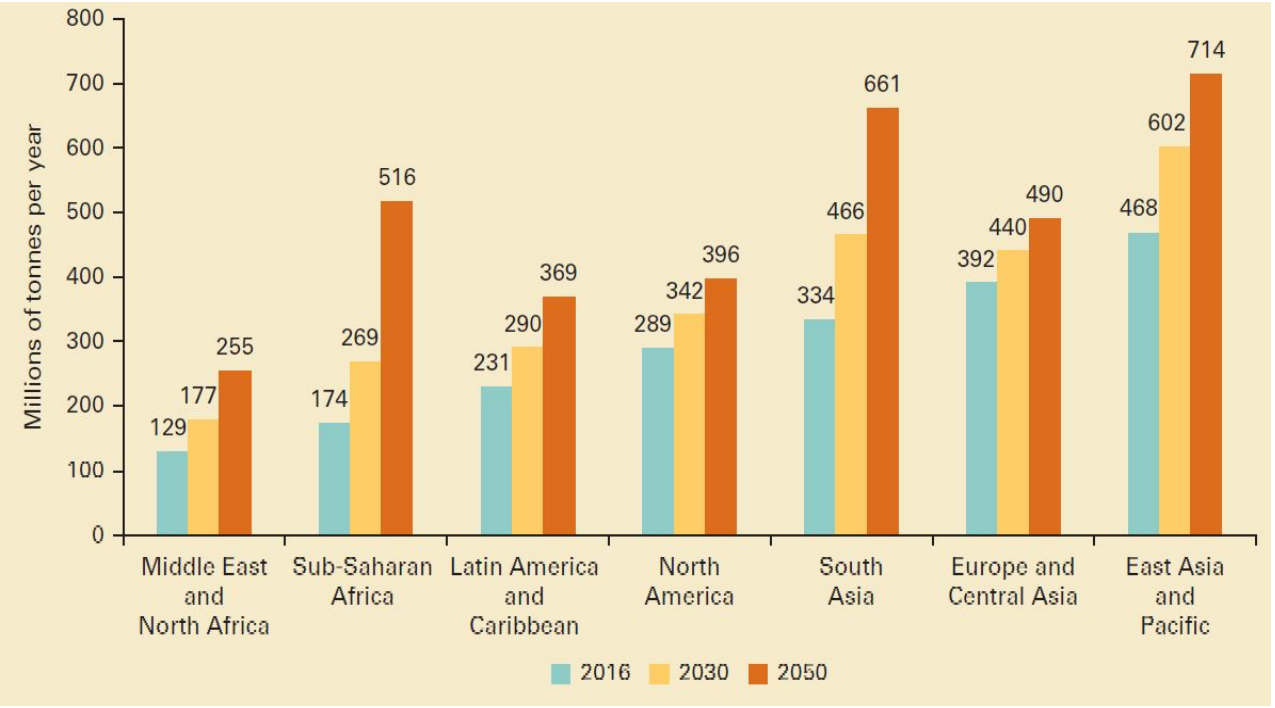
ID: 18030052

NCRA
NATIONAL CENTRE OF ROBOTICS & AUTOMATION

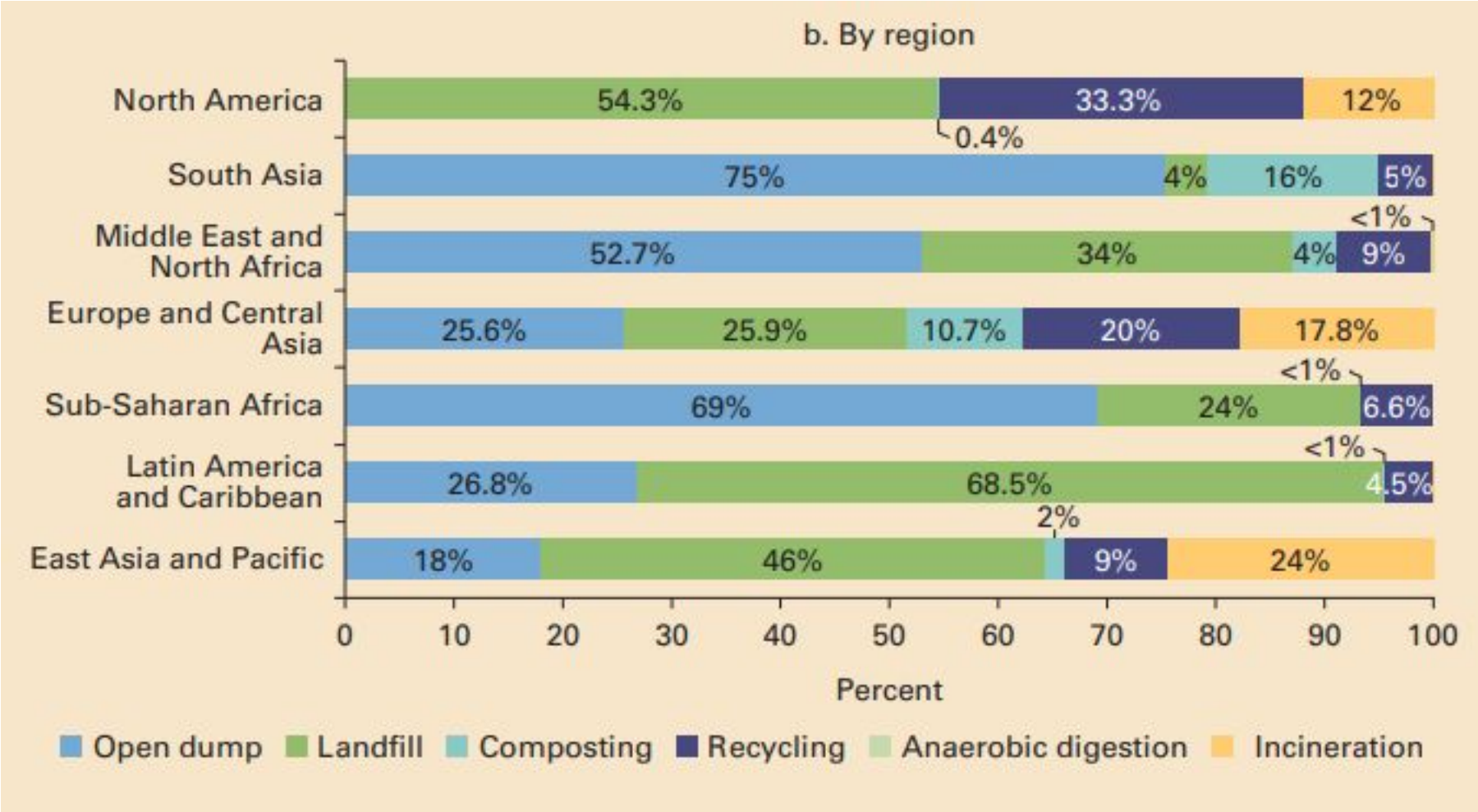
LUMS

CV Lab
LUMS

Annual Solid Waste Generation



World bank, waste 2.0 Report (2018)



World bank, waste 2.0 Report (2018)

Let's talk about our local city Lahore

According to Lahore waste management company(LWMC)

WWF 2016 “UBC” Report

Lahore generates 4500 tons/day solid waste and LWMC can operates only 2790 tons/day in the collection of waste.

What happens to the remaining trash?

The remaining trash is handled by local people

How people handle the trash

- One way is burning the trash

How people handle the trash

- One way is burning the trash

How people handle the trash

- One way is to burning trash

This is not possible because "***Punjab govt. has imposed a ban on the burning of trash under Section 144 (6) CrPC, 1898***". Due to air pollution (SMOG)

How people handle the trash

- Second way is to throw the trash into open water channels

How people handle the trash

- Second way is to throw the trash into open water channels

In worst situations

Problems caused by trash in water channels

- Marine Pollution
- Biodegradable trash damaged the agricultural land productivity
- Environmental Pollution
- Flooding

- Marine Pollution

- Marine Pollution
- Reduced Fertilized Land Productivity

- Marine Pollution
- Reduced Fertilized Land Productivity
- Environmental Pollution

- Marine Pollution
- Reduced Fertilized Land Productivity
- Environmental Pollution
- Flooding

How can we quantify trash in water channels

- One way to hire people and ask them to count the floating trash in the water channels

How can we quantify trash in water channels

- One way to hire people and ask them to count the floating trash in the water channels

“But this is not feasible”

How can we quantify trash in water channels

- Second way is to have some automatic AI+Computer Vision based solution

There are two automatic AI+Computer Vision based solutions for quantification of trash

- Trash Detection in water channel
- Segmentation of tarsh and water in water channels

Why not trash detection ?

- Trash detection give a bounding box to whole pile of trash and considers it as a single trash object.
- So it is not possible to quantify how much trash in water channels if it is jumbled up together.

Why semantic segmentation for this problem?

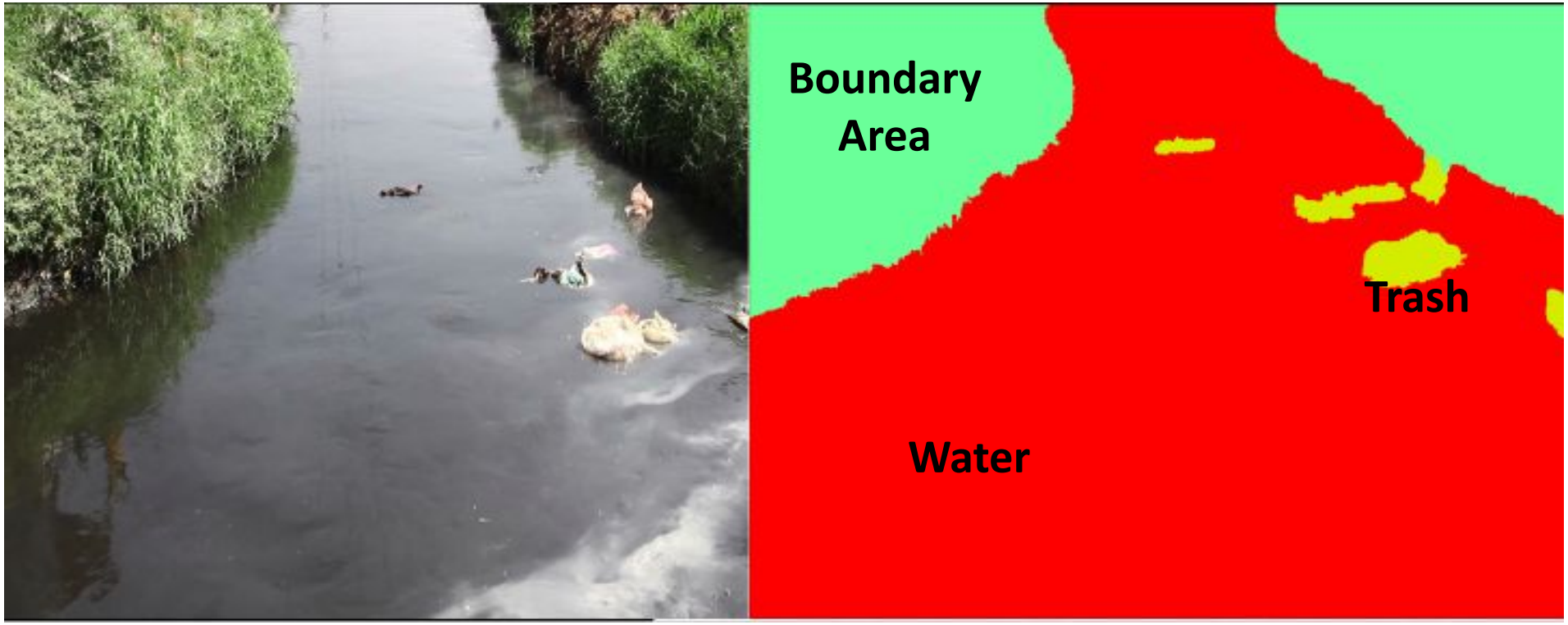
It gives label at pixel level, Which can be used to quantify that how much trash is floating on the water surface

What is semantic Segmentation

1) Input and RGB Image
2) Output: classification of each pixel of an input image

Input Image

Semantic Segmentation Mask



Dataset Collection

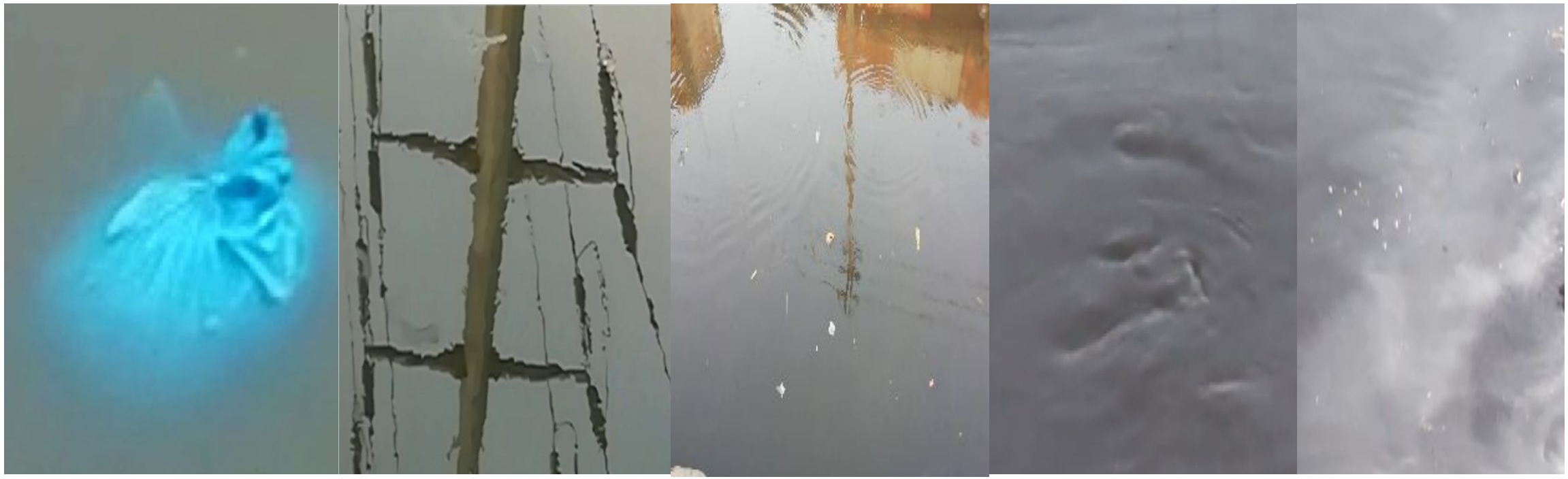
- Dataset was collected from multiple water channels of Punjab
- Annotated each frame of the dataset(Per frame annotation take almost 15 to 20 Minutes) using LabelMe[1]
- Currently I have 5500 annotated frames

Dataset Collection Points

Country	City	Name and Location of water channel	GPS Corrdinate	
			Latitude	Longitude
Pakistan	Lahore	Rohi Nala near LUMS	31.472753	74.409848
Pakistan	Lahore	Rohi Nala near Alfalah Town	31.483265	74.417278
Pakistan	Lahore	Contonment Drain near ITU backside of village	31.474366	74.341350
Pakistan	Lahore	Contonment Drain near SMA Hall Road	31.471948	74.335089
Pakistan	Lahore	Hudiara Drain near COMSET	31.398139	74.20912
Pakistan	Sheikhupura	SKP Drain near Shah Khalid Town	31.667509	74.265385

Sample Dataset with Semantic Annotation

Challenges



Submerged Object

Reflection

RainBuble & Micro trash

Swings

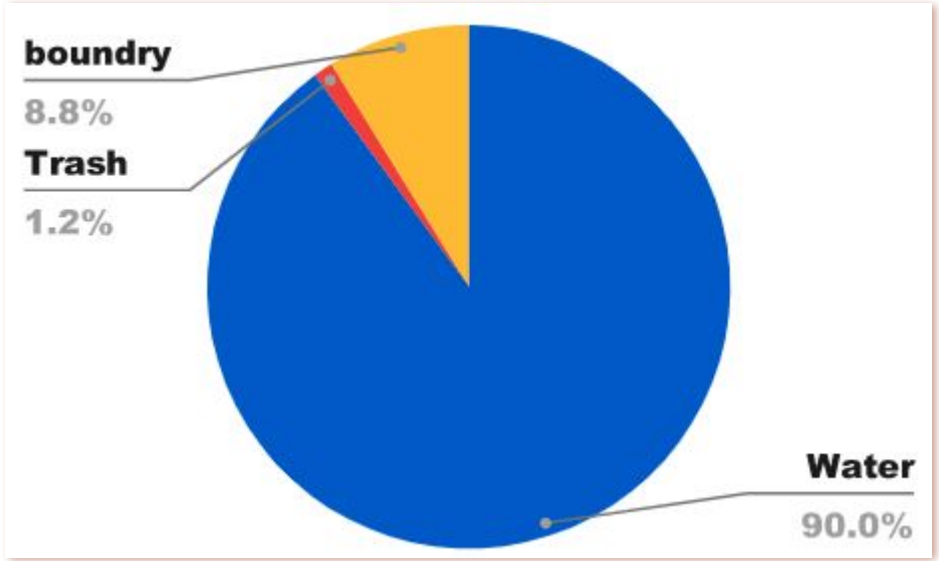
Different Color

Research Aims

This thesis aims to quantify the trash in water channels for this I have to collect a dataset of trash in water channel and also give efficient techniques to identify the trash object in water channels by semantic segmentation methodology which can be used on edge devices.

Why state of the art CNN model are not useful

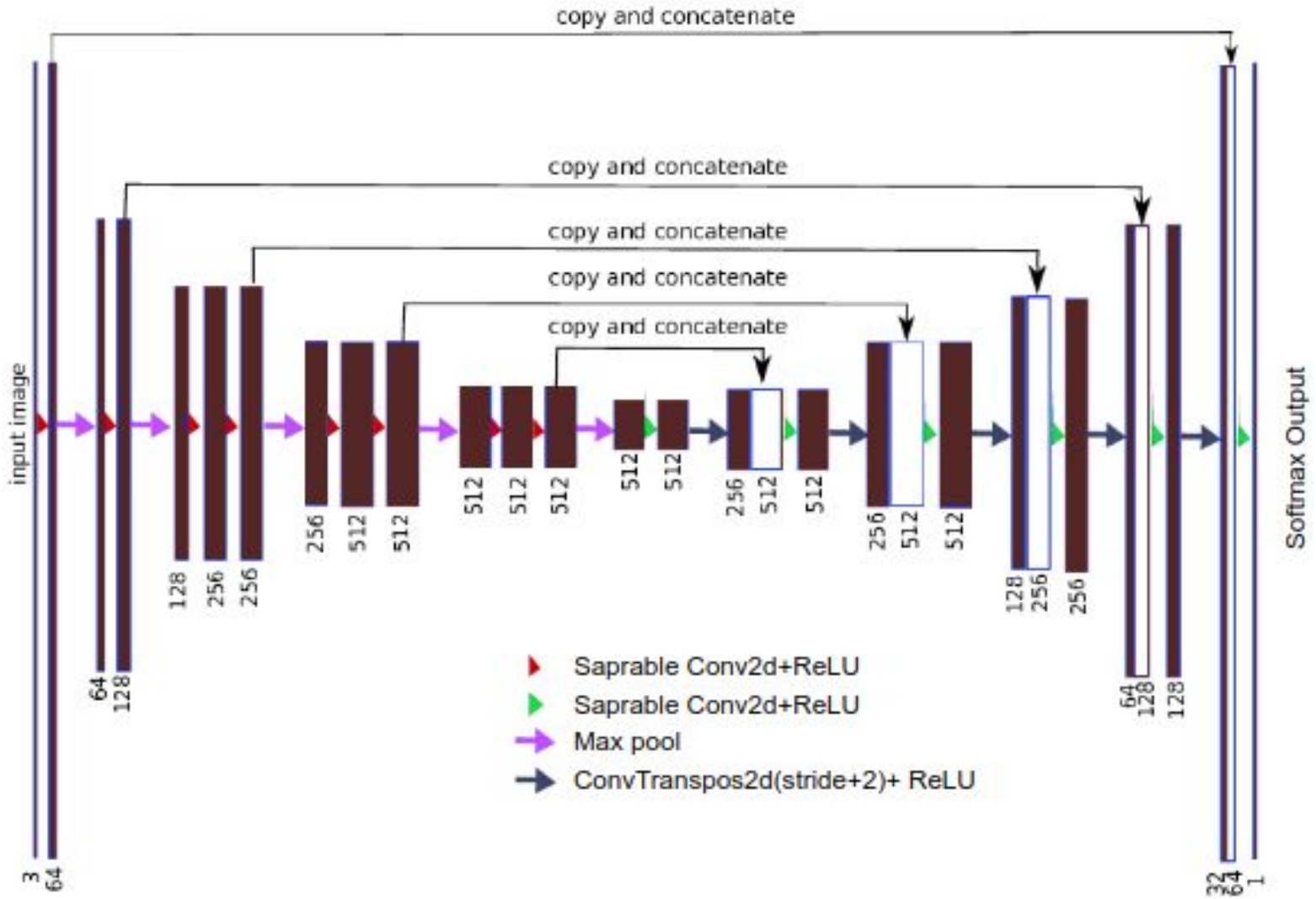
- Number of FLOPS need to performed by the CNN model is more then the edge device limitations.
- Class Imbalance Problem



Pixel Distribution

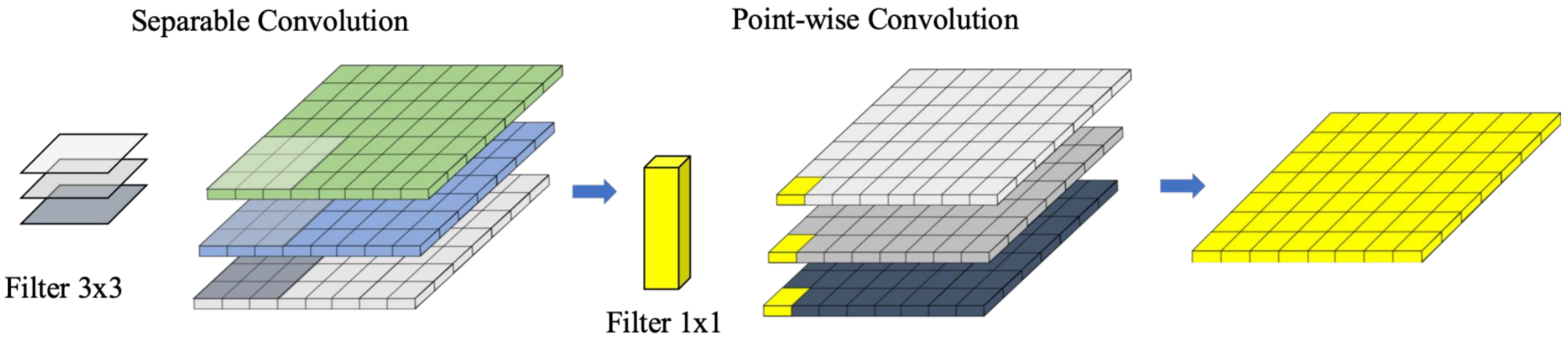
Our Design

Abstract overview of our CNN model for semantic segmentation



Layer of Model Are Separable Convolution flowed by point-wise convolution

Due to change of Convolution layer the number of Parameter is 10x reduced from stat-of-art Model



Results after applying the separable convolution

Model	**No. of Parameter in Millions**	**Accuracy**	**F1-Score**	**FPS**	**Class Level Accuracy**	
					Water	**Trash**
UNet	31	0.99	0.99	8	0.99	**0.87**
SegNet	29	0.90	0.930	8	0.90	0.88
UNET+Sep	3.9	0.986	0.987	14	0.99	0.57
SegNet+Sep	3.3	0.984	0.99	**16**	**0.99**	0.69

Problem with the separable+pointwise Convolution

As number of parameters are reduced the model overfits on the water class.

So we change the loss function

Default loss function in UNet

$$\mathrm{CE}\left(p, \hat{p}\right) = -\left(p \log(\hat{p}) + (1-p) \log(1-\hat{p})\right)$$

Weighted Cross Entropy

For imbalance dataset Weighted Cross Entropy (WCE) function is most commonly used

WCE can be defined as follows:

$$\mathrm{WCE}\left(p, \hat{p}\right) = -\left(\beta p \log(\hat{p}) + (1-p)\log(1-\hat{p})\right)$$

β=sum((1-p)/(Batch_size*Height*width)

Focal Loss Function

Focal loss tries down-weight the contribution of easy examples so that CNN focuses more on Hard examples

$$CB_f(p, y) = \alpha \sum_{j=1}^{C} (1 - p_i) log(p_i),$$

Proposed loss function

These all loss function hyperparameter values are chosen by ML Practitioner. We introduced the loss function based on inverse probability weighting of class pixels

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

Loss Function

$$\mathrm{CE}\left(p, \hat{p}\right) = -\left(p \log(\hat{p}) + (1-p) \log(1-\hat{p})\right)$$

$$\mathrm{WCE}\left(p, \hat{p}\right) = -\left(\beta p \log(\hat{p}) + (1-p) \log(1-\hat{p})\right)$$

Our Purposed loss function

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

Results

Model	# para Millions	Loss	Acc	F1 score	FPS	class-wise Acc.	
						Water	Trash
SegNet [2]	29	CE	0.90	0.93	8	0.90	0.88
Our SegNet + Sep(h)	16.8	CE	0.90	0.93	12	0.97	0.70
Our SegNet + Sep	3.3	CE	0.90	0.92	16	0.99	0.69
UNET [44]	31	CE	0.99	0.99	8	0.99	0.87
Our UNET	31	CB_f	0.990	0.99	8	0.99	0.88
Our UNET	31	CB_{ipw}	0.994	0.994	8	0.99	0.92
Our UNET+Sep(h)	18	CE	0.99	0.99	12	0.99	0.72
Our UNET+Sep(h)	18	CB_f	0.99	0.99	12	0.99	0.78
Our UNET+Sep(h)	18	CB_{ipw}	0.992	0.991	12	0.99	0.82
Our UNET+Sep	3.9	CE	0.987	0.986	14	0.99	0.57
Our UNET+ Sep	3.9	CB_f	0.99	0.99	14	0.99	0.75
Our UNET+ Sep	3.9	CB_{ipw}	0.991	0.991	14	0.99	0.81

Trash Quantification Method

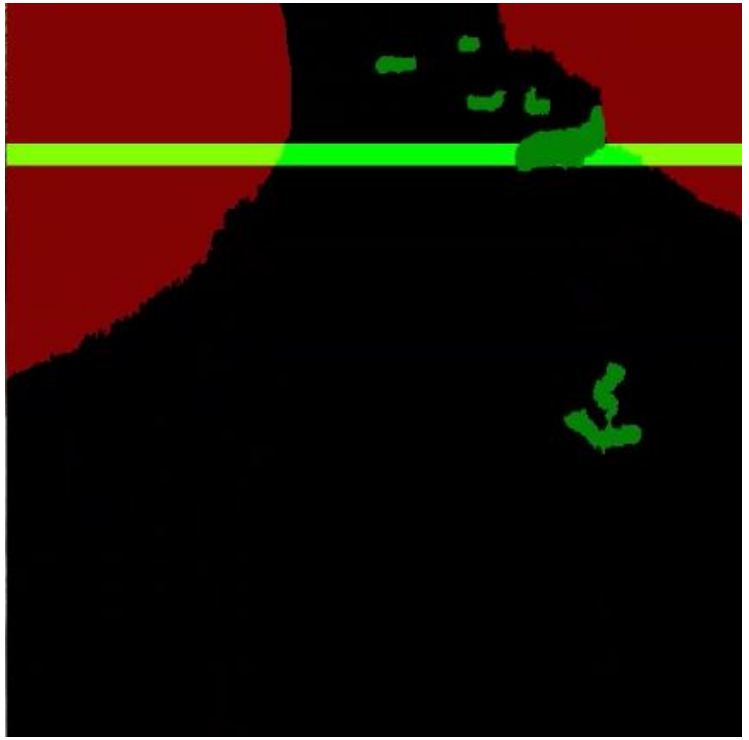
- First we take input from the user that how much width covered in the water channel in scale of feet
- Then we divide the detected water channel total pixel used in the width by received input from user, which give us the value of one pixel in the scale of feet.
- So we have one pixel in feet scale
- Then we define the patch height by checking the motion of the floating trash or water. i.e tracking the difference between same object pixel in consecutive frame.
- After that we define the patch from which the trash pixel are counted then multiply it with feet scale pixel

Trash Quantification Demo

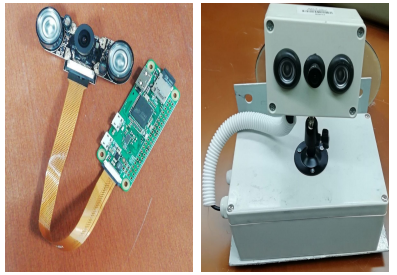
Trash Quantification Results

Detail	Quantitative Result
Total pixel float	6.9 million approx.
Total trash pixel	0.058 million approx.
Each Pixel	0.0744062 feet approx.
Total floating trash	**4351.87** feet approx.

Methodology



Camera Installation on Canal for data collection



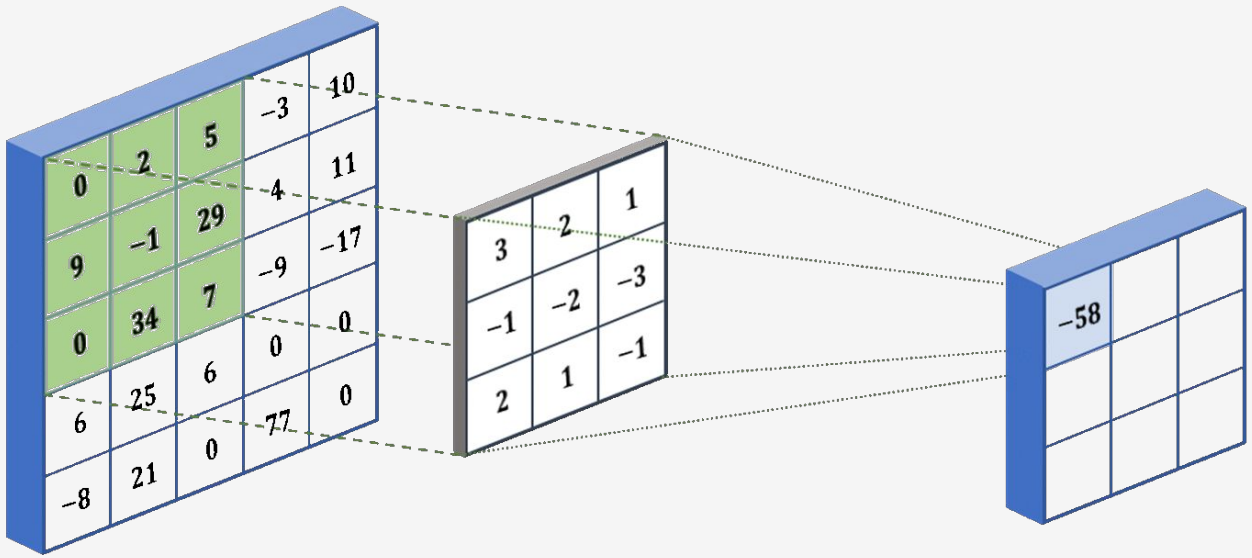
Raspberry Pi Camera node

Future Plan

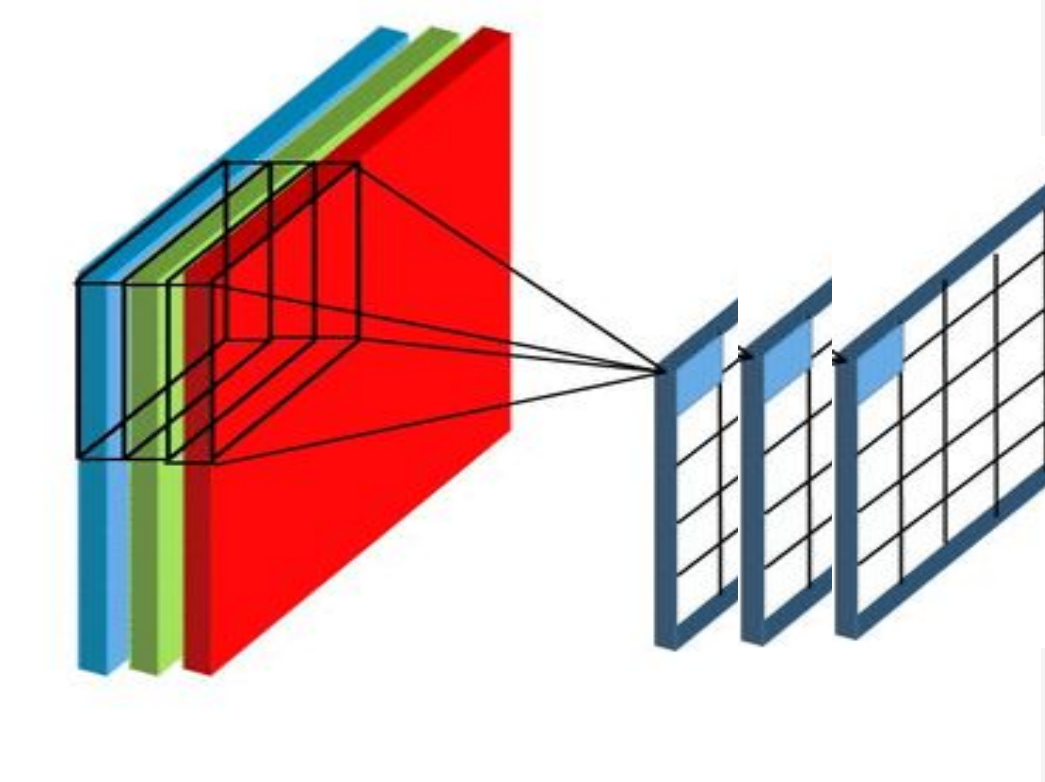
- Implement the solution in live environment using edge devices i.e raspberry pi
- After getting the analysis of different water channel we will write journal paper.

Questions?

What is Convolution Neural Network



Convolution Neural Network



Separable CNN