Class Imbalance, SMOTE, borderline SMOTE, ADASYN

Class Imbalance can put our algorithm off balance

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It was the late 1990s when Niesh V Chawla (The main brain behind SMOTE), then a graduate student at the University of South Florida was working on a binary classification problem. He was dealing with mammography images and his task was to build a classifier that will take a pixel as an input and will classify it as a normal pixel or a cancerous pixel. He was quite happy when he achieved 97% classification accuracy. His happiness was shortlived when he saw 97.6% of pixels were normal.

You may be thinking, what's the problem? There are two issues

- Let's say in a sample of 100 pixels, 98 are normal and 2 are cancerous, and if we write a program, which predicts anything to be normal. What will be the classification accuracy? A whopping 98%. **Did the program learn? Not at all.**
- There is yet another issue. The classifiers strive to get good performance in the training data and as normal observations are more, **they will concentrate on learning the pattern of the 'normal' class more.** It's just like what any student would do when they know 98% of questions will come from Algebra and 2% from Trigonometry. They will safely ignore Trignometry

So, why this problem is manifested it's because there is a great disparity between the frequency or count of the classes. **We call such a dataset to exhibit class imbalance. The normal class is referred to as the majority class and the rare class is called the minority class.**

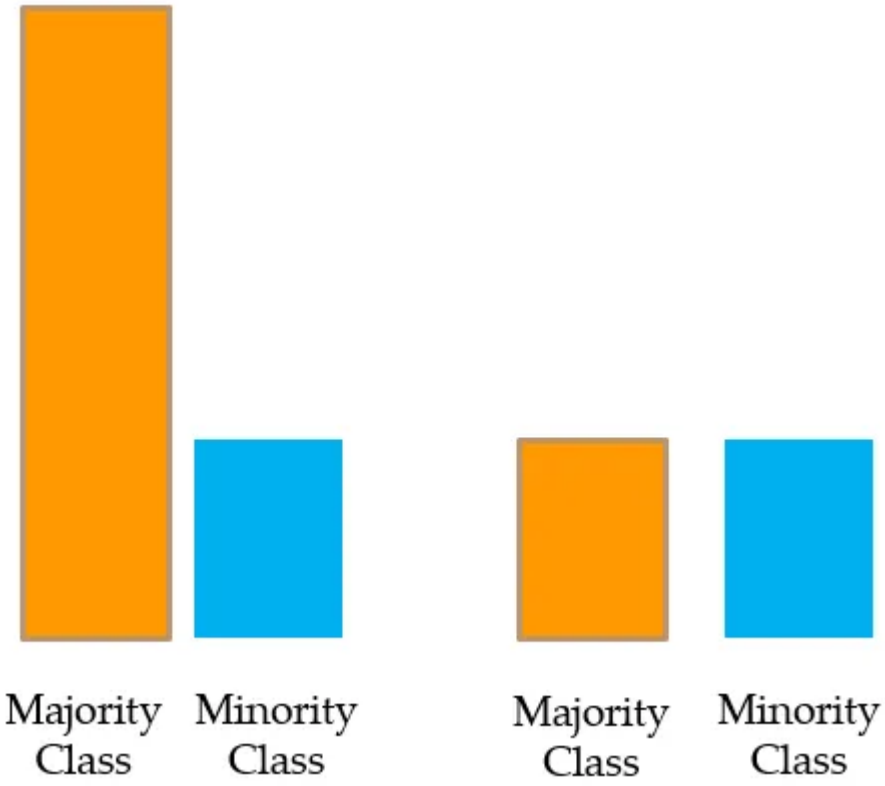
A Seagull as the minority class (https://unsplash.com/photos/SQBtDa6cKDA)

Does this exist in real-life applications? Take the example of spam detection, fake news detection, fraud detection, suspicious activity detection, intrusion detection, etc, where the class imbalance problem is manifested.

Solutions to bringing some balance:

The basic approaches are called resampling techniques. There are two basic approaches.

Undersampling:-

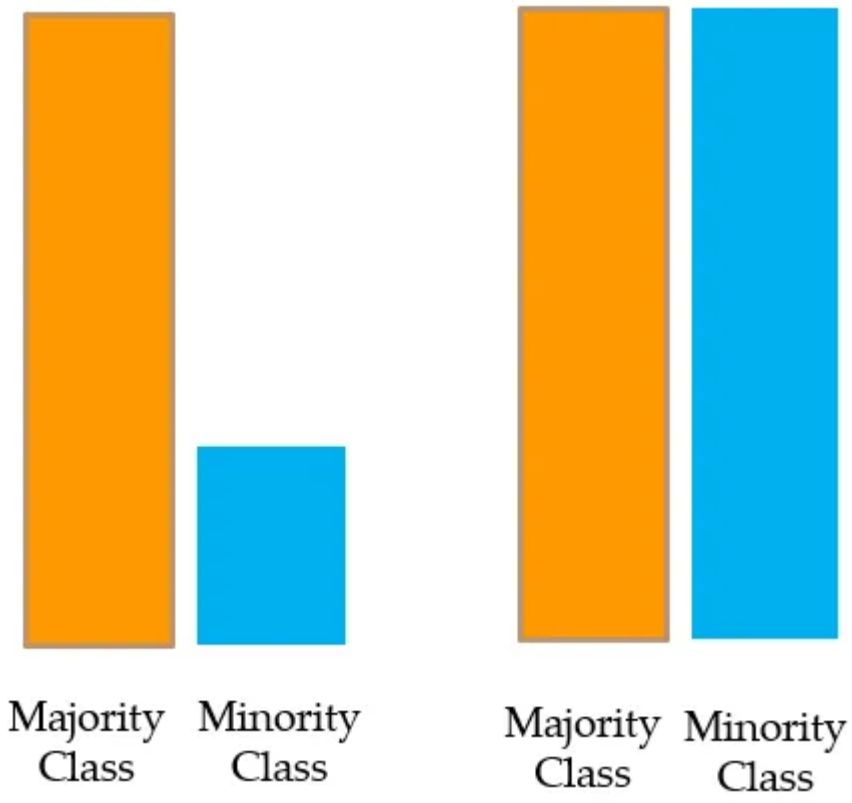


Undersampling or downsampling the majority class (Image Source Author)

We pick random samples from the majority class and make it equal to the minority class count. This is called the **undersampling or downsampling of the majority class.**

Issue: **It's not a good idea to ignore or let go so much of original data.**

Oversampling:-



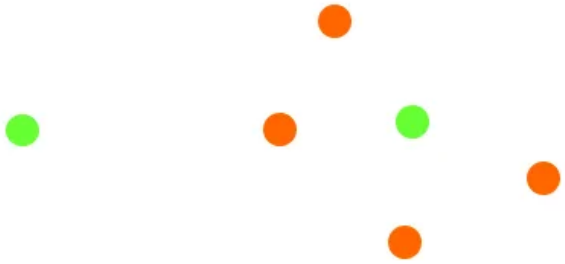
Oversampling or upsampling the minority class (Image Source Author)

Here, sampling with replacement is applied to the minority class to create as many observations as there are in the majority class and the two classes are balanced. This is called **oversampling or upsampling** the minority class.

Issue: **Repetition of the same minority class data leads to overfitting.**

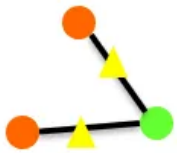
SMOTE:

The full form of SMOTE, **S**ynthetic **M**inority **O**versampling **Te**chnique. Here Synthetic observations are generated from the Minority class



Step 1:
Identify a point from the minority class

Step 2:
Identify it's nearest neighbors. (Here 4 neighbors are taken. All minority neighbors)



Step 3:
Assume we want to add 2 times more synthetic observations
Select 2 nearest neighbor randomly
Draw a line between the point and the selected neighbors
Create a synthetic observation along the line

SMOTE, Synthetic Minority Observation Generation Process (Source: Author)

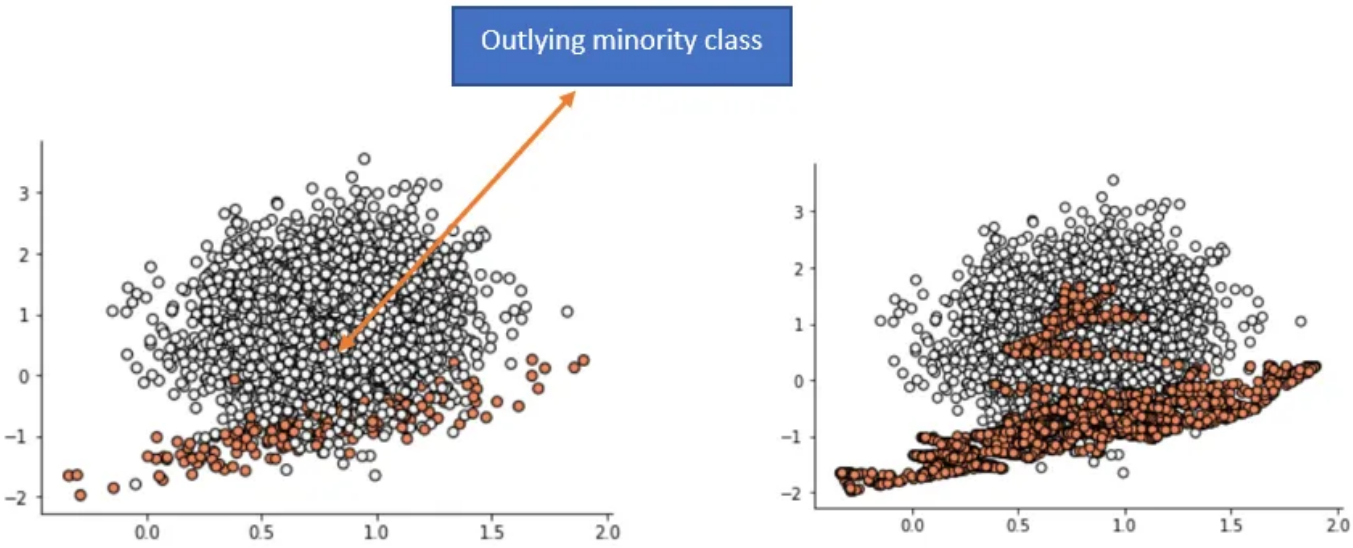
Let there be two observations (x1,y1) and (x2,y2) from the minority class. As a first step, a random number between 0 and 1 is created, let's call it r. The synthetic point will be (x1 + r*(x2 -x1), y1 + r*(y2 -y1)). It's illustrated further with the following example.

Original Data Points	
Attr 1	Attr 2
6	4
4	3

Synthetic Data Points		
r	Attr 1	Attr 2
0.2	5.6	3.8
0.5	5	3.5
0.8	4.4	3.2

Synthetic points generate from minority class (Image Source: Author)

An issue with SMOTE:

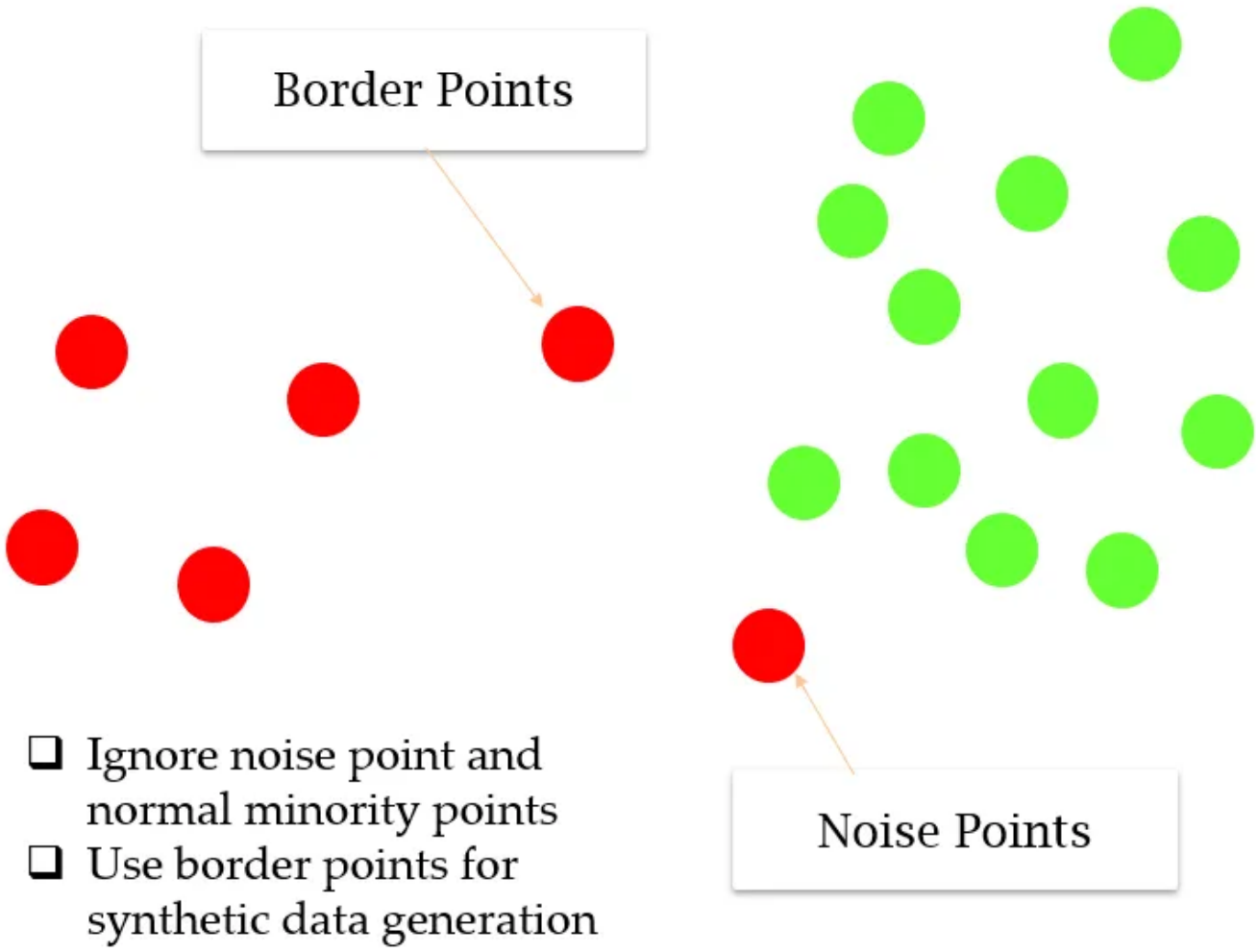


Left Side: Original Data Right Side: Data after SMOTE is Applied (Image Source: Author)

If there are observations in the minority class which are outlying and appears in the majority class, it causes a problem for SMOTE, by creating a line bridge with the majority class.

Borderline SMOTE:-

This solves the above issue.



Border Line SMOTE : (Image Source Author)

This algorithm starts by classifying the minority class observations. It classifies any minority observation as a noise point if all the neighbors are the majority class and such an observation is ignored while creating synthetic data (Similar to DBSCAN). Further, it classifies a few points as border points that have both majority and minority class as neighborhood and resample completely from these points (Extreme observations on which a support vector will typically pay attention to).

Issue: End up giving more attention to these extreme observations.

ADASYN:

ADASYN is a more generic framework, for each of the minority observations it first finds the impurity of the neighborhood, by taking the ratio of majority observations in the neighborhood and k.

Minority Class	Minority Neighbours	Majority Neighbours	Impurity Ratio
Obs 1	3	2	.6
Obs 2	4	1	.4
Obs 3	1	4	.8
Obs 4	5	0	0

ADASYN Impurity Ratio

Now, first of all, this impurity ratio is converted into a probability distribution by making the sum as 1. Then higher the ratio more synthetic points are generated for that particular point. **Hence the number of synthetic observations to be created for Obs 3 is going to be double that of Obs 2.** So it's not so extreme as Borderline SMOTE and the boundary between the noise point, border point, and regular minority points are much softer. (Not a hard boundary). Thus the name adaptive.

This is also explained in the following video tutorial, please give it a watch

Endnote:

Class Imbalance is a very practical problem. Resampling-based approaches not promising, which motivated researchers to develop SMOTE, which was gradually improved by borderline SMOTE, ADASYN, etc. For learning about more of the variants reference 2 is a great read.

Reference

[1] Chawla NV, Bowyer KW, Hall LO, Kegelmeyer WP. SMOTE: synthetic minority over-sampling technique. Journal of artificial intelligence research. 2002 Jun 1;16:321–57.

[2] Fernández A, Garcia S, Herrera F, Chawla NV. SMOTE for learning from imbalanced data: progress and challenges, marking the 15-year anniversary. Journal of artificial intelligence research. 2018 Apr 20;61:863–905.

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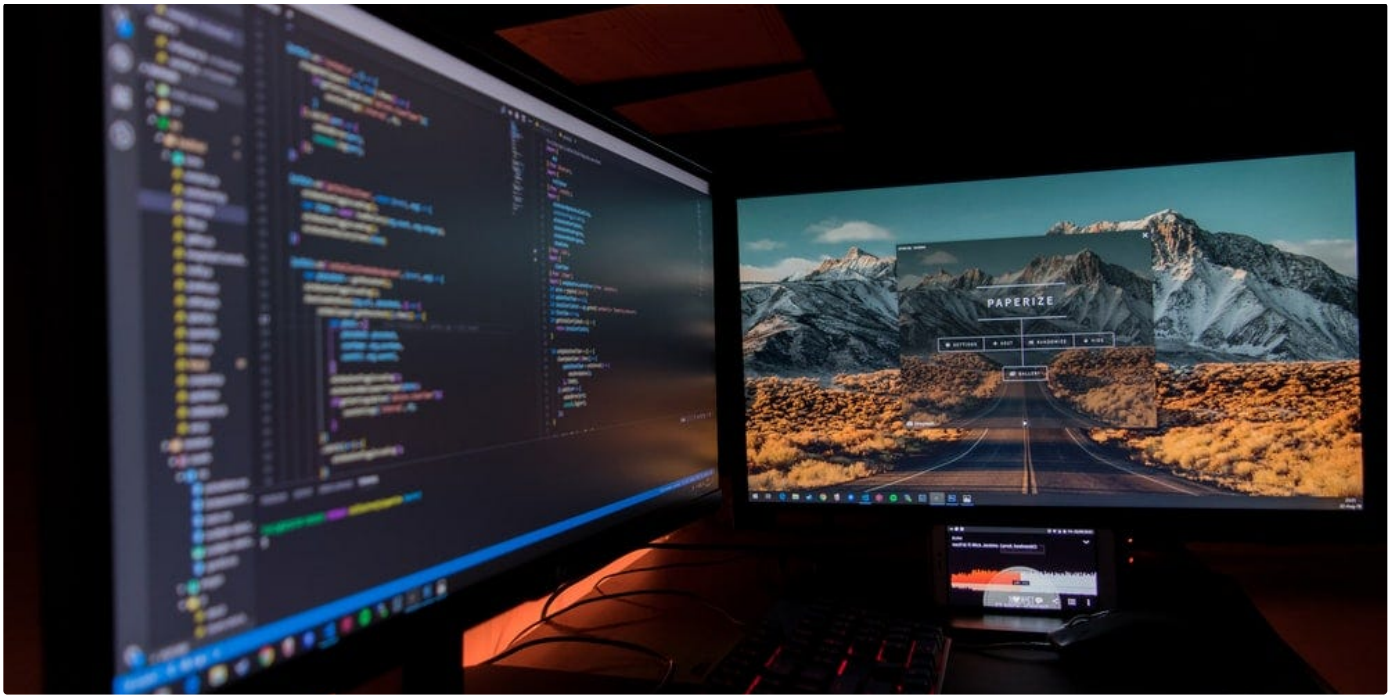

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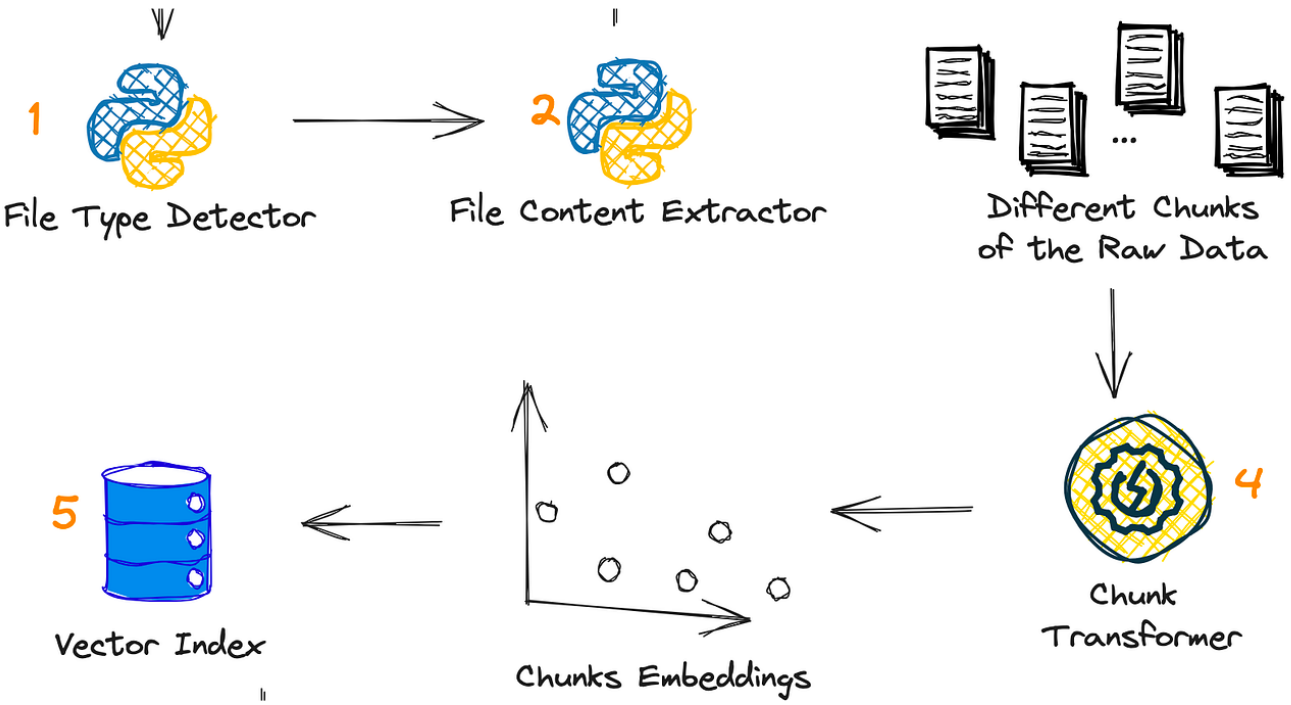

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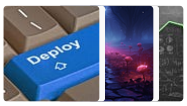

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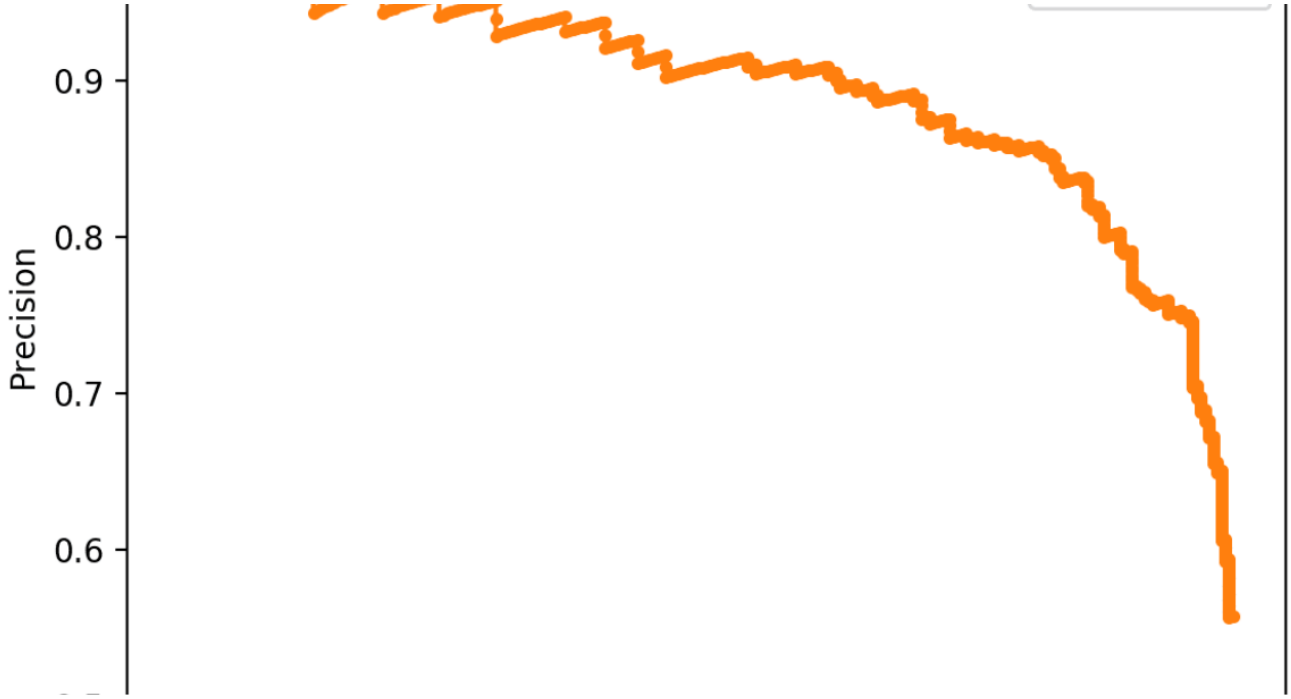

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