Using AI to Predict Server Hard Drive Failure

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What's the **Problem?**

- A datacenter contains servers which contain hard drives, used to store application data

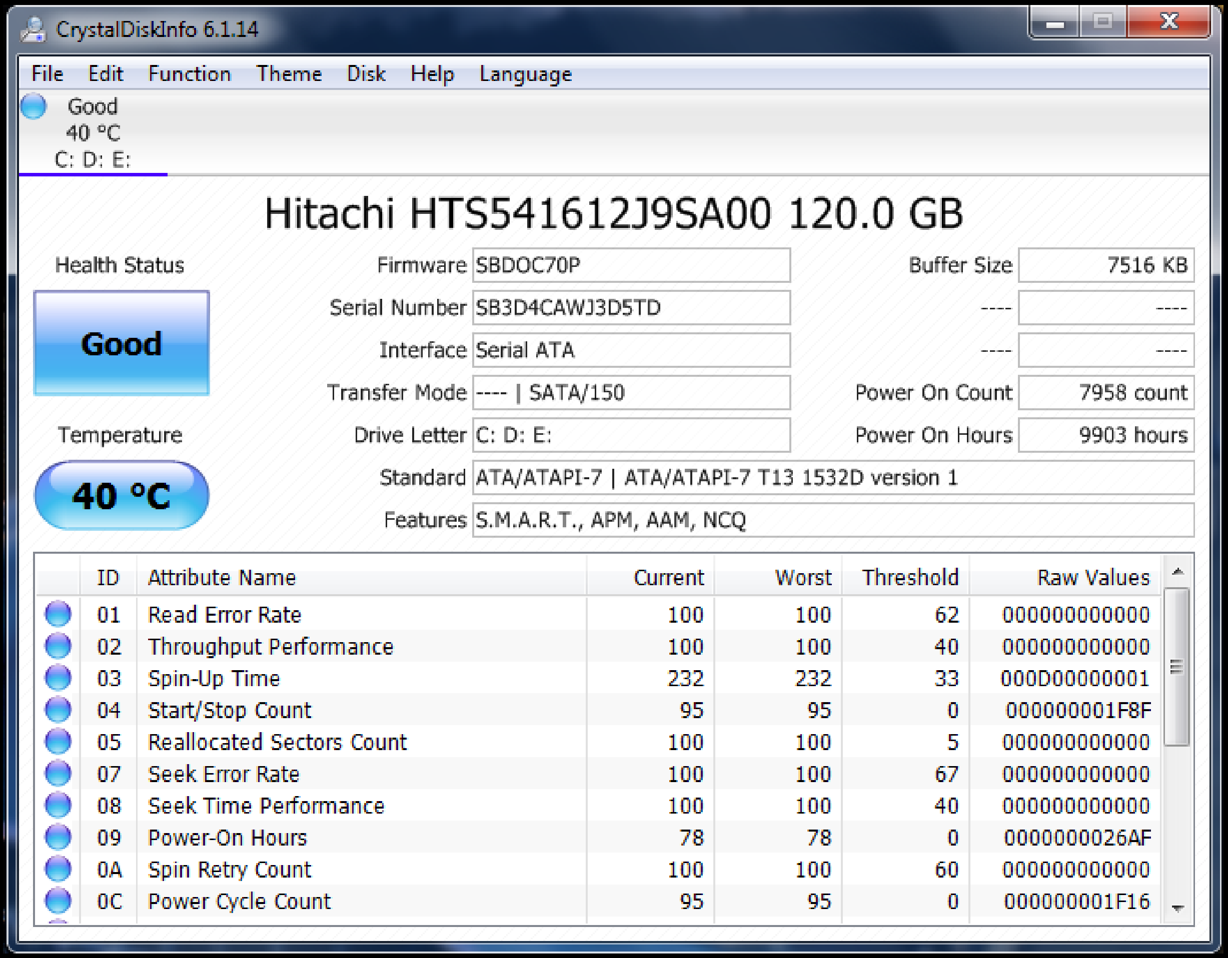
- For 98% of companies, one hour of downtime costs **over $150,000**

  Source: ITIC 2017-2018 Global Server Hardware, Server OS Reliability Survey

- Server operators rely on arbitrary rules or wait for failure to replace drives

- **What if we could predict hard drive failures?**

A S.M.A.R.T.er Solution



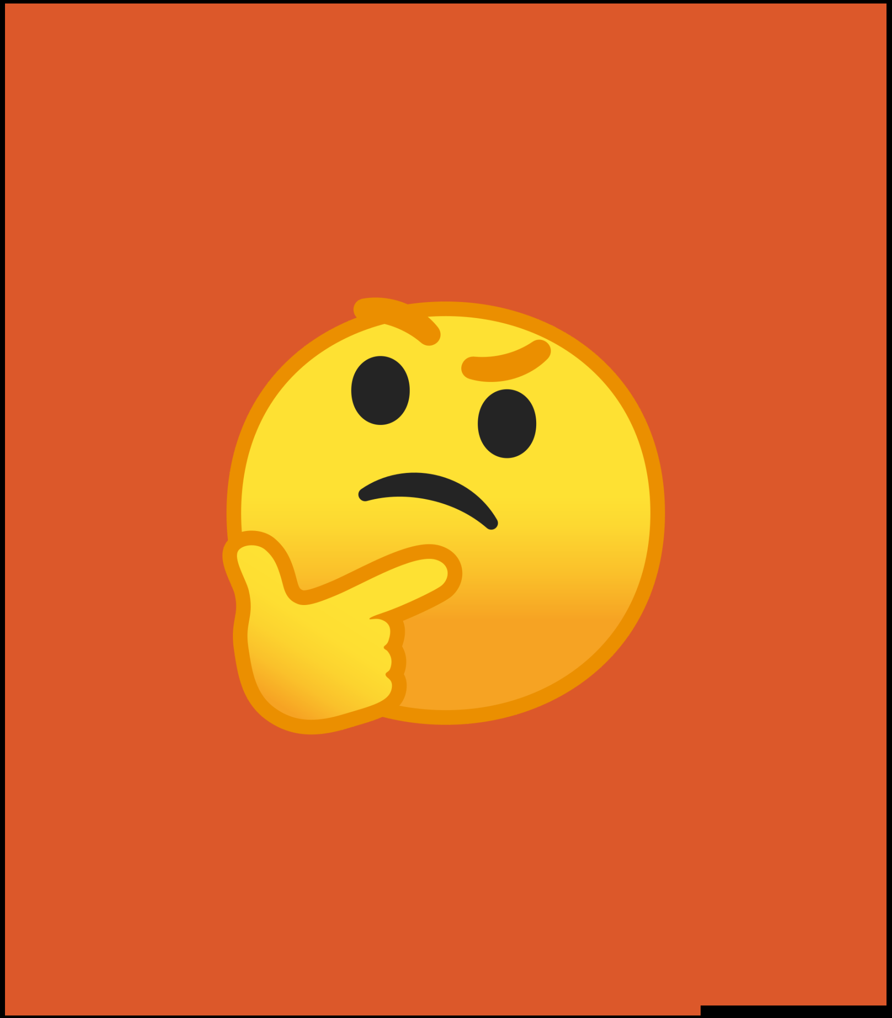
Modern hard drives provide S.M.A.R.T. stats

Self-monitoring

Train and test predictive models

So Many Questions...

1. What are the most important features to consider?
2. How accurate can classifiers get?
3. Can models be ported to other drives?



Backblaze's Dataset

Backup company provides S.M.A.R.T. and failure stats for its hard drives, from Q1 2019 to Q3 2021

Daily snapshots of >175,000 disks' stats, 131 columns of data

date	serial_number	model	capacity_bytes	failure	smart_1_normalized	smart_1_raw	...
2021-04-01	ZHZ65F2W	ST1200NM0008	12,000,138,625,024	0	82	159,565,280	...
2021-04-01	ZLW0EGC7	ST12000NM001G	12,000,138,625,024	0	74	22,618,672	...
2021-04-01	ZA1FLE1P	ST8000NM0055	8,001,563,222,016	0	82	167,665,584	...
...	...	...	...	...	...	...	...

The Stuff We Used

12-core Intel Core
i7-9750H, 2.60GHz

16 GB RAM

Pop_OS! 21.04

Anaconda 4.10.3

Python 3.8.12

NumPy, Pandas, Ruptures,
Scikit-learn, Multiprocessing

Visual Studio Code

Jupyter Notebook

Which Models Should We Study?

Q1 2020 Dataset

	count	unique	fail_count	failure_rate	missing_stats
ST8000DM004	209	2	1	0.4785%	4
TOSHIBA MQ01ABF050	39,102	413	39	0.0997%	9
...	...	...	...	...	...
ST4000DM000	1,744,529	19,142	68	0.0039%	5
ST12000NM0008	750,681	10,876	29	0.0039%	6
ST12000NM0007	3,368,588	36,997	126	0.0037%	6

ST4000DM000 It Is!

- One of the **most used drives**
- **High failure rate**
- Reports **nearly all S.M.A.R.T. stats**

No Stats For You!

```
df.isnull().sum().sort_values(ascending=False).head(72)
```

smart_255_raw	132,339
smart_250_normalized	132,339
smart_15_raw	132,339
smart_15_normalized	132,339
...	...
smart_183_raw	112,270
smart_8_raw	94,583
smart_8_normalized	94,583

Q1_2020 Dataset (132,339 rows)

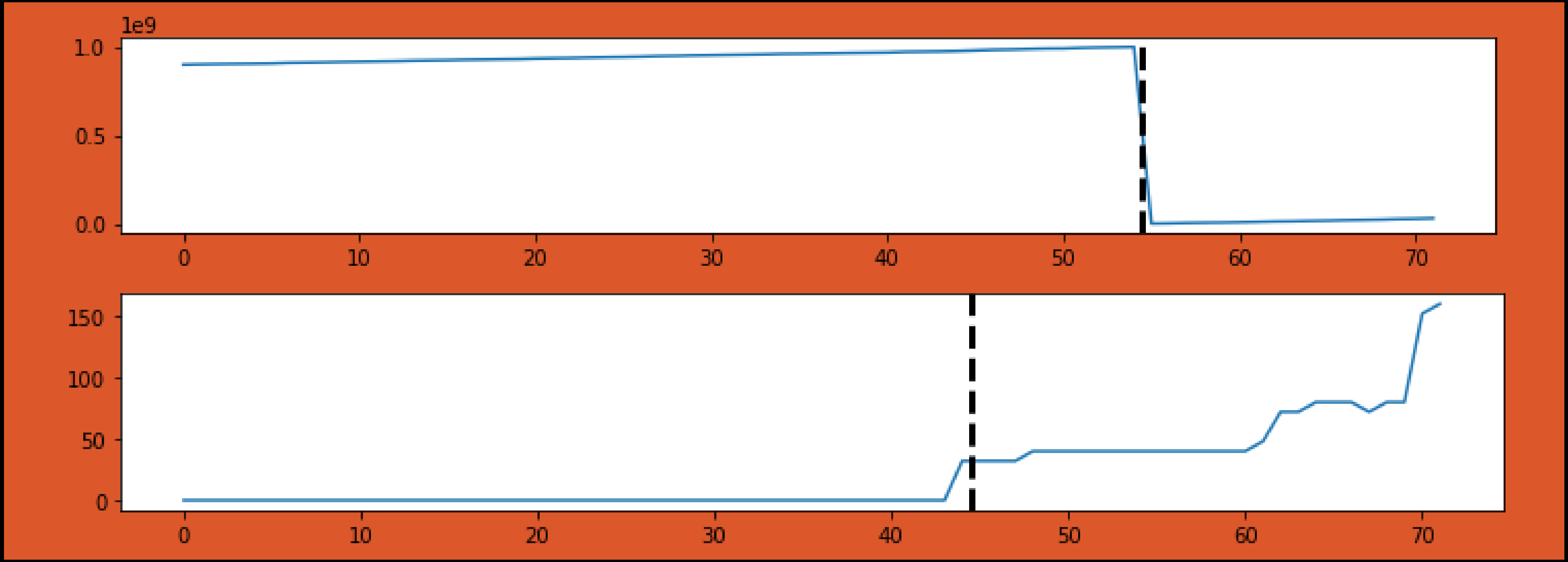
The Quest for Relevancy

RQ1: Which S.M.A.R.T. stats must be considered?

- Dataset: **Q1 2019** to **Q4 2020**
- **615** failed ST4000DM000 drives
- Up to **60 days** of data before failure

Change Is Now

ruptures: change point detection in Python, Truong et al., 2018



Seek Error Rate (SMART_7_RAW), Off-line Uncorrectable (SMART_198_RAW)

The Results (Number 4 Will Shock You)

Analysis ran on 615 failed drives, from Q1 2019 to Q4 2020 (last 60 days)

Name	Description	Frequency
smart_242_raw	Total LBAs Read	43.74%
smart_9_normalized	Power-On Hours Count (Norm.)	42.44%
smart_241_raw	Total LBAs Written	42.28%
smart_7_raw	Seek Error Rate	33.66%
smart_7_normalized	Seek Error Rate (Norm.)	25.69%
smart_193_raw	Load/Unload Cycles	21.46%
smart_187_{raw,normalized}	Reported Uncorrectable Errors	15.12%
smart_197_raw	Current Pending Sectors	15.12%
smart_198_raw	Off-line Uncorrectable	15.12%
...and 19 more	including Reallocated Sectors	>1.00%

Be Accur8 M8

RQ2: How accurate can models get?

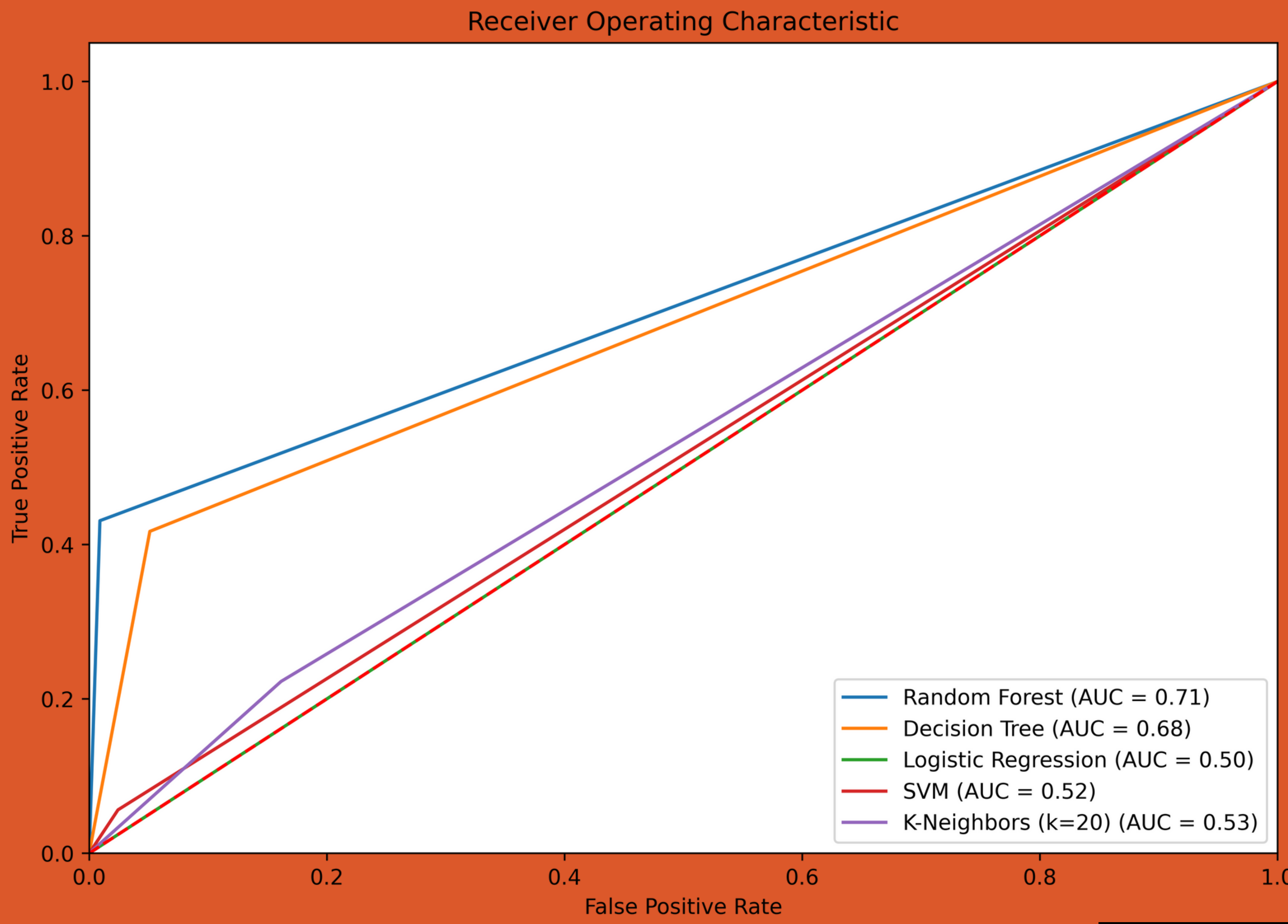
- Training set: Q1 2019 to Q4 2020
- Testing set: Q1 & Q2 2021
- Dataset processing: **backtracking**
  failure = 1 up to 15 days before actual failure
- Low failed drive count: **sampling**
  1/3 failed drives, 2/3 healthy drives

The Accuracy of this... Classifier

RQ2: How accurate can models get?

	Accuracy	Recall	F1-Score
Random Forest	**0.8138**	**0.4309**	**0.5942**
Decision Tree	0.7807	0.4170	0.5461
Logistic Regression	0.6836	0.0000	0.0000
SVM	0.6848	0.0562	0.1014
K-Neighbors (k = 20)	0.6436	0.2225	0.2832
K-Neighbors (k = 2)	0.6513	0.1114	0.1682

Dwayne "The ROC" Johnson



Takeaways

Thank you for listening :)

Discussions

- Possible to predict disk failures using common classifiers
- Many factors are at play
- Slight clustering of failed disks, as shown by K-Neighbors
- Low recall and F1-Score overall

Limitations

- Analysis limited by chosen S.M.A.R.T. attributes
- Single drive model
- No real time-series approach

Next steps

- Answer RQ3: how do these classifiers fare on other drives?
- Try more classifiers/models
- Try other drives
- Expand dataset to Q3 2021