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Toward the Detection of Polyglot Files

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What is a Polyglot?

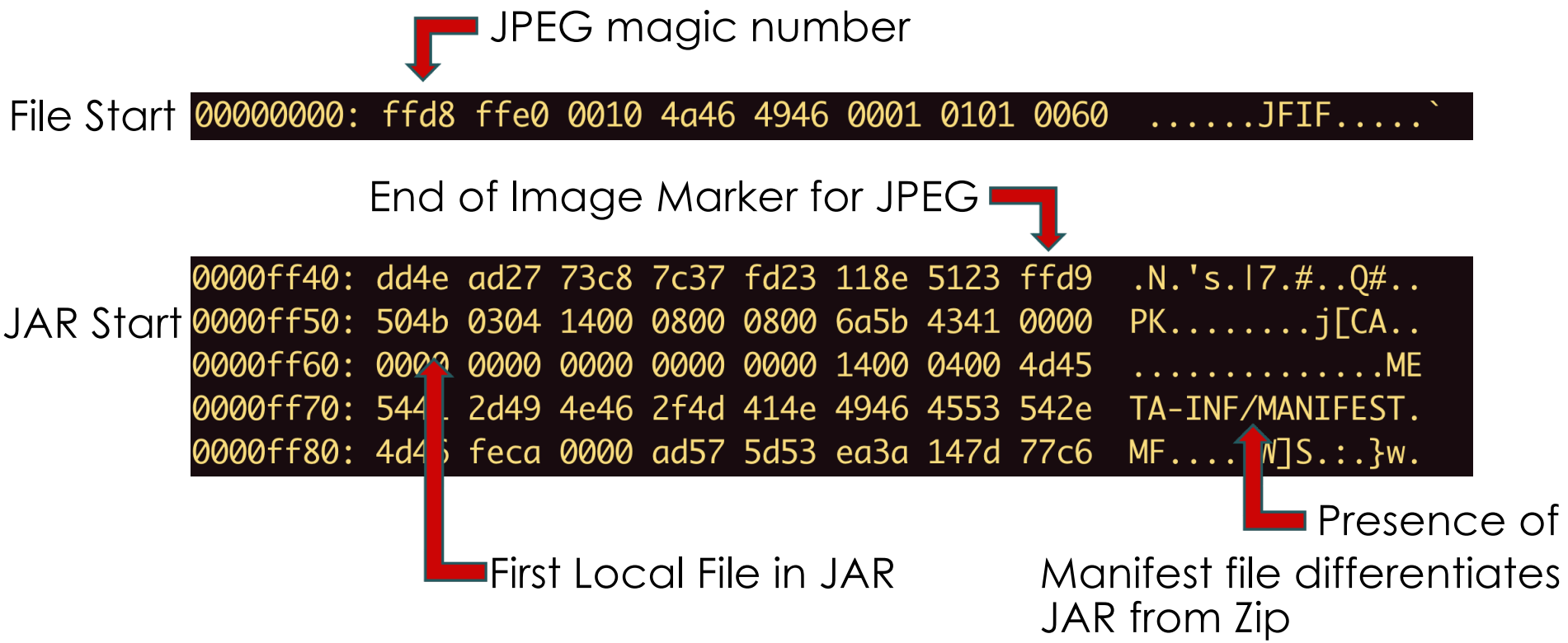
- A single file that is fully valid in two different formats
- Example: JPG+JAR polyglot can execute Java code or yield an image depending on the interpreting program.
- Danger: Interpreting programs simply ignore content from second format
- Large-scale analysis of leading commercial malware detectors revealed failure to detect 100% of polyglot malware in data set[1]

[1]Robert A Bridges, Sean Oesch, Miki E Verma, Michael D Iannacone, Kelly MT Huffer, Brian Jewell, Jeff A Nichols, Brian Weber, Justin M Beaver, Jared M Smith, et al . 2020. Beyond the Hype: A Real-World Evaluation of the Impact and Cost of Machine Learning-Based Malware Detection. arXiv preprint arXiv:2012.09214 (2020).

Generating Polyglots

- Open-source *Mitra* tool combines compatible files into polyglots
  - Created by Ange Albertini
  - https://github.com/corkami/mitra
- Creates 4 types of polyglots from pairs of donor files
  - Stacks: file 2 appended to end of file 1
  - Parasites: file 2 placed inside comment markers of file 1
  - Zippers: both files placed within each other's comment markers
  - Cavities: file 2 placed inside padding space of file 1
- *Mitra* attempts all 4 types of combination on each pair of files

Hexdump of JPEG+JAR Stack-type Polyglot



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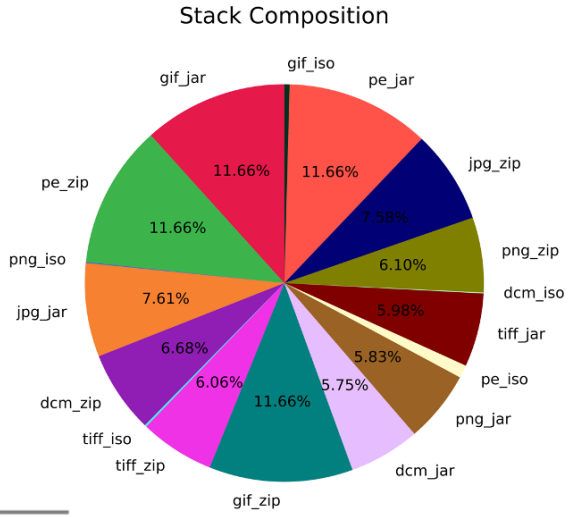
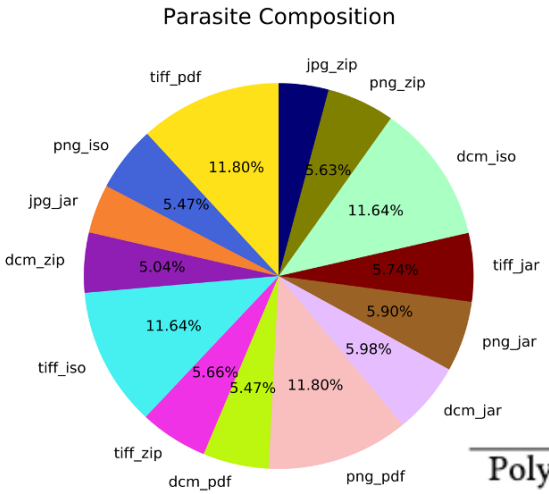
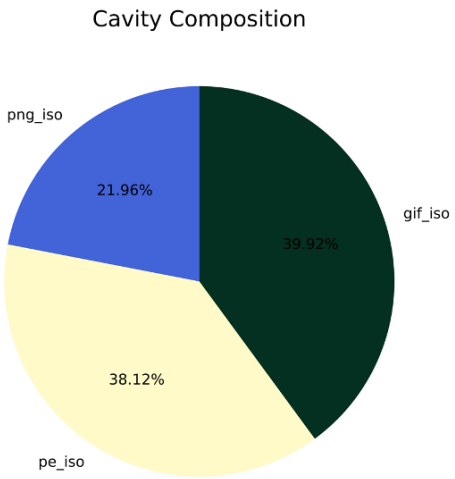
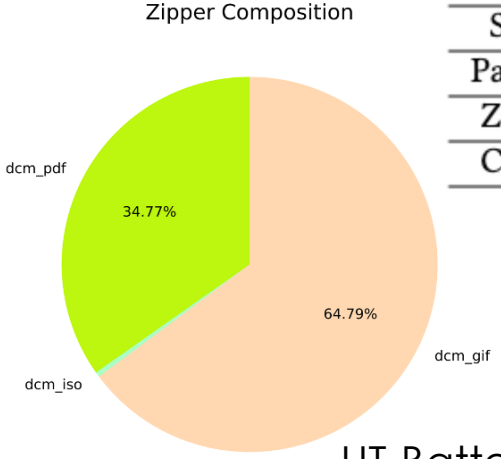
Polyglot Data Set for ML/DL Training





Data Set	Train	Test
Monoglot	31,199	7,799
Polyglot	25,210	6,303





Polyglot Type	Train	Test
Stack	10,267	2,574
Parasite	10,301	2,542
Zipper	1,795	463
Cavity	2,847	724

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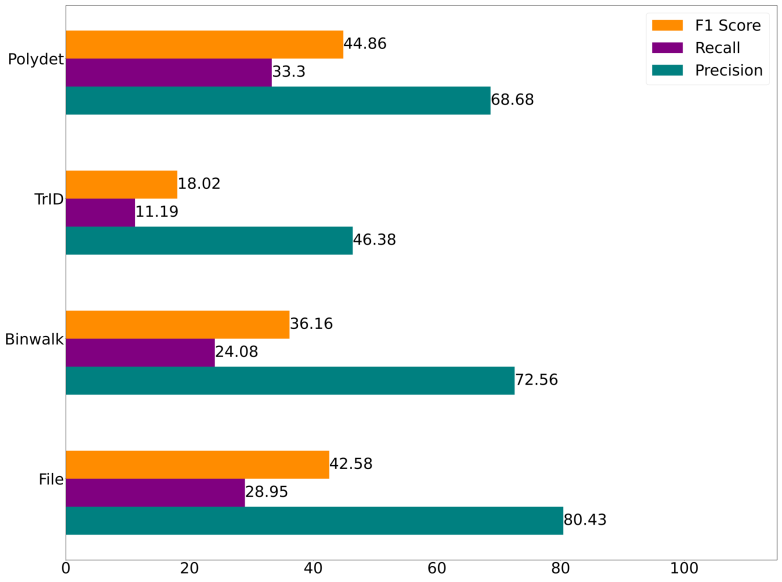
Existing Tools for Polyglot Detection

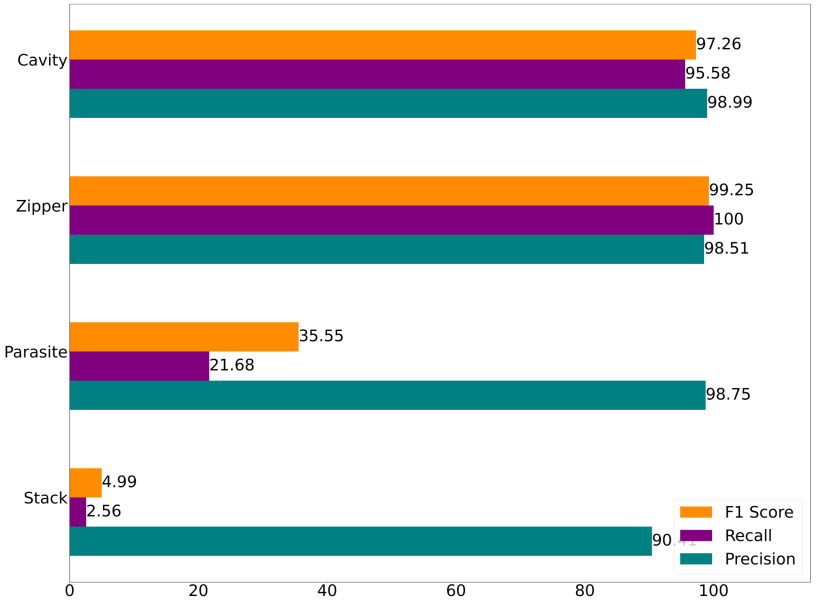
- *File* is the ubiquitous tool for identifying a file's format
- *TrID* is a similar tool used by Virustotal
- *Binwalk*, a file carving utility, has been used to detect polyglots
- *Polyfile*, a DARPA-funded tool, is a utility designed to analyze the structure of abnormal files, including polyglots

Existing Tool Performance

Recall, precision, F1 score for all 4 tools



Breakdown of *file* utility's performance



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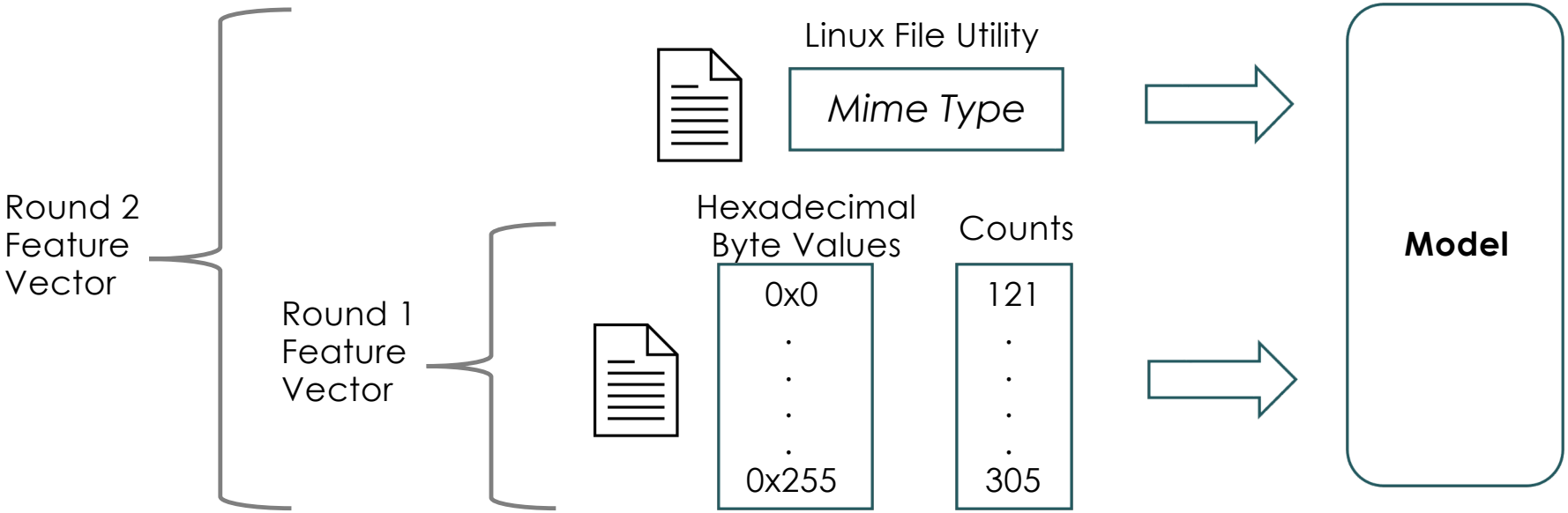
Machine Learning – Input Features



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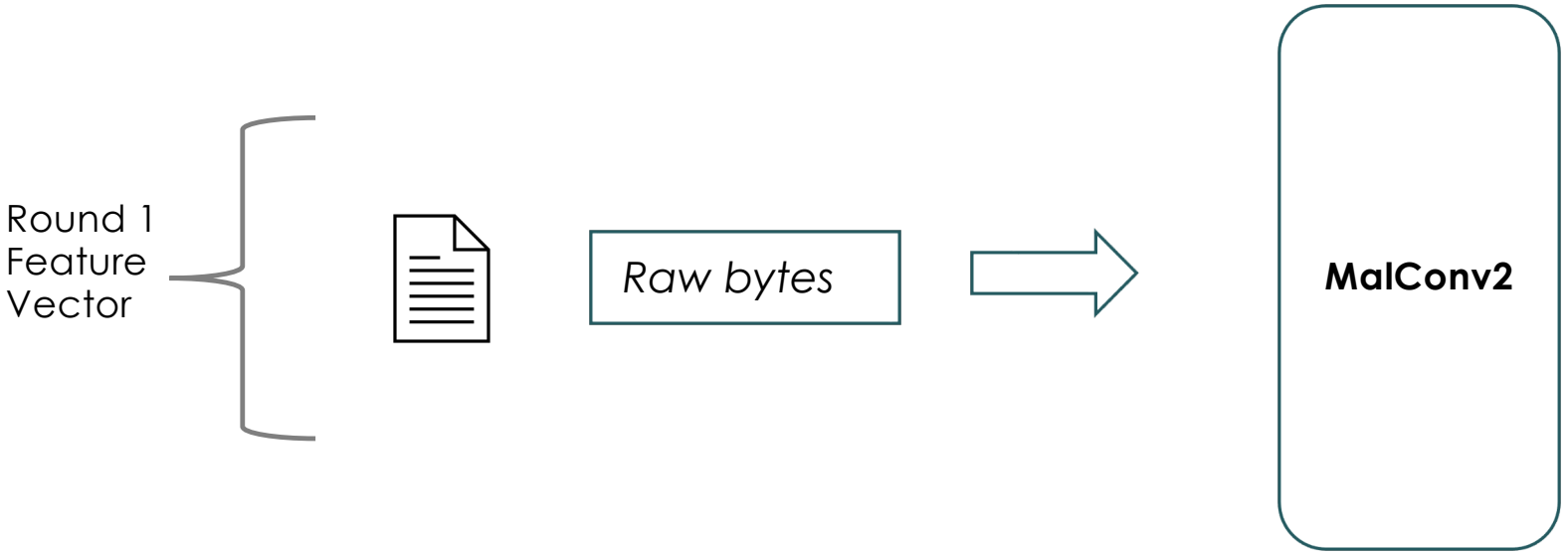
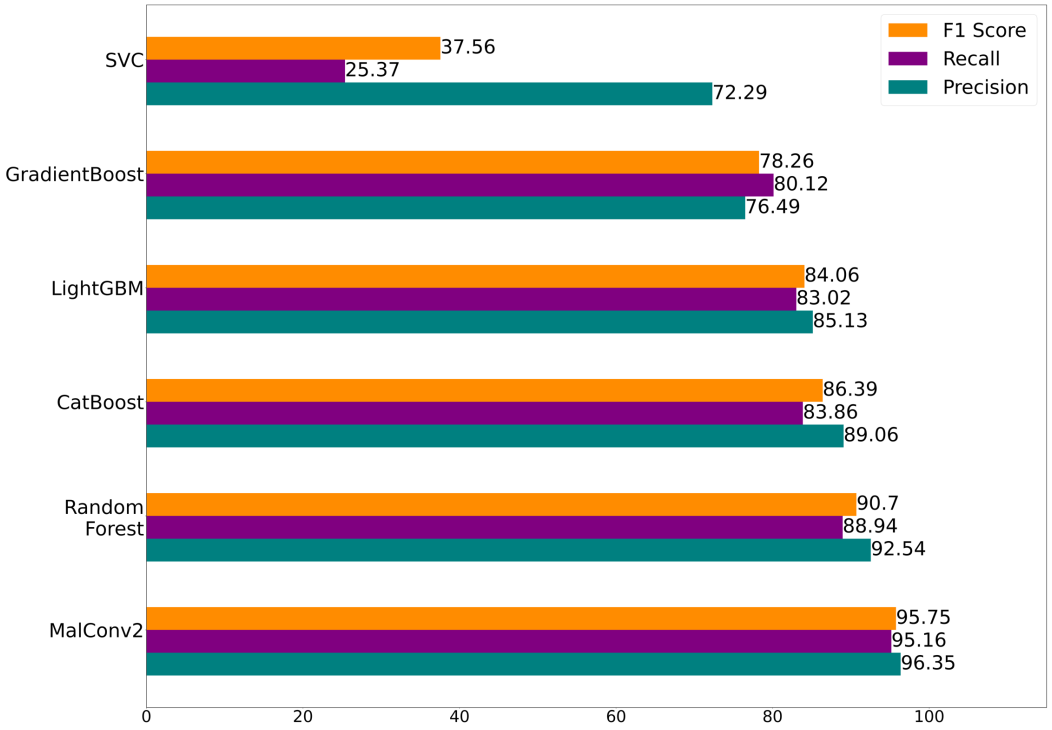
Deep Learning – Input Features



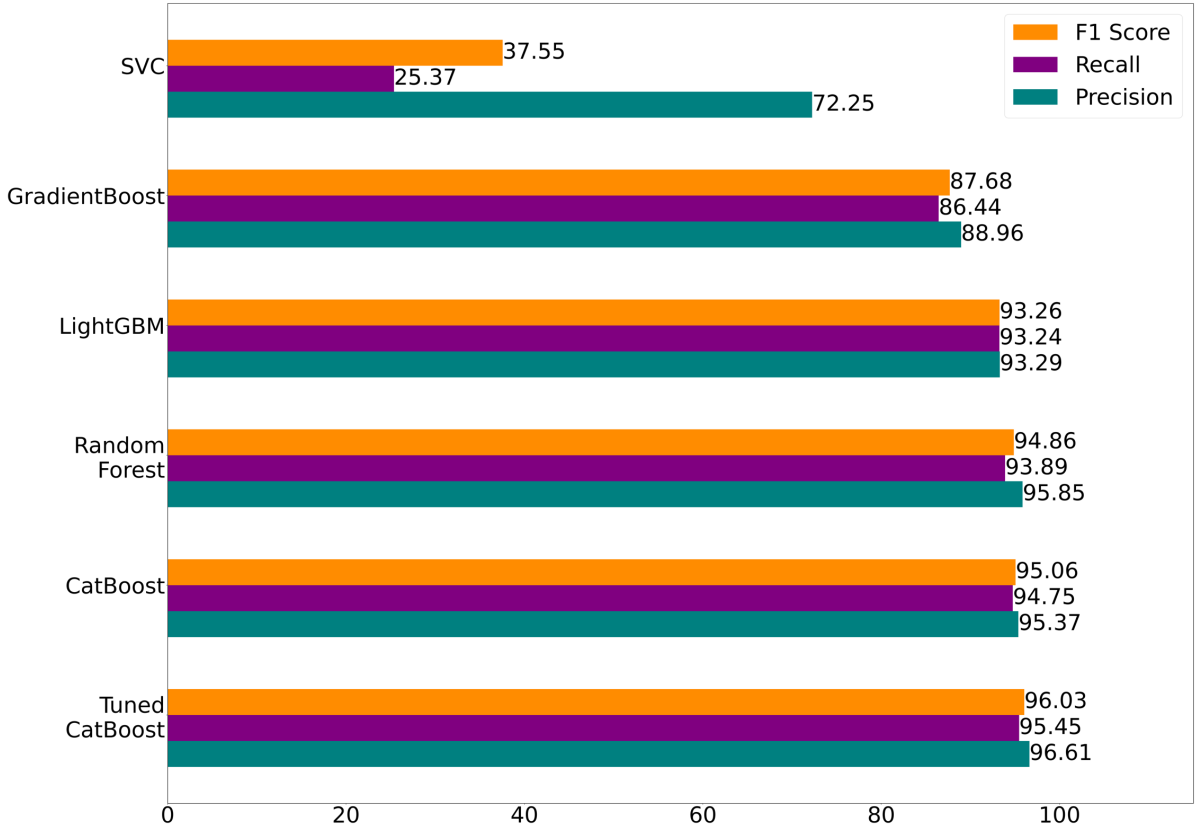
ML/DL Performance: Round 1

Results of several ML models and one deep learning model



- MalConv2 trains on the raw bytes of the file
- The ML models, on the other hand, train on a byte occurrence vector
- This 255-character vector summarizes the occurrence of all possible hexadecimal values per file

ML Performance: Round 2



- New feature vector for ML models consists of byte occurrence vector concatenated with mime-type output from *file* utility
- MalConv2 did not improve from additional feature
- Tuned CatBoost performed best across all metrics

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Conclusion and Next Steps

- Polyglot files present a serious challenge for existing utilities
- ML/DL show promise for detection
- Need to perform tuning and feature selection to maximize performance
- Need to demonstrate high throughput for practical use in industry

Questions?

- Contact: kochlr@ornl.gov or oeschts@ornl.gov

Supplemental: Detection of Novel Polyglots

- Tested our models against small dataset of novel polyglot malware
  - Cannot release data due to NDA
- Random Forest: 75% accuracy
- MalConv2: 83.80% accuracy
- CatBoost: 99.4% accuracy

Supplemental: Deep Learning Model Selection

- We chose Malconv2
  - Binary classifier designed for malware detection
  - 1-D convolutional neural network
- Reasons for selection
  - File type agnostic
  - Feature vector = raw bytes
  - Larger input capacity (16MB) than competing models