# Supplementary material
## TLog: A multi-task framework for anomaly detection in software logs

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*Abstract*—This is a supplementary material for the paper "TLog: A multi-task framework for anomaly detection in software logs" submitted for review at IEEE ICDM 2021. It contains implementation details, performance score definitions as well as the results from the response to two research questions RQ1 and RQ2.

## I. IMPLEMENTATION DETAILS

The experiments were run on a machine using Ubuntu 18.04, with processing power Intel(R) Core(TM) i5-9600K CPU @ 3.70GHz, RAM 128 GB, and GPU NVIDIA RTX 2080.

## II. METRICS DEFINITION

The predictive performance is accessed using standard classification metrics that take into account the potential imbalance of the data, based on the number of *true positives (TP)*, *true negatives (TN)*, *false positives (FP)* and *false negatives (FN)*. *TP* is the number of correctly detected anomalies. *TN* is the number of correctly detected normal samples. *FP* is the number of incorrectly detected anomalies and *FN* is the number of missed anomalies.

The single class (binary classification case) measures considered in this work are precision, recall and F1 [1]. Their definition is given further on. The index *st* emphasize that they are calculated for one target.

**Precision (single target)**:

$$precision_{st} = \frac{tp}{tp + fp} \tag{1}$$

**Recall (single target)**:

$$recall_{st} = \frac{tp}{tp + fn} \tag{2}$$

$F_1$ **(single target):**

$$F_{1_{st}} = \frac{2 \times precision_{st} \times recall_{st}}{precision_{st} + recall_{st}} \tag{3}$$

## III. DETAILED RESULTS

In the following we provide the detailed results from RQ1 and RQ2.

### REFERENCES

[1] D. M. W. Powers, "Evaluation: From precision, recall and f-measure to roc., informedness, markedness & correlation," *Journal of Machine Learning Technologies*, pp. 37–63, 2011.

TABLE I
LOG ANOMALY DETECTION F1 SCORE

| split | TLog-c1 | TLog-c2 | IF | PCA | TLog-p | DeepLog | TLog-sli | dataset name |
|---|---|---|---|---|---|---|---|---|
| 0.1 | 1.0 | 1.0 | 0.85 | 0.98 | 0.0 | 1.0 | 0.95 | SPIRIT |
| 0.2 | 1.0 | 1.0 | 0.96 | 0.98 | 0.0 | 1.0 | 0.94 | SPIRIT |
| 0.4 | 0.98 | 0.99 | 0.84 | 0.93 | 0.93 | 0.98 | 0.86 | SPIRIT |
| 0.6 | 0.99 | 0.99 | 0.83 | 0.94 | 0.01 | 0.99 | 0.86 | SPIRIT |
| 0.8 | 0.98 | 0.99 | 0.83 | 0.94 | 0.33 | 0.99 | 0.87 | SPIRIT |
| 0.1 | 1.0 | 1.0 | 0.0 | 0.85 | 1.0 | 0.11 | 0.16 | TBIRD |
| 0.2 | 1.0 | 1.0 | 0.65 | 0.81 | 1.0 | 0.12 | 0.16 | TBIRD |
| 0.4 | 1.0 | 1.0 | 0.41 | 0.0 | 1.0 | 0.13 | 0.18 | TBIRD |
| 0.6 | 1.0 | 1.0 | 0.0 | 0.0 | 0.75 | 0.17 | 0.14 | TBIRD |
| 0.8 | 1.0 | 0.53 | 0.2 | 0.0 | 0.74 | 0.13 | 0.13 | TBIRD |
| 0.1 | 0.66 | 0.64 | 0.19 | 0.4 | 0.75 | 0.42 | 0.01 | NOVA |
| 0.2 | 0.72 | 0.45 | 0.31 | 0.32 | 0.57 | 0.34 | 0.01 | NOVA |
| 0.4 | 0.72 | 0.37 | 0.33 | 0.28 | 0.55 | 0.35 | 0.01 | NOVA |
| 0.6 | 0.75 | 0.43 | 0.39 | 0.32 | 0.55 | 0.36 | 0.01 | NOVA |
| 0.8 | 0.77 | 0.49 | 0.45 | 0.31 | 0.48 | 0.33 | 0.01 | NOVA |
| 0.1 | 0.92 | 0.96 | 0.19 | 0.4 | 0.09 | 0.05 | 0.12 | production |
| 0.2 | 0.12 | 0.88 | 0.31 | 0.32 | 0.16 | 0.04 | 0.2 | production |
| 0.4 | 0.9 | 0.45 | 0.33 | 0.28 | 0.05 | 0.03 | 0.19 | production |
| 0.6 | 0.87 | 0.7 | 0.39 | 0.32 | 0.12 | 0.01 | 0.18 | production |
| 0.8 | 0.95 | 0.35 | 0.45 | 0.31 | 0.05 | 0.0 | 0.16 | production |
| 0.1 | 0.53 | 0.31 | 0.06 | 0.05 | 0.28 | 0.1 | 0.11 | BGL |
| 0.2 | 0.83 | 0.59 | 0.13 | 0.15 | 0.26 | 0.15 | 0.11 | BGL |
| 0.4 | 0.57 | 0.35 | 0.1 | 0.13 | 0.28 | 0.13 | 0.11 | BGL |
| 0.6 | 0.83 | 0.36 | 0.22 | 0.21 | 0.53 | 0.18 | 0.1 | BGL |
| 0.8 | 0.66 | 0.2 | 0.28 | 0.36 | 0.49 | 0.15 | 0.09 | BGL |

TABLE II
LOG ANOMALY DETECTION PRECISION SCORE

| split | TLog-c1 | TLog-c2 | IF | PCA | TLog-p | DeepLog | TLog-sli | dataset name |
|---|---|---|---|---|---|---|---|---|
| 0.1 | 1.0 | 1.0 | 0.92 | 0.97 | 0.12 | 1.0 | 0.9 | SPIRIT |
| 0.2 | 1.0 | 1.0 | 0.92 | 0.96 | 0.1 | 1.0 | 0.89 | SPIRIT |
| 0.4 | 0.97 | 0.99 | 0.73 | 0.86 | 0.88 | 0.96 | 0.75 | SPIRIT |
| 0.6 | 0.99 | 0.99 | 0.71 | 0.88 | 0.07 | 0.99 | 0.75 | SPIRIT |
| 0.8 | 0.96 | 0.99 | 0.7 | 0.88 | 0.91 | 0.99 | 0.77 | SPIRIT |
| 0.1 | 1.0 | 1.0 | 0.0 | 0.74 | 1.0 | 0.06 | 0.09 | TBIRD |
| 0.2 | 1.0 | 1.0 | 0.48 | 0.68 | 1.0 | 0.07 | 0.09 | TBIRD |
| 0.4 | 1.0 | 1.0 | 0.26 | 0.0 | 1.0 | 0.07 | 0.1 | TBIRD |
| 0.6 | 1.0 | 1.0 | 0.0 | 0.0 | 0.6 | 0.11 | 0.08 | TBIRD |
| 0.8 | 1.0 | 0.36 | 0.11 | 0.0 | 0.58 | 0.08 | 0.07 | TBIRD |
| 0.1 | 0.94 | 0.95 | 0.11 | 0.26 | 0.92 | 0.34 | 0.01 | NOVA |
| 0.2 | 0.73 | 0.36 | 0.19 | 0.2 | 0.74 | 0.23 | 0.01 | NOVA |
| 0.4 | 0.99 | 0.26 | 0.24 | 0.17 | 0.76 | 0.26 | 0.01 | NOVA |
| 0.6 | 0.99 | 0.32 | 0.31 | 0.2 | 0.79 | 0.27 | 0.01 | NOVA |
| 0.8 | 0.99 | 0.38 | 0.37 | 0.19 | 0.52 | 0.23 | 0.01 | NOVA |
| 0.1 | 0.86 | 0.91 | 0.11 | 0.26 | 0.05 | 0.09 | 0.06 | production |
| 0.2 | 0.06 | 0.79 | 0.19 | 0.2 | 0.09 | 0.08 | 0.11 | production |
| 0.4 | 0.81 | 0.29 | 0.24 | 0.17 | 0.03 | 0.0 | 0.11 | production |
| 0.6 | 0.77 | 0.53 | 0.31 | 0.2 | 0.07 | 0.0 | 0.1 | production |
| 0.8 | 0.91 | 0.21 | 0.37 | 0.19 | 0.03 | 0.0 | 0.08 | production |
| 0.1 | 0.38 | 0.19 | 0.03 | 0.03 | 0.16 | 0.05 | 0.06 | BGL |
| 0.2 | 0.8 | 0.43 | 0.07 | 0.08 | 0.17 | 0.09 | 0.06 | BGL |
| 0.4 | 0.42 | 0.22 | 0.05 | 0.07 | 0.19 | 0.07 | 0.06 | BGL |
| 0.6 | 0.81 | 0.22 | 0.12 | 0.12 | 0.99 | 0.12 | 0.05 | BGL |
| 0.8 | 0.6 | 0.12 | 0.16 | 0.22 | 0.97 | 0.08 | 0.05 | BGL |

TABLE III
LOG ANOMALY DETECTION RECALL SCORE

| split | TLog-c1 | TLog-c2 | IF | PCA | TLog-p | DeepLog | TLog-sli | dataset name |
|---|---|---|---|---|---|---|---|---|
| 0.1 | 1.0 | 1.0 | 0.8 | 1.0 | 0.0 | 1.0 | 1.0 | SPIRIT |
| 0.2 | 1.0 | 1.0 | 1.0 | 1.0 | 0.0 | 1.0 | 1.0 | SPIRIT |
| 0.4 | 0.99 | 0.99 | 1.0 | 1.0 | 0.99 | 1.0 | 1.0 | SPIRIT |
| 0.6 | 1.0 | 0.99 | 1.0 | 1.0 | 0.0 | 1.0 | 1.0 | SPIRIT |
| 0.8 | 1.0 | 0.99 | 1.0 | 1.0 | 0.2 | 1.0 | 1.0 | SPIRIT |
| 0.1 | 1.0 | 1.0 | 0.0 | 1.0 | 1.0 | 0.48 | 1.0 | TBIRD |
| 0.2 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.46 | 1.0 | TBIRD |
| 0.4 | 1.0 | 1.0 | 1.0 | 0.0 | 1.0 | 0.79 | 1.0 | TBIRD |
| 0.6 | 1.0 | 1.0 | 0.0 | 0.0 | 1.0 | 0.35 | 1.0 | TBIRD |
| 0.8 | 1.0 | 1.0 | 1.0 | 0.0 | 1.0 | 0.52 | 1.0 | TBIRD |
| 0.1 | 0.51 | 0.48 | 0.59 | 0.79 | 0.63 | 0.56 | 0.18 | NOVA |
| 0.2 | 0.71 | 0.59 | 0.76 | 0.8 | 0.46 | 0.6 | 0.17 | NOVA |
| 0.4 | 0.56 | 0.62 | 0.54 | 0.81 | 0.43 | 0.56 | 0.17 | NOVA |
| 0.6 | 0.61 | 0.63 | 0.52 | 0.78 | 0.42 | 0.54 | 0.18 | NOVA |
| 0.8 | 0.63 | 0.68 | 0.57 | 0.79 | 0.45 | 0.65 | 0.18 | NOVA |
| 0.1 | 1.0 | 1.0 | 0.59 | 0.79 | 0.41 | 1.0 | 1.0 | production |
| 0.2 | 1.0 | 1.0 | 0.76 | 0.8 | 0.81 | 1.0 | 1.0 | production |
| 0.4 | 1.0 | 1.0 | 0.54 | 0.81 | 0.23 | 1.0 | 1.0 | production |
| 0.6 | 1.0 | 1.0 | 0.52 | 0.78 | 0.73 | 1.0 | 1.0 | production |
| 0.8 | 1.0 | 1.0 | 0.57 | 0.79 | 0.16 | 1.0 | 1.0 | production |
| 0.1 | 0.87 | 0.81 | 0.76 | 0.52 | 0.98 | 0.58 | 0.93 | BGL |
| 0.2 | 0.86 | 0.95 | 1.0 | 1.0 | 0.55 | 0.49 | 0.72 | BGL |
| 0.4 | 0.9 | 0.95 | 0.82 | 1.0 | 0.56 | 0.82 | 0.73 | BGL |
| 0.6 | 0.85 | 0.94 | 0.99 | 0.83 | 0.36 | 0.32 | 0.73 | BGL |
| 0.8 | 0.73 | 0.66 | 0.87 | 0.91 | 0.33 | 0.61 | 0.6 | BGL |

TABLE IV
SEQUENTIAL LOG ANOMALY DETECTION F1 SCORE

| session window | DT | LR | IF | PCA | TLog | LogRobust | datasetname |
|---|---|---|---|---|---|---|---|
| 5m | 0.12 | 0.12 | 0.07 | 0.09 | 0.60 | 0.20 | BGL |
| 15m | 0.28 | 0.24 | 0.08 | 0.38 | 0.61 | 0.21 | BGL |
| 30m | 0.19 | 0.31 | 0.04 | 0.38 | 0.64 | 0.25 | BGL |
| 60m | 0.34 | 0.36 | 0.05 | 0.12 | 0.69 | 0.29 | BGL |
| 180m | 0.4 | 0.44 | 0.11 | 0.02 | 0.78 | 0.37 | BGL |
| 360m | 0.56 | 0.47 | 0.21 | 0.54 | 0.82 | 0.44 | BGL |
| 540m | 0.59 | 0.35 | 0.25 | 0.1 | 0.88 | 0.50 | BGL |
| 720m | 0.64 | 0.49 | 0.40 | 0.66 | 0.91 | 0.15 | BGL |
| 5m | 0.94 | 0.99 | 0.47 | 0.0 | 1.0 | 0.99 | TBIRD |
| 15m | 0.99 | 0.99 | 0.28 | 0.0 | 1.0 | 1.0 | TBIRD |
| 30m | 0.99 | 0.99 | 0.83 | 0.94 | 1.0 | 1.0 | TBIRD |
| 60m | 0.98 | 0.98 | 0.91 | 0.61 | 1.0 | 1.0 | TBIRD |
| 180m | 1.0 | 0.88 | 0.69 | 0.57 | 1.0 | 1.0 | TBIRD |
| 360m | 1.0 | 0.85 | 0.85 | 0.0 | 1.0 | 1.0 | TBIRD |
| 540m | 1.0 | 0.88 | 1.0 | 0.0 | 1.0 | 1.0 | TBIRD |
| 720m | 1.0 | 0.85 | 0.85 | 0.4 | 1.0 | 1.0 | TBIRD |
| 5m | 0.00 | 0.66 | 0.00 | 0.0 | 0.83 | 0.0 | SPIRIT |
| 15m | 0.03 | 0.0 | 0.0 | 0.00 | 0.64 | 0.0 | SPIRIT |
| 30m | 0.06 | 0.0 | 0.0 | 0.0 | 0.49 | 0.00 | SPIRIT |
| 60m | 0.13 | 0.0 | 0.00 | 0.0 | 0.34 | 0.00 | SPIRIT |
| 180m | 0.06 | 0.0 | 0.04 | 0.0 | 0.19 | 0.01 | SPIRIT |
| 360m | 0.03 | 0.0 | 0.12 | 0.0 | 0.14 | 0.01 | SPIRIT |
| 540m | 0.16 | 0.0 | 0.09 | 0.0 | 0.13 | 0.02 | SPIRIT |
| 720m | 0.5 | 0.0 | 0.06 | 0.0 | 0.12 | 0.03 | SPIRIT |
| 5m | 0.65 | 0.70 | 0.54 | 0.54 | 0.82 | 0.65 | NOVA |
| 15m | 0.74 | 0.74 | 0.55 | 0.69 | 0.91 | 0.8 | NOVA |
| 30m | 0.8 | 0.79 | 0.58 | 0.82 | 0.91 | 0.87 | NOVA |
| 60m | 0.94 | 0.84 | 0.87 | 0.94 | 0.95 | 0.94 | NOVA |
| 180m | 1.0 | 0.66 | 0.85 | 0.0 | 1.0 | 0.85 | NOVA |
| 360m | 1.0 | 0.88 | 1.0 | 0.0 | 1.0 | 0.88 | NOVA |
| 540m | 1.0 | 0.66 | 0.0 | 0.0 | 1.0 | 1.0 | NOVA |
| 720m | 1.0 | 0.5 | 0.0 | 0.0 | 1.0 | 1.0 | NOVA |

TABLE V

SEQUENTIAL LOG ANOMALY DETECTION PRECISION SCORE

| session window | DT | LR | IF | PCA | TLog | LogRobust | datasetname |
|---|---|---|---|---|---|---|---|
| 5m | 0.17 | 0.29 | 0.19 | 0.31 | 0.82 | 0.11 | BGL |
| 15m | 0.24 | 0.27 | 0.19 | 0.51 | 0.82 | 0.12 | BGL |
| 30m | 0.22 | 0.31 | 0.14 | 0.59 | 0.83 | 0.14 | BGL |
| 60m | 0.34 | 0.3 | 0.24 | 1.0 | 0.87 | 0.17 | BGL |
| 180m | 0.44 | 0.48 | 0.45 | 1.0 | 0.91 | 0.23 | BGL |
| 360m | 0.45 | 0.42 | 0.67 | 0.62 | 0.92 | 0.28 | BGL |
| 540m | 0.5 | 0.53 | 0.67 | 1.0 | 0.96 | 0.34 | BGL |
| 720m | 0.57 | 0.47 | 0.82 | 0.67 | 0.99 | 0.2 | BGL |
| 5m | 1.0 | 1.0 | 1.0 | 0.0 | 1.0 | 1.0 | TBIRD |
| 15m | 1.0 | 1.0 | 1.0 | 0.0 | 1.0 | 1.0 | TBIRD |
| 30m | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | TBIRD |
| 60m | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | TBIRD |
| 180m | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | TBIRD |
| 360m | 1.0 | 1.0 | 1.0 | 0.0 | 1.0 | 1.0 | TBIRD |
| 540m | 1.0 | 1.0 | 1.0 | 0.0 | 1.0 | 1.0 | TBIRD |
| 720m | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | TBIRD |
| 5m | 0.0 | 1.0 | 0.0 | 0.0 | 1.0 | 0.0 | SPIRIT |
| 15m | 0.02 | 0.0 | 0.0 | 0.0 | 1.0 | 0.0 | SPIRIT |
| 30m | 0.03 | 0.0 | 0.0 | 0.0 | 0.99 | 0.0 | SPIRIT |
| 60m | 0.07 | 0.0 | 0.0 | 0.0 | 0.99 | 0.0 | SPIRIT |
| 180m | 0.03 | 0.0 | 0.03 | 0.0 | 1.0 | 0.0 | SPIRIT |
| 360m | 0.02 | 0.0 | 0.07 | 0.0 | 1.0 | 0.01 | SPIRIT |
| 540m | 0.1 | 0.0 | 0.05 | 0.0 | 1.0 | 0.01 | SPIRIT |
| 720m | 1.0 | 0.0 | 0.03 | 0.0 | 1.0 | 0.01 | SPIRIT |
| 5m | 0.7 | 0.76 | 0.62 | 0.57 | 0.71 | 0.49 | NOVA |
| 15m | 0.73 | 0.73 | 0.72 | 0.78 | 0.85 | 0.67 | NOVA |
| 30m | 0.85 | 0.88 | 0.74 | 0.85 | 0.87 | 0.8 | NOVA |
| 60m | 0.94 | 0.93 | 1.0 | 0.94 | 0.92 | 0.94 | NOVA |
| 180m | 1.0 | 0.8 | 0.86 | 0.0 | 1.0 | 0.86 | NOVA |
| 360m | 1.0 | 1.0 | 1.0 | 0.0 | 1.0 | 1.0 | NOVA |
| 540m | 1.0 | 1.0 | 0.0 | 0.0 | 1.0 | 1.0 | NOVA |
| 720m | 1.0 | 1.0 | 0.0 | 0.0 | 1.0 | 1.0 | NOVA |

TABLE VI
SEQUENTIAL LOG ANOMALY DETECTION RECALL SCORE

| session window | DT | LR | IF | PCA | TLog | LogRobust | datasetname |
|---|---|---|---|---|---|---|---|
| 5m | 0.1 | 0.08 | 0.04 | 0.05 | 0.6 | 1.0 | BGL |
| 15m | 0.34 | 0.22 | 0.06 | 0.31 | 0.62 | 0.95 | BGL |
| 30m | 0.16 | 0.32 | 0.02 | 0.29 | 0.65 | 1.0 | BGL |
| 60m | 0.34 | 0.47 | 0.03 | 0.07 | 0.7 | 1.0 | BGL |
| 180m | 0.37 | 0.41 | 0.07 | 0.01 | 0.79 | 0.95 | BGL |
| 360m | 0.72 | 0.53 | 0.13 | 0.49 | 0.82 | 1.0 | BGL |
| 540m | 0.71 | 0.26 | 0.16 | 0.05 | 0.89 | 1.0 | BGL |
| 720m | 0.73 | 0.52 | 0.27 | 0.67 | 0.91 | 0.12 | BGL |
| 5m | 0.89 | 1.0 | 0.31 | 0.0 | 1.0 | 1.0 | TBIRD |
| 15m | 0.99 | 0.99 | 0.16 | 0.0 | 1.0 | 1.0 | TBIRD |
| 30m | 0.99 | 0.99 | 0.72 | 0.9 | 1.0 | 1.0 | TBIRD |
| 60m | 0.98 | 0.98 | 0.84 | 0.44 | 1.0 | 1.0 | TBIRD |
| 180m | 1.0 | 0.8 | 0.53 | 0.4 | 1.0 | 1.0 | TBIRD |
| 360m | 1.0 | 0.75 | 0.75 | 0.0 | 1.0 | 1.0 | TBIRD |
| 540m | 1.0 | 0.8 | 1.0 | 0.0 | 1.0 | 1.0 | TBIRD |
| 720m | 1.0 | 0.75 | 0.75 | 0.25 | 1.0 | 1.0 | TBIRD |
| 5m | 0.5 | 0.5 | 0.5 | 0.5 | 0.83 | 1.0 | SPIRIT |
| 15m | 1.0 | 0.0 | 0.0 | 0.5 | 0.64 | 1.0 | SPIRIT |
| 30m | 1.0 | 0.0 | 0.0 | 0.0 | 0.49 | 1.0 | SPIRIT |
| 60m | 0.5 | 0.0 | 0.5 | 0.0 | 0.35 | 1.0 | SPIRIT |
| 180m | 0.33 | 0.0 | 0.33 | 0.0 | 0.19 | 1.0 | SPIRIT |
| 360m | 0.33 | 0.0 | 0.67 | 0.0 | 0.14 | 1.0 | SPIRIT |
| 540m | 0.67 | 0.0 | 0.67 | 0.0 | 0.13 | 1.0 | SPIRIT |
| 720m | 0.33 | 0.0 | 0.67 | 0.0 | 0.12 | 1.0 | SPIRIT |
| 5m | 0.61 | 0.65 | 0.48 | 0.52 | 0.82 | 0.99 | NOVA |
| 15m | 0.75 | 0.75 | 0.45 | 0.62 | 0.91 | 1.0 | NOVA |
| 30m | 0.76 | 0.72 | 0.48 | 0.79 | 0.92 | 0.97 | NOVA |
| 60m | 0.94 | 0.78 | 0.78 | 0.94 | 0.96 | 0.94 | NOVA |
| 180m | 1.0 | 0.57 | 0.86 | 0.0 | 1.0 | 0.86 | NOVA |
| 360m | 1.0 | 0.8 | 1.0 | 0.0 | 1.0 | 0.8 | NOVA |
| 540m | 1.0 | 0.5 | 0.0 | 0.0 | 1.0 | 1.0 | NOVA |
| 720m | 1.0 | 0.33 | 0.0 | 0.0 | 1.0 | 1.0 | NOVA |