

積體電路設計研究所

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Application-Aware Early-Exit Fault Classification for Video Decoder Using Miter-Based Analysis



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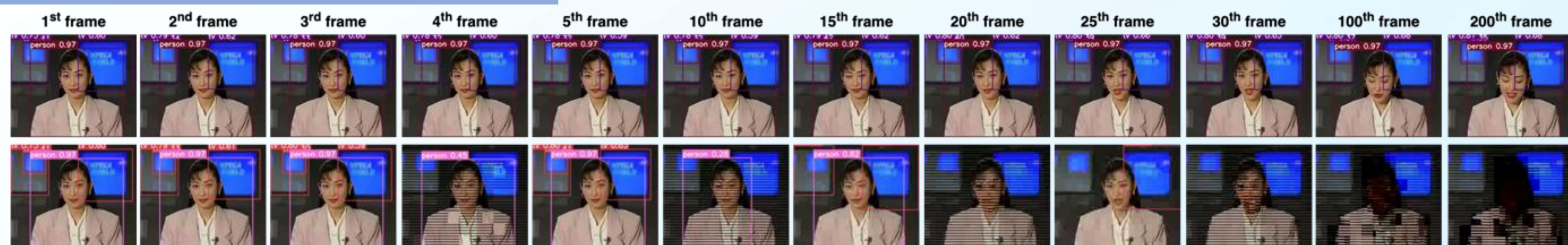
Abstract

Traditional structural testing often overlooks the actual impact of hardware faults on system-level applications, especially in error-tolerant components like video decoders. This work presents an application-aware fault classification framework that integrates a miter-based architecture with an early-exit strategy, using object detection accuracy as the evaluation target. Experimental results show that this approach achieves 100% classification precision while reducing simulation time by over 98%. This work has been accepted for oral presentation at the Asian Test Symposium in Japan in December 2025.

Basic Idea and Proposed Miter Architecture

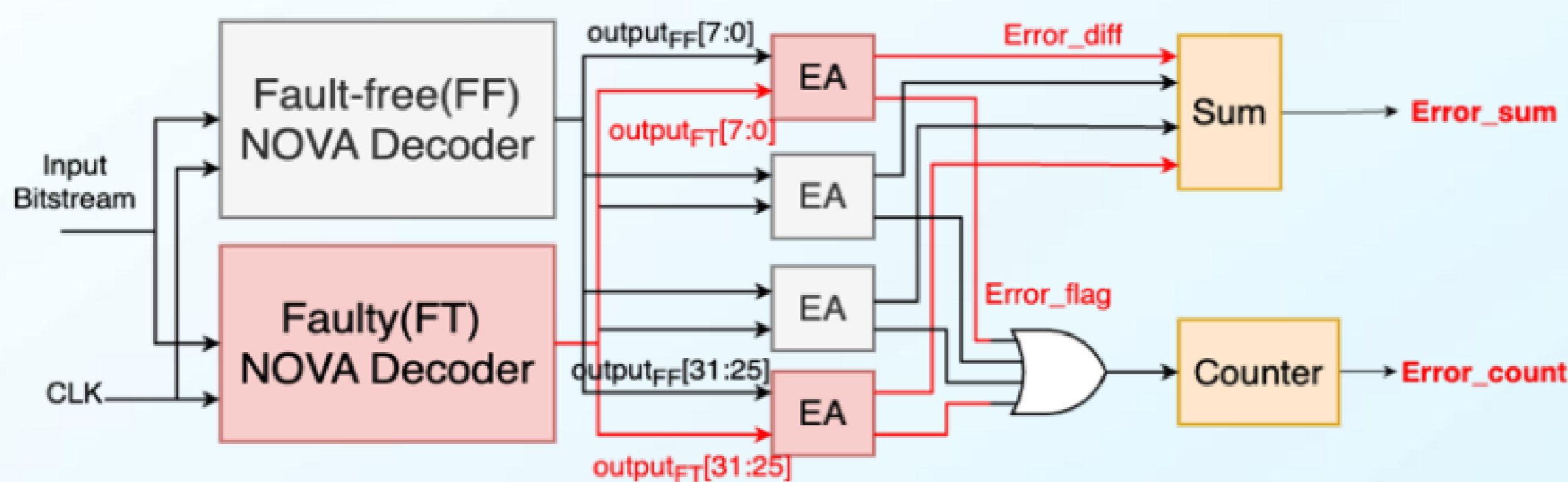
Case (a) SA0
@IQT/U1000/B1
mAP 100%

Case (b) SA0
@Inter_pred_top/Inter_pred_sliding_window/U970/B1
mAP 1.67%



| | | 1 st frame | 2 nd frame | 3 rd frame | 4 th frame | 5 th frame | 10 th frame | 15 th frame | 20 th frame | 25 th frame | 30 th frame | 100 th frame | 200 th frame |
|-----|-----------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|------------------------|------------------------|------------------------|------------------------|------------------------|-------------------------|-------------------------|
| (a) | Error magnitude | 91 | 184 | 277 | 370 | 463 | 928 | 1300 | 2003 | 2749 | 3636 | 11055 | 21049 |
| | # mismatch | 481 | 911 | 1341 | 1771 | 2201 | 4357 | 6081 | 8655 | 10833 | 13016 | 44493 | 90050 |
| | Error Ratio | 0.189 | 0.202 | 0.207 | 0.209 | 0.210 | 0.213 | 0.214 | 0.231 | 0.254 | 0.279 | 0.248 | 0.234 |
| (b) | Error magnitude | 0 | 170 k | 365 k | 560 k | 756 k | 1758 k | 2.59 M | 3.98 M | 5.31 M | 6.71 M | 30.9 B | 71.2 B |
| | # mismatch | 0 | 3.5 k | 7.3 k | 11.2 k | 15.3 k | 35.8 k | 53.2 k | 83.4 k | 110.6 k | 138.3 k | 535.6 k | 1.1 M |
| | Error Ratio | 0 | 49.319 | 49.555 | 49.657 | 49.483 | 49.184 | 48.713 | 47.636 | 48.009 | 48.521 | 57.705 | 63.813 |

mAP: mean Average Precision

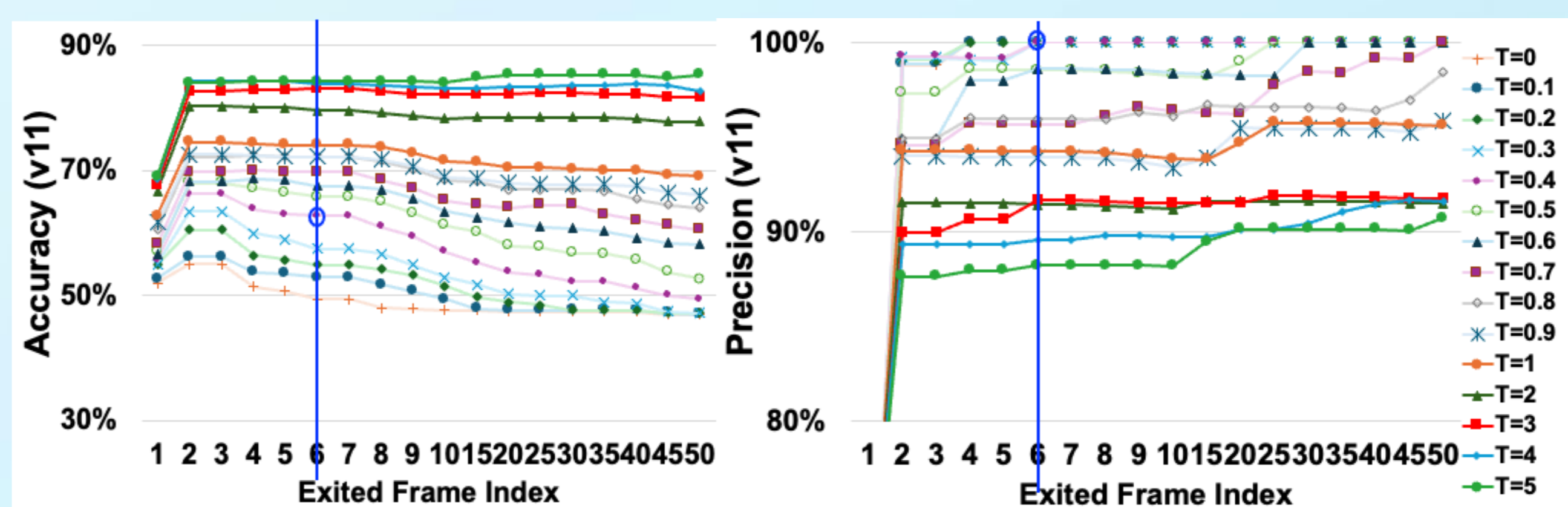
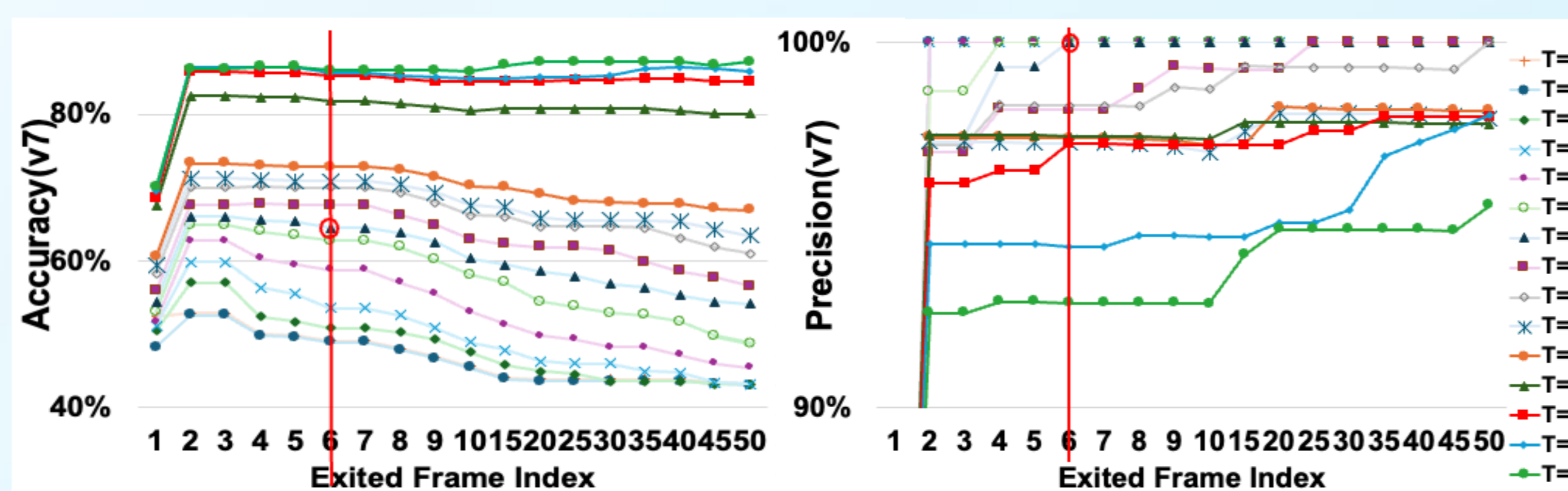


Error Analyzer (EA)-To compare the POs of the two decoders and flags *mismatches*

Summation and Counter-To compute two metrics: the total accumulated error magnitude and the total number of mismatched byte

$$\text{Define: Error Ratio (ER)} = \frac{\text{Total accumulated error magnitude}}{\text{Total \# of pixel mismatches}}$$

Experimental Results



Total faults: 456; Exit Frame Index: 6; threshold: 0.4

$$\text{Accuracy} = \frac{\# \text{ of faults classified correctly}}{\# \text{ of all faults}}, \text{ Precision} = \frac{\# \text{ of faults that do not impact the mAP}}{\# \text{ of faults classified as tolerable}}$$

Table 2. Fault classification results for the two sub-modules

| Application | YOLOv7/v11 | |
|--|----------------------------------|---------|
| Submodule (a) plane_a_precomputation @Intra Prediction | Exit Frame | 6 |
| | Threshold | 3 |
| | # of tolerable faults (# faults) | 29 (82) |
| Submodule (b) Bilinear @Inter Prediction | Exit Frame | 6 |
| | Threshold | 1 |
| | # of tolerable faults (# faults) | 62(304) |

Table 3. Simulation time (mins)

| | Submodule (a) | Submodule (b) |
|---|---------------------------------------|---|
| Faulty Video Generation ^I | 29,520 | 109,440 |
| mAP Evaluation ^{II} (YOLOv7) | 19.1 (3080 Ti) 23.23 (4070) | 71.9 (3080 Ti) 85.3 (4070) |
| mAP Evaluation ^{III} (YOLOv11) | 15.0 (3080 Ti) 19.1 (4070) | 55.7 (3080 Ti) 71.9 (4070) |
| Sum ^{I+II} (YOLOv7) | 29,539.1 (3080 Ti) 29,543.2 (4070) | 109,511.9 (3080 Ti) 109,525.3 (4070) |
| Sum ^{I+III} (YOLOv11) | 29,535.0 (3080 Ti) 29,539.1 (4070) | 109,495.7 (3080 Ti) 10,9511.9 (4070) |
| Proposed (partial video frame simulation+ ER calculation) | 347 | 1,336 |
| Simulation Time Reduction | 98.83% | 98.78% |