Error Detector Placement for Soft Computation

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Soft Computing Applications

- Applications in AI, multimedia processing…
- Expected to dominate future workloads [Dubey'07]

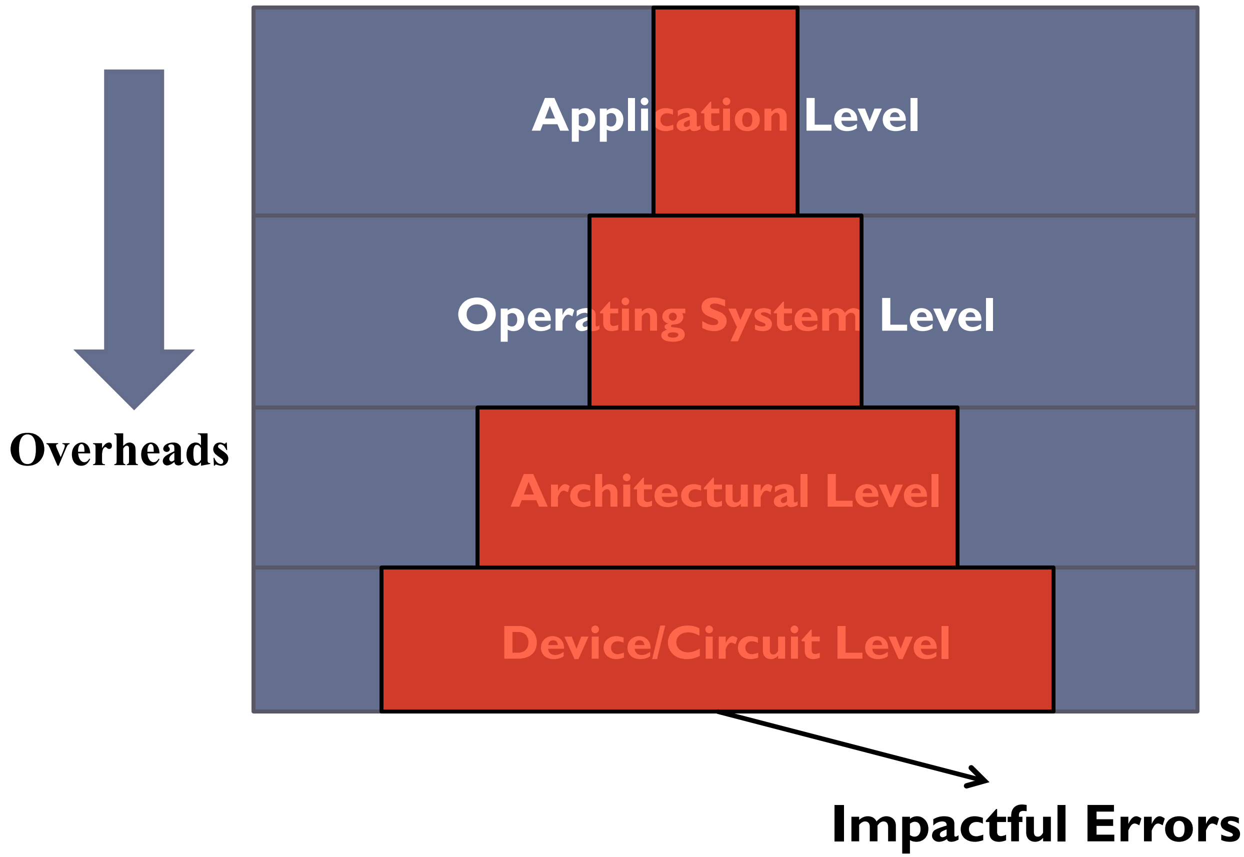
Original image (left) versus faulty image from JPEG decoder

Egregious Data Corruptions

- Large or unacceptable deviation in output
- Based on fidelity metric (e.g., PSNR)

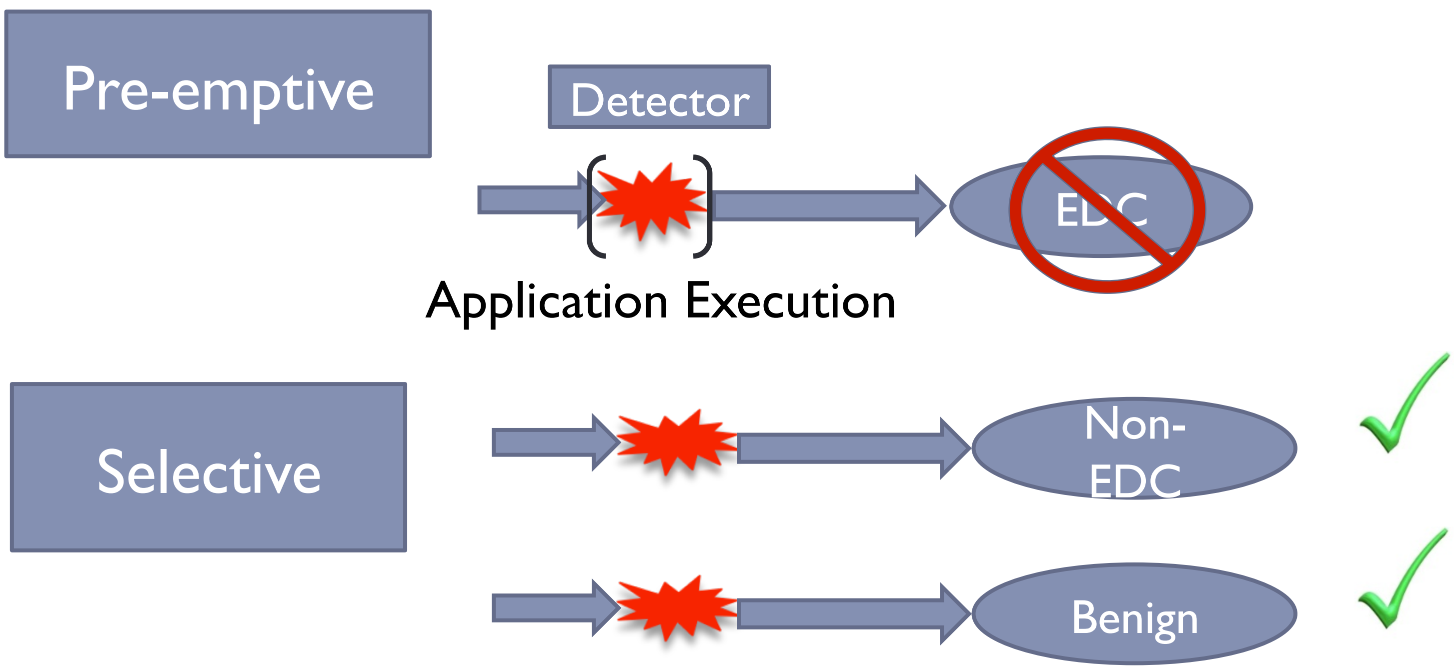

EDC image (PSNR of 11.37) of JPEG vs Non-EDC image (PSNR of 44.79)

Why Software Solutions?



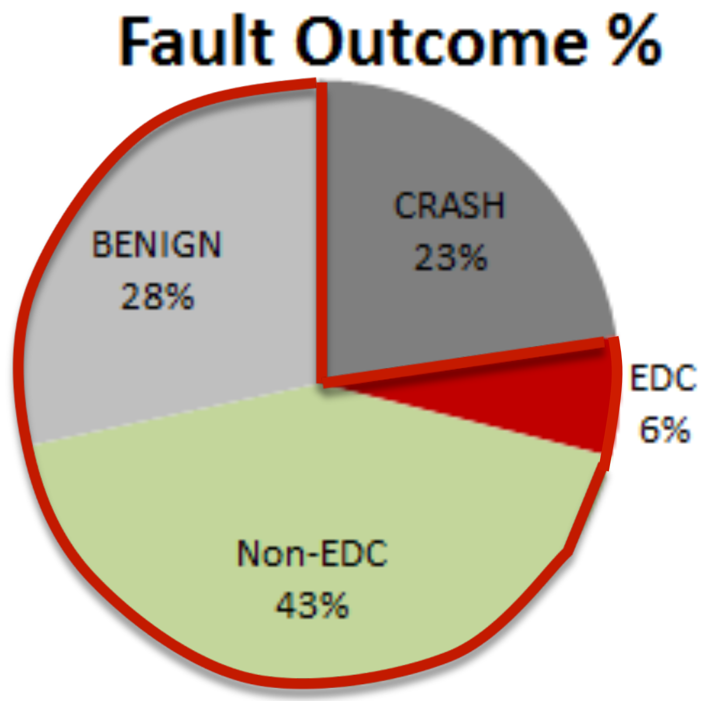
Goal

- Detect EDC causing faults



Why detect EDC Causing Faults?

- ➢ Unacceptable outcome to the end user



- ➢ 92% : tolerable outcomes

Blindly detecting all faults is wasteful

Outline

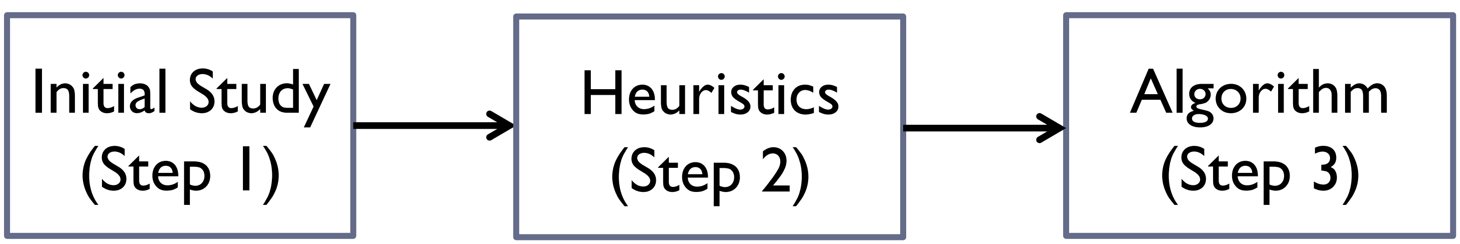
- Motivation
- Approach
- Experimental Setup and Results
- Conclusion

Approach

- Step 1: Separate EDCs from Non-EDCs by fault injections

- Step 2: Heuristics identifying code regions prone to EDC causing faults

- Step 3: Automated algorithm for detector placement

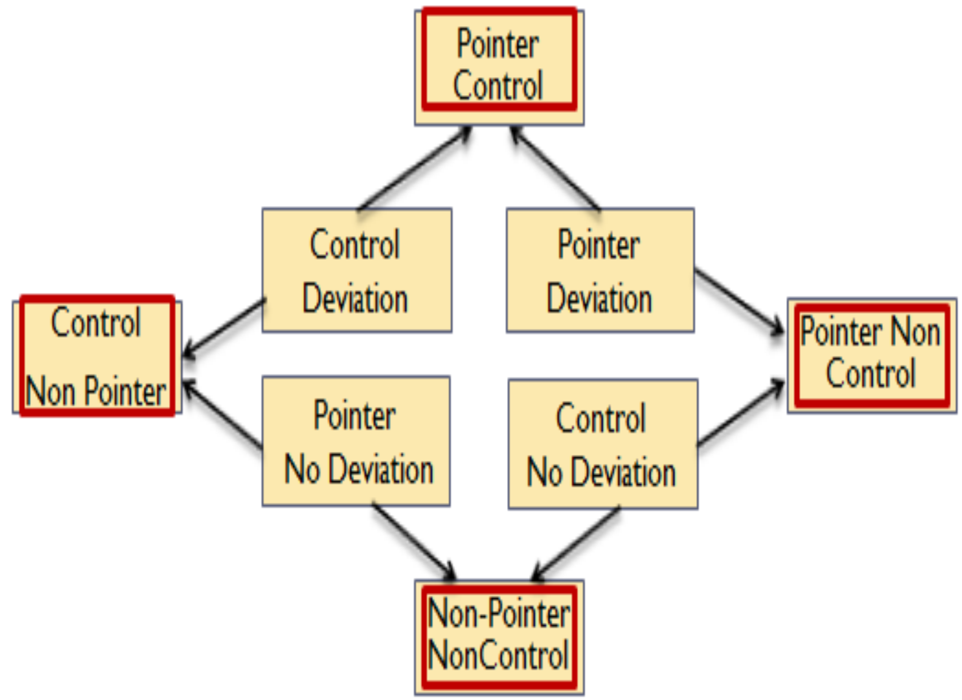


Step 1: Initial Study

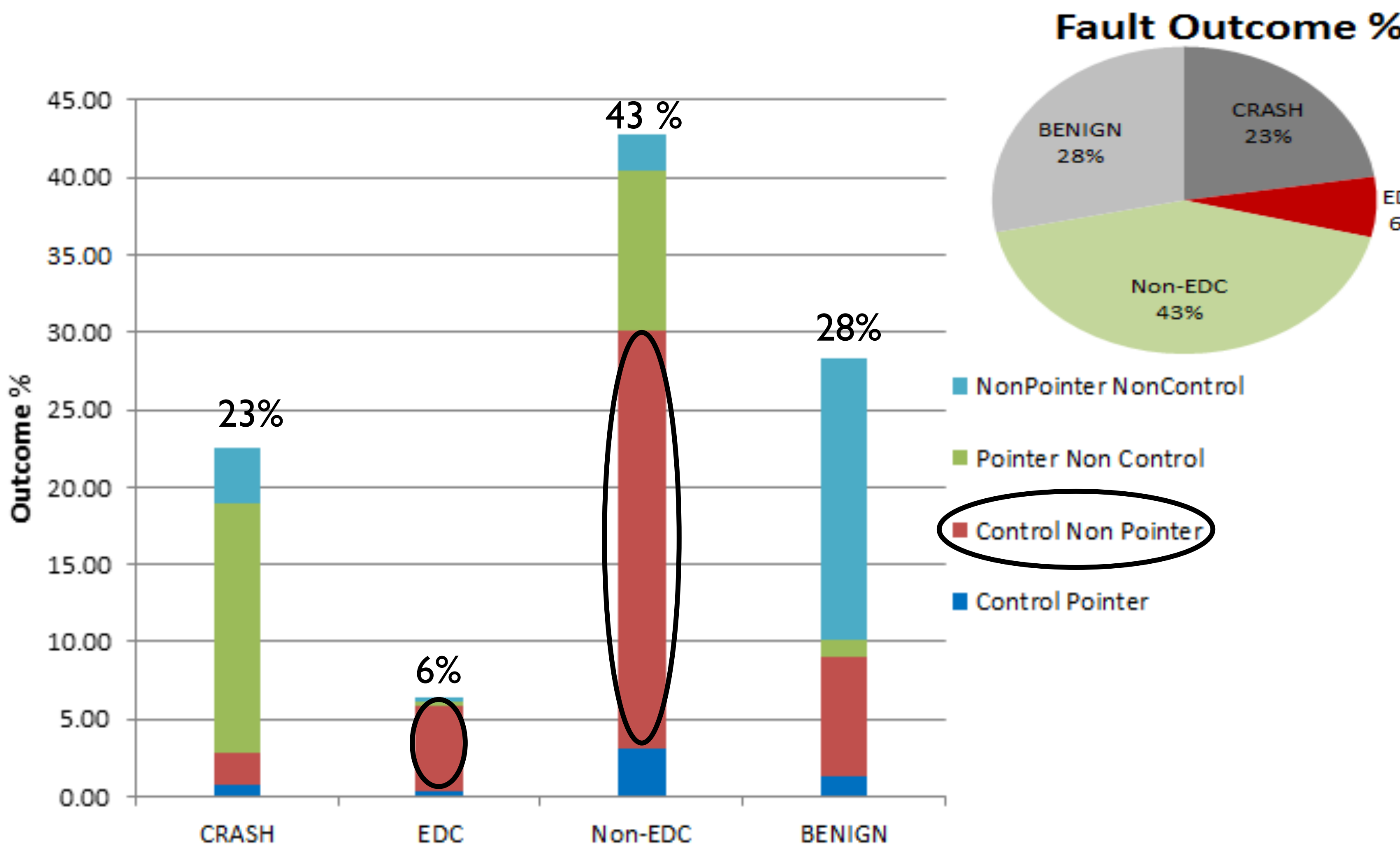
- Fault injection using LLFI [Thomas'13]
- Correlation between data type – fault outcome

Monitor Control/Pointer Data

- Instrument code
- Fault Injection



Data Categorization of Fault Outcomes



High correlation between Control Non-Pointer and EDC/Non-EDC

Step 2: Heuristics

```
void conv422to444 (char *src, char *dst,  int height, int width, int
offset) {
    for(j=0; j < height; j++){
      for(i=0; i < width; i++) {
        im1 = (i < 1) ? 0 : i – 1
        …
        dst[im1] = Clip[(21*src[im1])>>8];
      }
      if( j + 1 < offset) {
          src += w;
          dst += width; }
    }
}
```

Step 2: Heuristics

Faults affecting branches with large amount of data within branch body, has a higher likelihood of resulting in EDC outcomes

```
void conv422to444 (char *src, char *dst,  int height, int width, int offset) {
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        dst[im1] = Clip[(21*src[im1])>>8];
     }
     if( j + 1 < offset) {
        src += w;
        dst += width; }
    }
}
```

- Fault in offset
- Branch Flip

High EDC Likelihood

Step 2: Heuristics

Faults affecting branches with large amount of data within branch body, has a higher likelihood of resulting in EDC outcomes

```
void conv422to444 (char *src, char *dst,  int height, int width, int offset) {
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         ...
         dst[im1] = Clip[(21*src[im1])>>8];
       }
       if( j + 1 < offset) {
           src += w;
           dst += width; }
    }
}
```

- Fault in result of branch

Low EDC Likelihood

Heuristics: Main Take Aways

- Program level, applied to soft computing applications
- Dependent on size of data affected
- Based entirely on static analysis of code

Step 3: Algorithm

Pre-emptive, Selective detection of EDC causing faults

Application Source Code

Performance Overhead

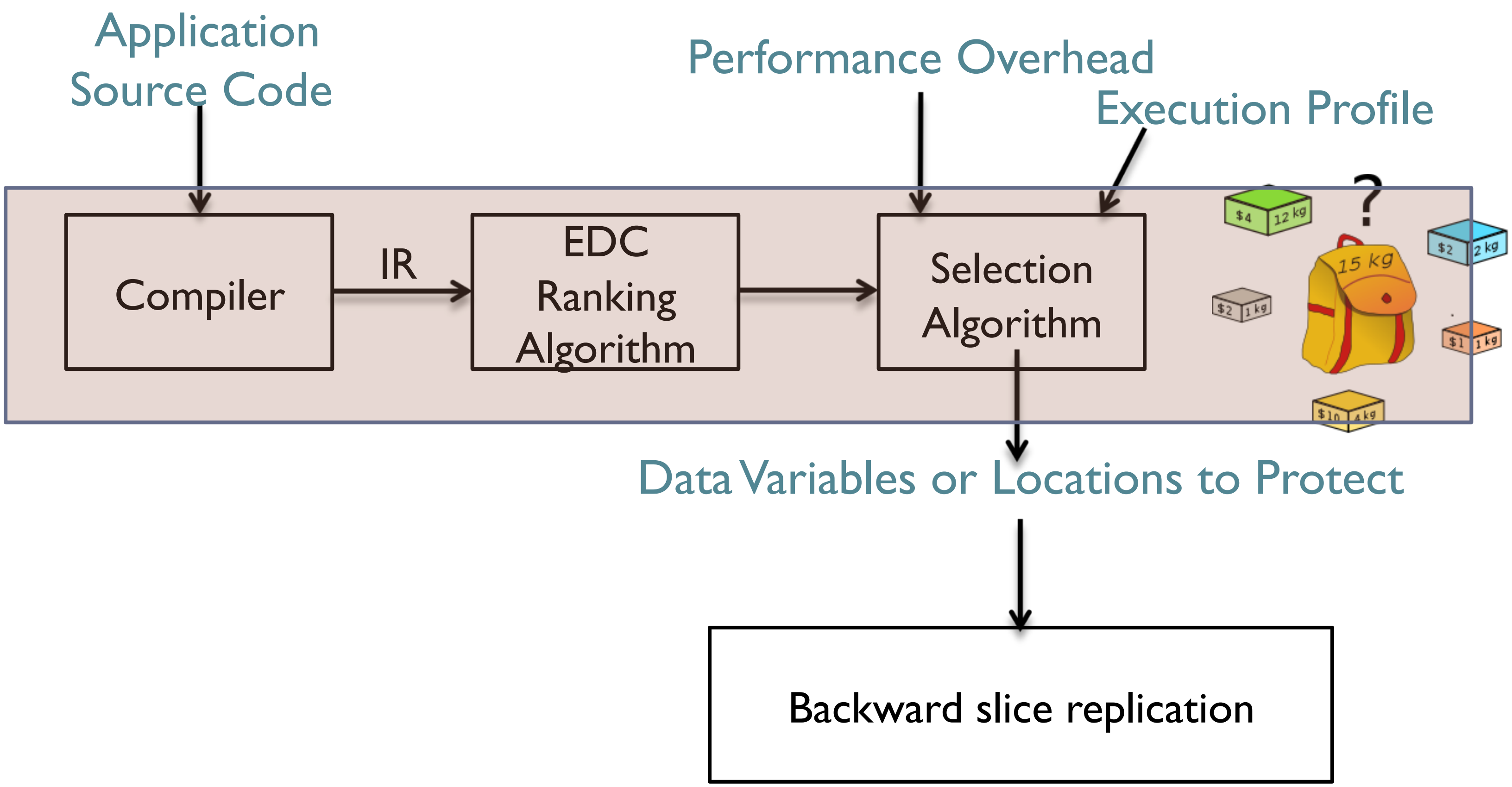
Execution Profile

Automated Detector Placement Algorithm

Data Variables or Locations to Protect

Step 3: Algorithm

Pre-emptive, Selective detection of EDC causing faults

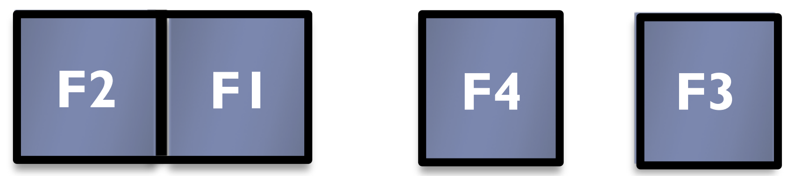


Selection Algorithm

```
void F1(…) {
    for(i = k; i < num; i++)
      …
}
void F2(void *src,  void *dst, …) {
    if(src < dst + offset)
       return;
    for(j = 0; j < width;  j++)
      ….
}
void F3(void * src, void *dst,…) {
     for(i =0;  i < n;  i++){
         if( k < r )
            src += k;
      …
}
void F4(…) {
     …
     k = F5 (…);
}
```

Function Exec Time

F2 > F1> F4 > F3



Selection Algorithm

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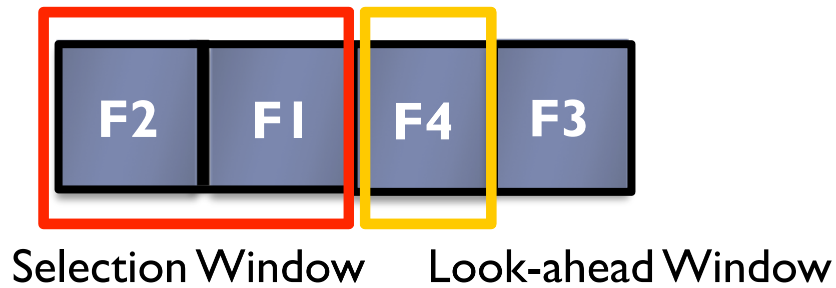
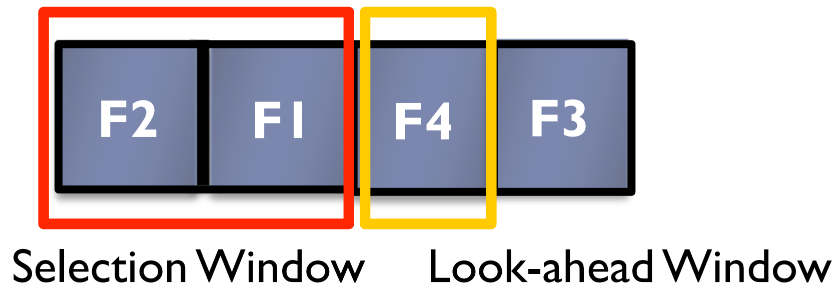
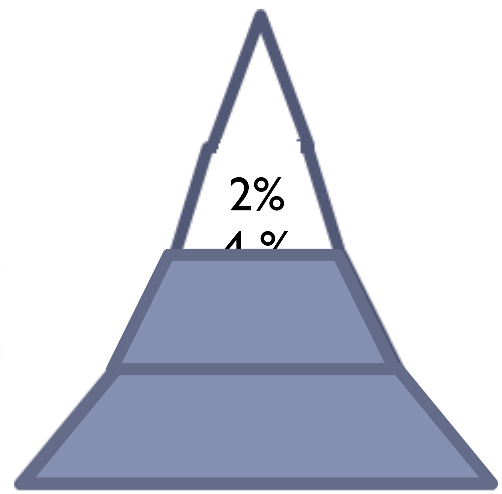


Selection Algorithm

```
void F1(…) {
    for(i = k; i < num; i++)   B1
      …
}
void F2(void *src,  void *dst, …) {
    if(src < dst + offset)  B2
       return;
    for(j = 0; j < width;  j++)  B3
      ….
}
void F3(void * src, void *dst,…) {
     for(i =0;  i < n;  i++){
         if( k < r )
             src += k;
      …
}
void F4(…) {
     …
     k = F5 (…);   C1
}
```



Inst	Rank	P.O. (%)
B2	3	10
B1	2.5	1
B3	2.5	2
C1	0.8	2



P.O = 5 %

Selection Algorithm

```
void F1(…) {
    for(i = k; i < num; i++)
      …
}
void F2(void *src,  void *dst, …) {
    if(src < dst + offset)
       return;
    for(j = 0; j < width;  j++)
      ….
}
void F3(void * src, void *dst,…) {
     for(i =0;  i < n;  i++){
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            src += k;
      …
}
void F4(…) {
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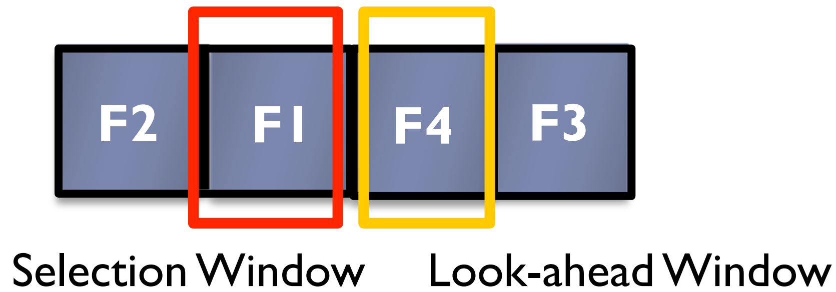
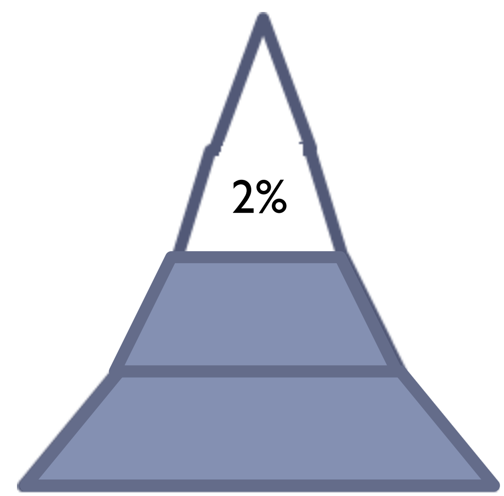
```





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Selection Algorithm

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}
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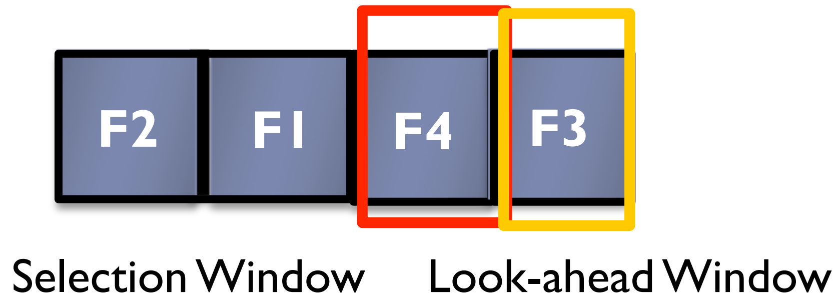
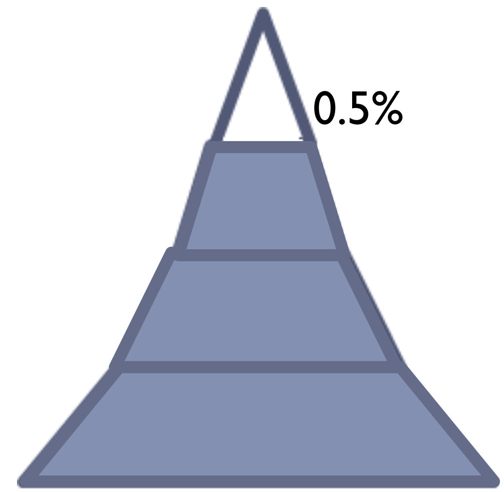
    if(src < dst + offset)
       return;
    for(j = 0; j < width;  j++)
      ….
}
void F3(void * src, void *dst,…) {
     for(i =0;  i < n;  i++){   B4
         if( k < r )          B5
            src += k;          P1
      …
}
void F4(…) {
     …
     k = F5 (…);   C1
}
```



Inst	Rank	P.O. (%)
B4	3	10
B5	2.5	1.5
P1	1	5
C1	0.8	2



P.O = 5 %

Selection Algorithm

```
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    for(i = k; i < num; i++) B1
       …
}
void F2(void *src,  void *dst, …) {
    if(src < dst + offset)  B2
      return;
    for(j = 0; j < width;  j++)B3
       ….
}
void F3(void * src, void *dst,…) {
     for(i =0;  i < n;  i++){   B4
         if( k < r )        B5
            src += k;        P1
      }
}
void F4(…) {
     …
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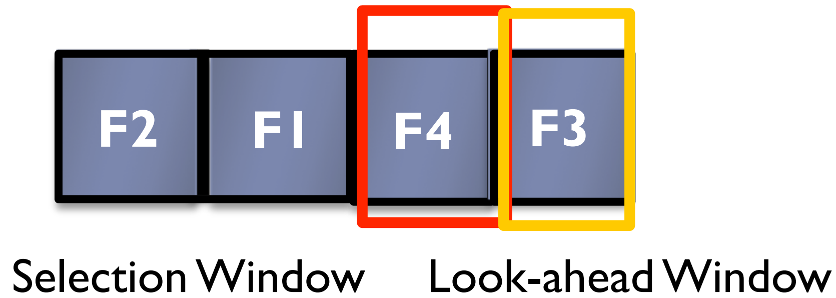
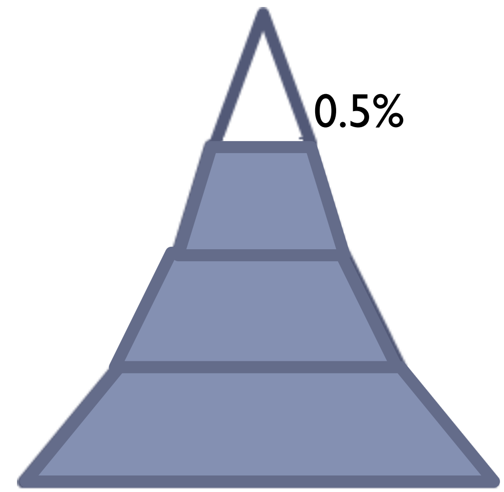
}
```



Detector Locations under 5% P.O.
B1 : i < num
B3: j < width
B5: k < r



P.O = 5 %

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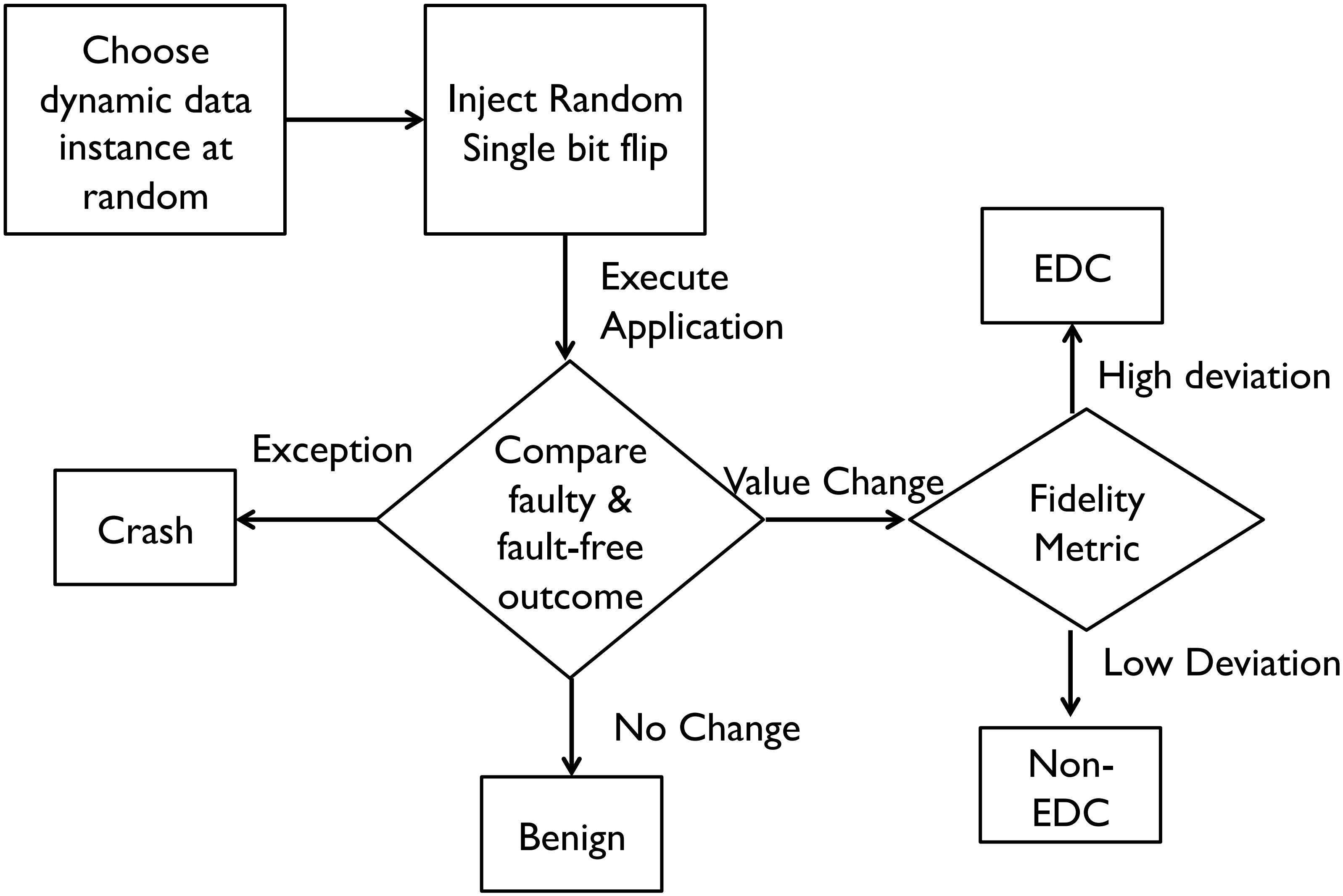
Experimental Setup

- Six Benchmarks from MediaBench, Parsec Suite
  - Fidelity Metric: PSNR, scaled distortion [Misailovic'12]

- Performed fault injections using LLFI
  - 2000 fault injections, one fault per run (1.3% at 95% CI)

- Measured coverage under varying performance overhead bounds

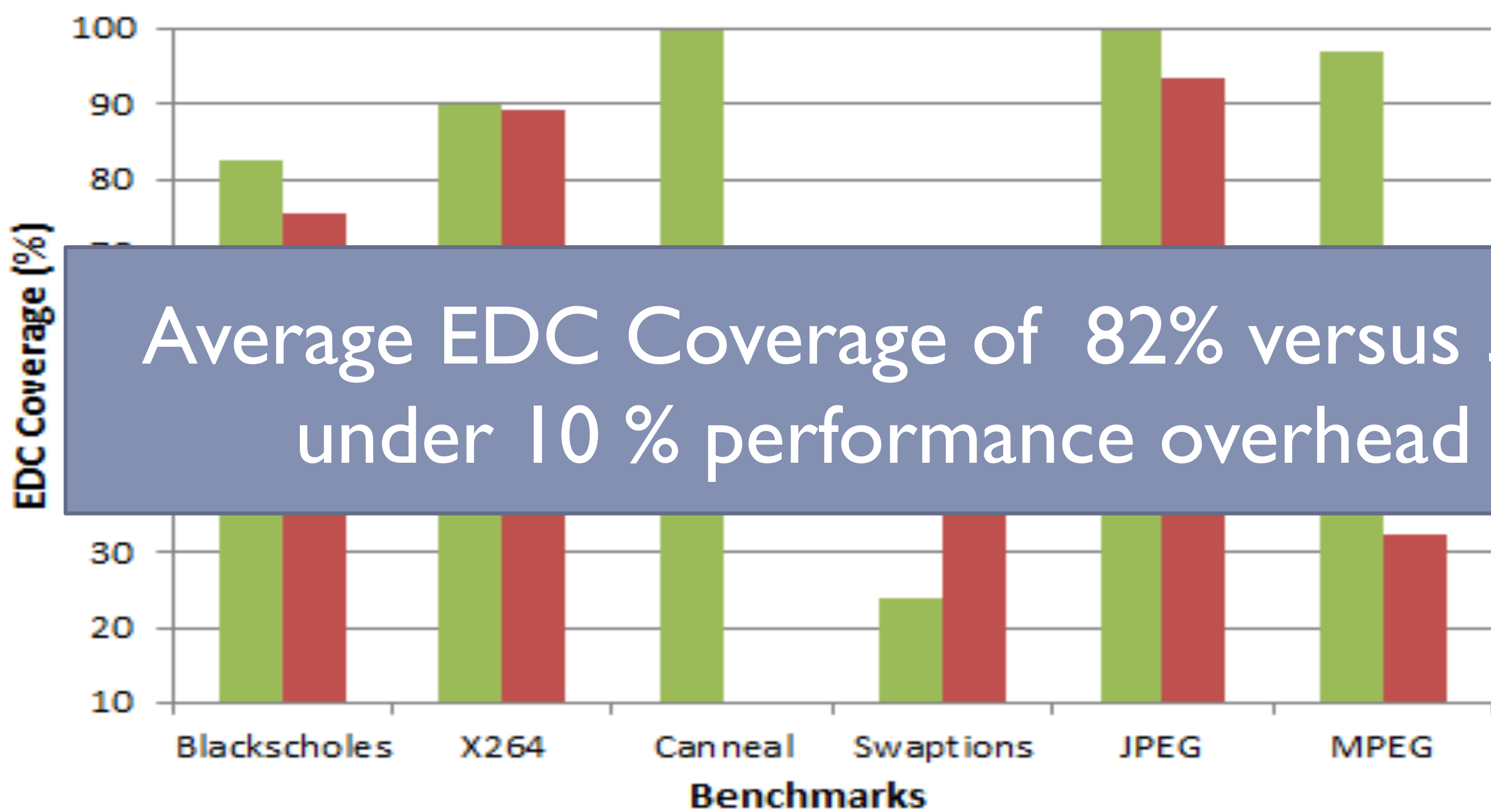
LLFI Experiment Framework



Coverage Evaluation

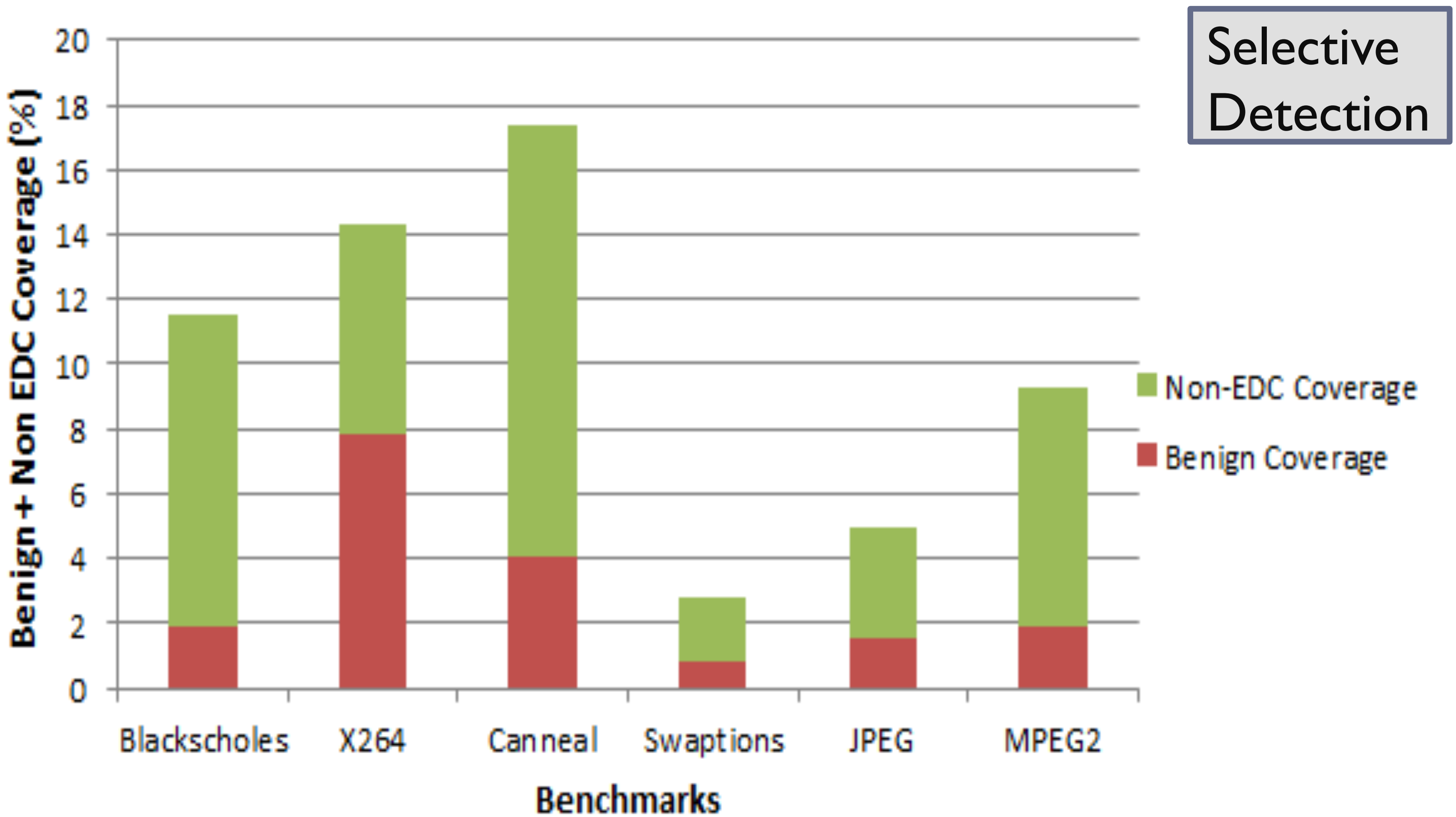
$$EDC\ Coverage = \frac{Number\ of\ Detected\ EDCs}{Total\ Number\ of\ EDCs}$$

Pre-emptive Detection



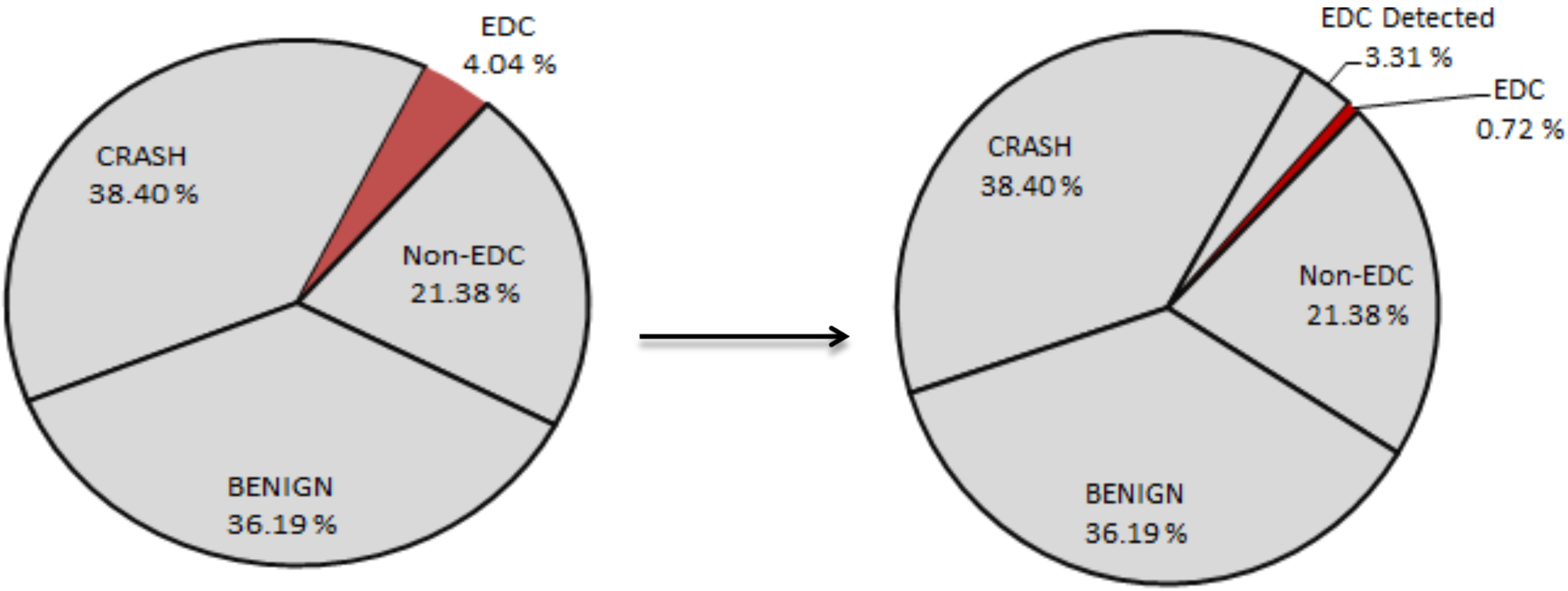
Average EDC Coverage of 82% versus 56% under 10 % performance overhead

Coverage Evaluation



Lower is better

Coverage Numbers in Perspective



Initial Coverage: 95.95 %

Coverage With our Technique: 99.3 %

Outline

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Conclusion

- Soft Computing applications
  - Egregious Data Corruptions (EDCs) are unacceptable outcomes
- Detector Placement Technique: pre-emptive and selective
  - Program level Heuristics – static analysis of code
  - Automated algorithm - varying performance overhead bounds

- Future Work
  - Actual detectors coverage
  - Compiler optimizations effect on technique

LLFI: http://github.com/DependableSystemsLab/LLFI

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