Comparing the Effects of Intermittent and Transient Hardware Faults on Programs

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Motivation

- Consequences

- Increase of intermittent faults [Constantinescu’03]

- Intermittent faults recur quickly [Nightingale’11]
Intermittent VS. Transient Faults

Intermittent:

Activity:
- Burst length
- Inactive time
- Active time

Permanent:

Time
Propagation of Intermittent Faults

```assembly
__main:
...
ADDIU $SP[29], $SP[29], -24
SW $R30, 16($SP[29])
```

$SP[29] No effect
Research Questions

- Do intermittent faults *differ* significantly with transients in their *impact* on software programs?

- If yes, how do the differences vary with the *length* (i.e., duration in cycles) of the fault?

- How do the differences vary with the *micro-architectural unit* in which the fault originates?
High-level Methodology

- Perform fault injection at $\mu$-architectural level
- Study effect of the faults at software level

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<tr>
<th>Software level</th>
<th>Failure Observation</th>
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<td>Architectural level</td>
<td>Observed failure: crash, hang, silent data corruption (SDC)</td>
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<td>$\mu$-architectural level</td>
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<td>Gate and circuit level</td>
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Outline

- Motivation and Overview
- Fault Model
- Experiment Setup
- Results
- Conclusion and Future Work
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Fault Type

- Intermittent: stuck-at-0/1 for specified durations of time
Fault Injection Location

- Inject faults in a RISC processor from [Patterson’08]
- Inject *only* 1 bit of the selected signal
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Experimental Infrastructure

- Fault injection framework: sim-outorder in SimpleScalar
Failure Detection

- Fault
  - Fault injection
  - Check Activation

- Error
  - No effect
  - Failure

- Time

- Crash
- Hang
- SDC
Benchmark Information

- 7 benchmark programs from Siemens suite [Hutchins’94]
  - characteristics of the programs
    - Lines of codes: < 1000 lines
    - Dynamic instruction #: 9,000 ~ 240,000
Experimental Procedure

Select a location → Each location except Mult_o

Select a type → Bit-flip, Stuck-at-0/1

Select a length → 1 cycle, 2, 5, 10, 25, 50, 100, 300, 800 cycles

Run → 1000 runs
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Research Questions Review

- Do intermittent faults *differ* significantly with transients in their *impact* on software programs?

- If yes, how do the differences vary with the *length* (i.e., duration in cycles) of the fault?

- How do the differences vary with the *micro-architectural unit* in which the fault originates?
Impact of Faults on Programs

- Crash percentage:
  - Stuck-at-1 > Transient > Stuck-at-0

Average crash percentage for different programs, 50 cycles for intermittent
Impact of Faults on Programs (cont.)

- SDC percentage:
  - Similar to each other

Average SDC percentage for different programs, 50 cycles for intermittent
Effects of Fault Length

- Intermittent:
  - Crash percentage increases with the increase of fault length
Effects of Intermittent Fault Origin

- Crash percentage:
  - Crash percentage different across different units
  - The difference between two fault types are different across different units

Crash percentage for different units (print_tokens2, 50 cycles)
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- Motivation and Overview
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Conclusion and Future Work

Conclusion

- Do intermittent faults differ significantly with transients?
  - Large *difference* in *crash* percentage
  - *Similar* for *hang* and *SDC* percentages
- How do the differences vary with the fault length?
  - Crash percentage *increases* with the increase of fault length
- How do the differences vary with the injected μ-architectural unit?
  - The difference is *dependent* on fault origin location

Future Work

- Consider other models for the two faults
- Develop intermittent-fault-tolerant software systems
- Study more complex processors