**Error-Tolerant Image Processing Application Based on Stochastic Logic**

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**Introduction & Motivation**

- An error-tolerant system is in urgent need to eliminate various external factors that can cause errors in modern techniques. A single transient fault may cause the whole system to perform erroneously. Unreliability in systems can lead to huge loss.
- Stochastic logic can create analog signal states in digital-based systems. It can be regarded as “bit-level” redundancy in some sense.
- Stochastic arithmetic can be adapted to computing such as image processing due to a number of features:
  - Tolerant transient fault
  - Simple hardware in some computing
  - Low silicon area and faster clock period
  - Progressive precision
  - More clock cycles to compute

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**Solution - Stochastic Logic**

- In stochastic logic, a normal input will take advantage of randomness and be transformed to a bit stream. The bit streams or wire bundles are digital, carrying zeros and ones, and the signal is conveyed through the statistical distribution of the logical values.
  - For example, 1010, 0001, and 010101011000011 are possible stochastic representations of 0/2 = 0.5
- Stochastic logic represents values by random sequence of a bit stream which can be transformed into probabilities.

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\begin{align*}
A &= 0.2B + 0.8C
\end{align*}
\]

**Solution - Architecture**

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**Filter Design**

- The image sharpening and smoothing are implemented by high-pass and low-pass filter masks.

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**Performance and Area**

- We synthesized and evaluated speed/area of conventional and stochastic designs. The clock period and area of stochastic design are both smaller than baseline design.
- The stochastic logic itself is only a small portion of the area. The most area is used to convert between regular number and stochastic number.
- The stochastic design will need more cycles to execute.
- The Period + Area = RCycle is roughly the same magnitude for baseline and stochastic design (if we only consider the core module).

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**Error Tolerance**

- We randomly flipped the input of the filters at different error rates to see the behavior.
- We use SSIM (Structural SIMilarity) and PSNR (the peak signal-to-noise ratio) to measure the similarity of pictures quantitatively.
- Data shown below is the average results of ten different pictures.

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**Discussion**

- The high-pass filter is more prone to faults
  - Low-pass filter will smooth the picture and tolerant to some extents
  - Progressive precision
  - Partial bit-stream provide a good estimate of the exact value
  - Possible random number resource to reduce hardware cost

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**Conclusion**

- The stochastic logic filter can be adapted to image processing filters to simplify the hardware design.
- It consumes less silicon area and can operate at a faster clock.
- While it will take more cycle numbers than conventional filter to execute, stochastic logic takes advantage of randomness and outperforms the baseline filter in terms of the error-tolerance capability.

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