Error-Tolerant Image Processing Application Based On Stochastic Logic
Checkpoint1 Report
Team Silicon

- **Problem to be addressed**
  Aggressive scaling of semiconductor devices exacerbate issues of reliability. High density of devices leads to more probable occurrences of hard errors during manufacturing. In addition, soft errors including particles striking and ray radiation will also have a larger impact on the high-density chips compared to the chips less progressive scaling and lower densities. A particle striking on the chip, for example, can cause a bit flip. Therefore, it is important to develop a method to enhance the reliability of the system.

- **Why does this problem matter?**
  The modern techniques that we adapt now are limited in ensuring absolute reliability. An error-tolerant system is in urgent need to eliminate various external factors that can cause errors. A single transient fault may cause the whole system to perform erroneously. Unreliability in systems can lead to huge loss in all fields, including economic loss of company as well as potential hazards in real-world applications.

- **Idea/solution to be investigated by the project**
  Our idea is to use stochastic logics to implement image processing hardware such as sharpening/smoothing filters and make it more error-tolerant for transient faults.

  Stochastic logic is error-tolerant due to its nature and can create analog signal states in digital-based systems. 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.

  The advantages of the stochastic logic are:
  1. Error tolerance. A single binary value is presented with bit stream which reduces the impact when transient fault happens. In normal operations, if the significant bit of one value is corrupted, it is likely to have a large impact on the result. However, in the stochastic logics, the impact is minimized by equally distributing value weight to all bits in the bit stream.
  2. Fast computation in specific applications. While the stochastic creates more bits than traditional logics, in some cases it will be faster by taking advantage of statistic concept. For example in Figure 1, the multiplication $y = x_1 \cdot x_2$ in directly computed by using a simple AND gate. Another example is scaled addition shown in Figure 2. Using a single MUX, the stochastic logic can perform a weighted average easily.

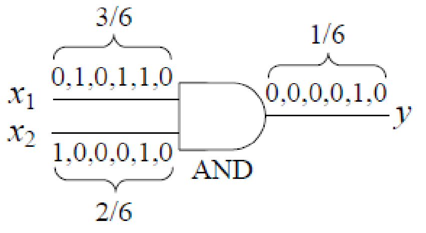


Figure 1. Multiplication in Stochastic Logic

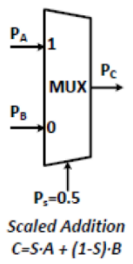


Figure 2. Scaled Addition

➢ Progress so far

1. Basic stochastic logic units
   a. Completed design of basic stochastic logic units, including Randomizer (LFSR, Comparator) and De-Randomizer.
   b. Adapted basic units to create a multiplier in stochastic logic. It takes advantage of the fact that the multiplication of two independent probabilities can be calculated directly as $p = p_1 \cdot p_2$ using the AND gate. After testing, the module achieved desired functionality.

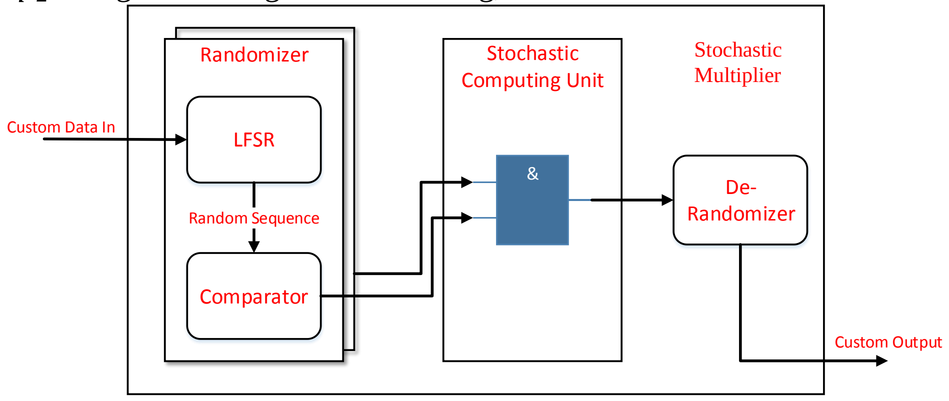
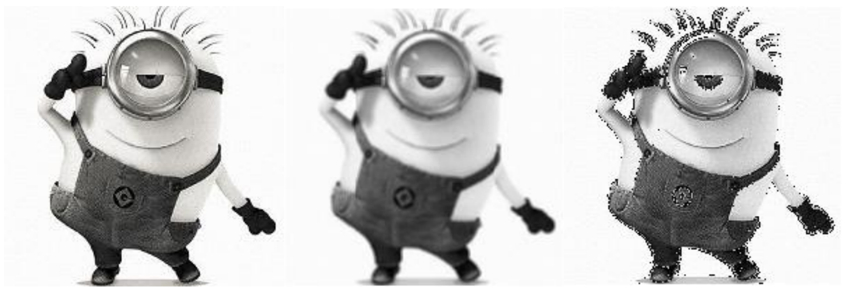


Figure 3. Stochastic Multiplier Architecture

2. Custom baseline smoothing and sharpening filter
   - We implemented the low-pass (smoothing) filter using image blur algorithm to smoothen the image and mitigate noise. The design is reconfigurable and the high-pass (sharpening) filter can be easily achieved by adjusting parameters of the image processing masks. An example has been attached below in Figure 4.



(a) Original *(b) Smoothing* *(b) Sharpening*

Figure 4. Smoothing and Sharpening Results with Custom Baseline filter

➢ Issues

1. Not clear about detailed implementation of addition/subtraction in stochastic logic
2. Not sure about how to optimize area delay product in stochastic filter

➢ Future works

In the next few weeks, we will be focusing on the design of the sharpening/smoothing filter in the stochastic logic. Also, we will be developing the control units to interface the stochastic units for testing purposes.