Ardrand: The feasibility of the Arduino as a random number generator

Benedikt Kristinsson
Advisor: Ýmir Vigfússon

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Randomness

- Hard on CPU

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- External sources needed

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Pseudo-Random Number Generator

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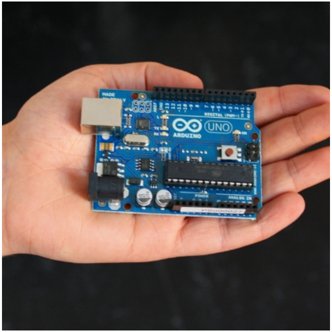
Today: Arduino



Arduino

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- Cheap ($30)

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> *If it is important for a sequence of [random] values generated to differ [...] initialize the random number generator with a fairly random input, such as analogRead() on an unconnected pin.*

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Analysis

1. Obtain sequences

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2. Algorithms used

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3. Statistical tests

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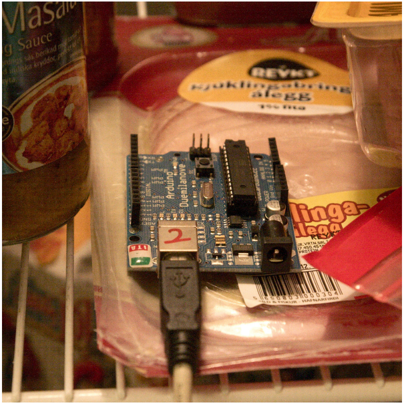

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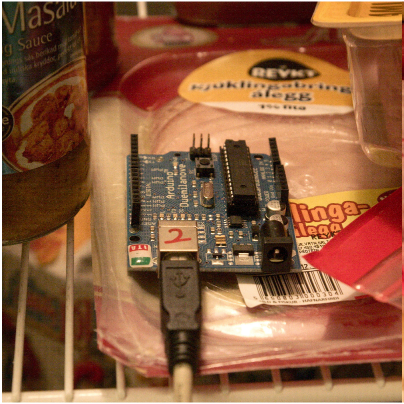

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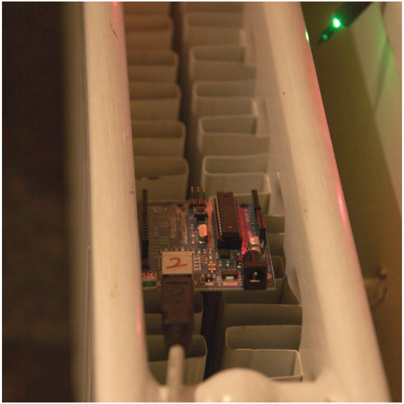

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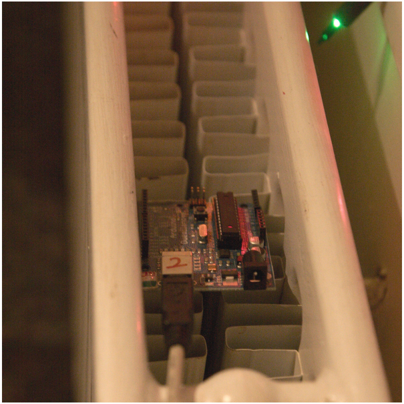

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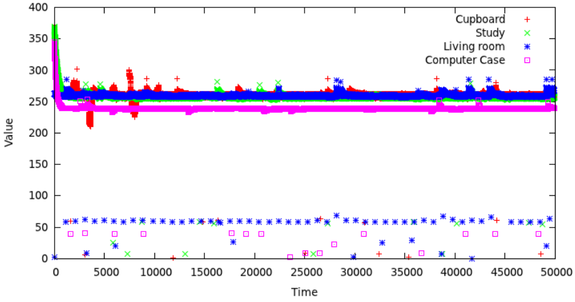

Yes!

Temperature is important

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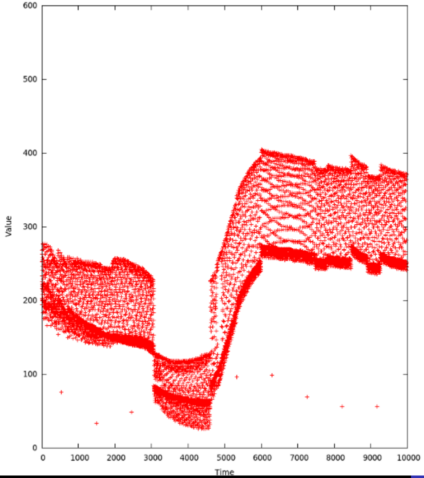

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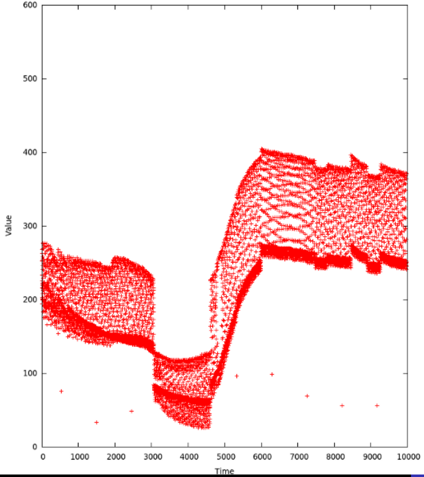

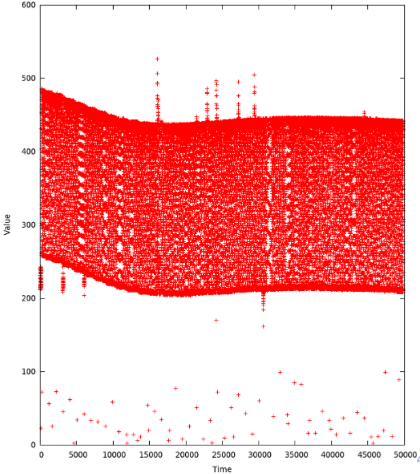

The von Neumann box

Used to remove bias from a generator

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Input two bits and discard them if they are the same. A 1,0-pair becomes a 1-bit and 0,1 pair becomes a 0-bit.

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Let p be the probability that the generator yields a 1-bit and q that it yields a 0-bit. This relies on the fact that 01 and 10 are equiprobable since $p \cdot q = q \cdot p$.

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Applied in all our algorithms.

Meanrand

Idea

Keep track of the mean of the values read, generate a 0 if below and a 1 otherwise.

- Observed bitrate: 25-85 bps

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Mixmeanupdownrand

Idea

See what happens if we mix `Mean-RAND` and `Updown-RAND`.
Generate one bit from either and XOR them together.

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Idea

Return the least significant (rightmost) bit for each value from `analogRead`

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Let $b = b_9, \ldots, b_1, b_0$ be a 10-bit integer generated by `analogRead`. Return b_0.

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- Passes most tests in some settings

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Return the XOR of the two least significant (rightmost) bits for each value from `analogRead`

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- Observed bitrate: $\approx$ 170 bps

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- Observed bitrate: ≈ 170 bps
- Second fastest, but not fast enough

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Statistical testing

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Monobit

Idea

A random sequences should contain roughly the same number of 1's and 0's. This gives a statistic on this ratio.

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Math

Let n_0 denote the number of 0's and n_1 the number of 1's. We then find

$$X_1 = \frac{(n_0 - n_1)^2}{2}$$

Results

Results

Passed

- Mean-RAND on all our computers

Results

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- `Mean-RAND` on all our computers
- `Leastsign-RAND` on all our computers

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Rejected	• Updown

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Rejected
- Updown
- MixMeanUpdown (inconsistently)

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Poker test

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Based on the idea of five-card hands in poker. In a random sequence we would expect each hand to show up about the same amount of time.

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Math

Let m be the size of the poker hand and $k = \lfloor \frac{n}{m} \rfloor$, where n is the length of the sequence. Find

$$X_3 = \frac{2^m}{k}\left(\sum_{i=1}^{2^m} n_i^2\right) - k$$

Results

Results

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- Leastsign-RAND on our laptops

Results

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- `Leastsign-RAND` on our laptops
- `Twoleastsign-RAND` on our laptops

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Results

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- `Leastsign-RAND` on our laptops
- `Twoleastsign-RAND` on our laptops

Rejected
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- `Mean-RAND`
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- All algoritms on desktop computer

Runs

Runs examples

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Find the number of runs of each length. The longer the run, the unlikelier it is. The FIPS publication has a nice table listing how many sequences of each length should appear.

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Math

Let G_i and B_i be the number of gaps and blocks of length i and e_i denote the expected number of blocks of length i. Find

$$X_4 = \sum_{i=1}^{k} \frac{(B_i - e_i)^2}{e_i} + \sum_{i=1}^{k} \frac{(G_i - e_i)^2}{e_i}$$

Results

Results

Passed

- `Leastsign-RAND` sometimes on laptops
- `Twoleastsign-RAND` always on one laptop
- `Twoleastsign-RAND` sometimes on another laptop

Rejected

- `Updown-RAND`
- `Mean-RAND`
- `MixMeanUpdown-RAND`
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Results

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Leastsign	ACC	ACC	(REJ)	ACC	290.55 bps

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- Twoleastsign passes NIST tests as well when it passes our tests

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Thank you

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