Random number generators

Comp Sci 1570 Introduction to C++

Outline

1 Definitions

2 Random number generation
Methods
Hardware
Software
Hybrid
Example: LCG
C++
rand()
srand()

Random number generator

- The generation of a sequence of numbers or symbols that cannot be reasonably predicted better than by a random chance, usually through a random-number generator (RNG).
- RNGs have applications in gambling, statistical sampling, computer simulation, cryptography, completely randomized design, and other areas where producing an unpredictable result is desirable.
- Two principal methods, computational pseudorandom number generation (PRNG) and a hardware random number generator (true random number generation, (TRNG).

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Hardware TRNG

- Measures some physical phenomenon expected to be random and then compensate for possible biases in the measurement process.
- E.g., atmospheric noise, thermal noise, and other external electromagnetic and quantum phenomena like cosmic background radiation or radioactive decay as measured over short timescales represent sources of natural entropy.
- In security applications, hardware generators are generally preferred over pseudo-random algorithms, where feasible.
- Speed at which entropy can be harvested from natural sources is dependent on the underlying physical phenomena being measured.
- Thus, sources of naturally occurring "true" entropy are said to be blocking – they are rate-limited until enough entropy is harvested to meet the demand.
- On most Linux distributions, the pseudo device file /dev/random will block until sufficient entropy is harvested from the environment.

Computational PRNG

- Computational algorithms can produce long sequences of apparently random results, which are in fact completely determined by a shorter initial value, known as a seed value or key.
- As a result, the entire seemingly random sequence can be reproduced if the seed value is known.
- Called a pseudorandom number generator (PNRG)
- Does not rely on sources of naturally occurring entropy, though it may be periodically seeded by natural sources.
- This generator type is non-blocking, so they are not rate-limited by an external event, making large bulk reads a possibility.
- While a pseudorandom number generator based solely on deterministic logic can never be regarded as a "true" random number source in the purest sense of the word, in practice they are generally sufficient even for demanding security-critical applications.

Hybrid approaches

- Some systems take a hybrid approach, providing randomness harvested from natural sources when available, and falling back to periodically re-seeded software-based cryptographically secure pseudorandom number generators (CSPRNGs).
- The fallback occurs when the desired read rate of randomness exceeds the ability of the natural harvesting approach to keep up with the demand.
- This approach avoids the rate-limited blocking behavior of random number generators based on slower and purely environmental methods.

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Linear congruential generator

- An example of a PNRG is a linear congruential generator (LCG), which is an algorithm that yields a sequence of pseudo-randomized numbers calculated with a discontinuous piecewise linear equation.
- One of the oldest and best-known pseudorandom number generator algorithms.
- Generator is defined by a recurrence relation:

$$X_{n+1} = (aX_n + c) \mod m$$

where X is the sequence of pseudorandom values, and

$m, 0 < m$ the "modulus"

$a, 0 < a < m$ the "multiplier"

$c, 0 \leq c < m$ the "increment"

$X_0, 0 \leq X_0 < m$ the "seed" or "start value"

are integer constants that specify the generator.

If $c = 0$, the generator is often called a multiplicative congruential generator (MCG), or Lehmer RNG.

If $c \neq 0$, the method is called a mixed congruential generator.

Work out an example

$$X_{n+1} = (aX_n + c) \mod m$$

where X is the sequence of pseudorandom values, and

$m, 0 < m$ the "modulus"

$a, 0 < a < m$ the "multiplier"

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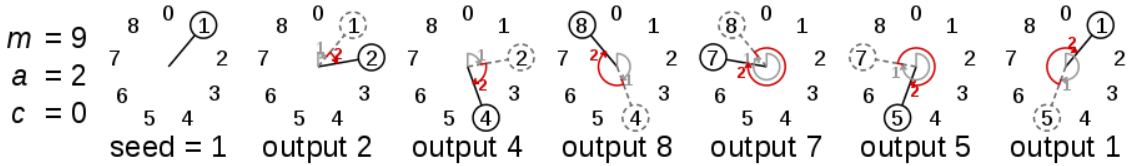
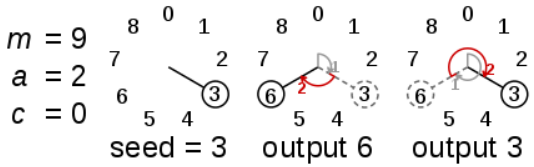
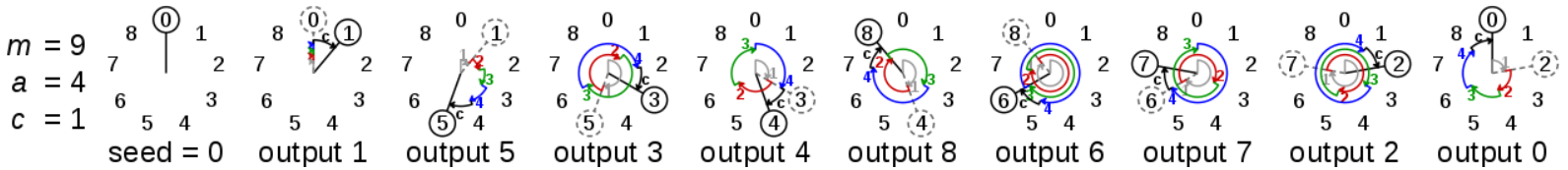
are integer constants that specify the generator.







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C++ function: rand()

int rand (void);

- Returns a pseudo-random integral number in the range between 0 and RAND_MAX, the value of which is library-dependent, but is guaranteed to be at least 32767 on any standard library implementation.
- Algorithm returns a sequence of apparently non-related numbers each time it is called.
- Uses a seed to generate the series, which should be initialized to some distinctive value using function srand.

C++ function: srand()

void srand (unsigned int seed);

- PRNG is initialized using the argument passed as seed.
- For every different seed value used in a call to srand, the pseudo-random number generator can be expected to generate a different succession of results in the subsequent calls to rand.
- Two different initializations with the same seed will generate the same succession of results in subsequent calls to rand.
- If seed is set to 1, the generator is reinitialized to its initial value and produces the same values as before any call to rand or srand.
- In order to generate random-like numbers, srand is usually initialized to some distinctive runtime value, like the value returned by function time.
- This is distinctive enough for most trivial randomization needs.