Random Numbers

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1. What are random numbers?

- Not really random, just very unpredictable.
- Often based on integer sequences:

$$r_{n+1} = ar_n + b \mod N$$

- ⇒ they repeat, but only with a long period.
- A good generator passes statistical tests.

2. Random workflow

1. First there is the random engine which contains the mathematical random number generator.
2. The random numbers used in your code then come from applying a distribution to this engine.
3. Optionally, you can use a random seed, so that each program run generates a different sequence.

3. Random generators and distributions

- Random device

```
std::default_random_engine generator;
% random seed:
std::random_device r;
std::default_random_engine generator{ r() };
```

- Distributions:

```
std::uniform_real_distribution<float> distribution(0.,1.);
std::uniform_int_distribution<int> distribution(1,6);
```

- Sample from the distribution:

```
std::default_random_engine generator;
std::uniform_int_distribution<> distribution(0,nbuckets-1);
random_number = distribution(generator);
```

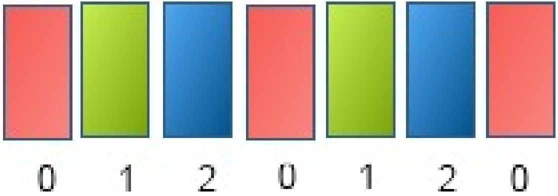
- Do not use the old C-style `random`!

4. Why so complicated?

- Large period wanted; C random has 2^{15} (implementation dependent)
- Multiple generators, guarantee on quality.
- Simple transforms have a bias:

```
int under100 = rand() % 100
```

Simple example: period 7, mod 3



5. Dice throw

```
// set the default generator
std::default_random_engine generator;

// distribution: ints 1..6
std::uniform_int_distribution<int> distribution(1,6);

// apply distribution to generator:
int dice_roll = distribution(generator);
  // generates number in the range 1..6
```

6. Poisson distribution

Poisson distributed integers:

```
std::default_random_engine generator;
float mean = 3.5;
std::poisson_distribution<int> distribution(mean);
int number = distribution(generator);
```

7. Local engine

Wrong approach: random generator local in the function.

Code:

```
// rand/static.cpp
int nonrandom_int(int max) {
  std::default_random_engine engine;
  std::uniform_int_distribution<>
     ints(1,max);
  return ints(engine);
};
    /* ... */
  // call `nonrandom_int three times
```

Output:

```
Three ints: 1, 1, 1.
```

8. Global engine

Good approach: single random generator static in the function.

Code:

```
// rand/static.cpp
int realrandom_int(int max) {
  static
     std::default_random_engine
     static_engine;
  std::uniform_int_distribution<>
     ints(1,max);
  return ints(static_engine);
};
```

Output:

```
Three ints: 15, 98, 70.
```

9. What does ‘static’ do?

- Static variable in function:
  persistent, shared between function calls
- Static variable in class:
  shared between all objects of that class

10. Class with static member

Class that counts how many objects have been generated:

Code:

```cpp
// object/static.cpp
class Thing {
private:
  static inline int number{0};
  int mynumber;
public:
  Thing() {
    mynumber = number++;
    cout << "I am thing "
         << mynumber << '\n';
  };
};
```

Output:

```
I am thing 0
I am thing 1
I am thing 2
```

Optional exercise 1

In the previous Goldbach exercise you had a prime number generator in a loop, meaning that primes got recalculated a number of times.

Optimize your prime number generator so that it remembers numbers already requested.

Hint: have a `static` vector.

11. Generator in a class

Note the use of `static`:

```cpp
// rand/randname.cpp
class generate {
private:
  static inline std::default_random_engine engine;
public:
  static int random_int(int max) {
    std::uniform_int_distribution<> ints(1,max);
    return ints(generate::engine);
  };
};
```

Usage:

```cpp
auto nonzero_percentage = generate::random_int(100)
```