The Fake Randomness Project: How to Detect Fake Coin Flips and Made-up Data

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Project Goals

- Create a set of interactive online experiments and software tools to test a user's ability to simulate true randomness and to test user-supplied data for randomness.
- Develop a suite of statistical tests that can serve as effective "fake randomness detectors", optimized for each experiment.
- Potential applications include educational uses, testing real-world data such as win/loss sequences in sports for randomness, and the use as a fraud detection tool.

Current Projects

Online Fake Coin Toss Experiment:

- Online experiment, at www.math.illinois.edu/fakerandomness.
- Implemented in javascript.
- User inputs a sequence of heads or tails, trying to mimick a random coin toss sequence.
- Program applies a series of randomness tests to the data and computes normalized scores for each of each individual test, as well as an overall "fakeness score" that represents the likelihood of the sequence to be "fake".
- Program provides progressive feedback in the form of a graph showing the current scores on each of the tests. (See screenshot on right.)

Standalone Program:

- Standalone tool to analyze binary data for deviations from randomness.
- Implemented in C++ in a Linux environment, and suitable for application to large sets of binary data.
- Current version implements 11 different randomness tests; see the right column for details.
- Each test is run on the user-supplied sequence, and on a control set of 50,000 computer-generated random sequences, used to normalize the scores.
- Unusually high or low normalized scores indicate deviations from random behavior.

Project History

- **Origins:** Project started out as a class project by Chad Franzen, Rishabh Marya, and Robert Weber, in the class "Probability and the Real World" (Math 199 CHP) by Professor Hildebrand in Spring 2014. The code was further developed by Rishabh Marya, Jiachun Chen and Xin Wei in Fall 2014, and is currently maintained by Tong Li and Xusheng Zhang.
- **Public exhibits:** Live demos of the "fake coin toss detector" at the Engineering Open House (March 2014 and March 2015), and at the UIUC Math Department Homecoming Open House (October 2014).
- **Professional presention:** 15 Minute oral presentation by Robert Weber at the summer meeting of the Mathematical Association of America in Portland, OR (August 2014).

Distinguishing Real Data from Random Data: Can You Spot the Fakes?

Below are three real-world binary sequences, each paired with a computer-generated random sequence of the same length and with the same overall proportions of heads and tails. Can you tell which is which? (Answers on the bottom right corner.)

Win/Loss sequence of Chicago White Sox, first half of 2010 season:

A1: W L L L L W W L W L L L L W L W W W W L L W L W W W L L W L W L L W L W L L W W L W L W L W L L W L L W L L W L W W W W W W W W W W W W L L W L W L W W

A2: W W W L W W W W W W W L W W L W W W W L L W W W L L W L W W W W W L W L W L L W W W W W L L W L W L L W W W W W L L L L L W L W L L W W W L W L L W W W L L L W W L L W W L

Scoring sequence in Bulls vs. Lakers NBA game, December 25, 2011:

B1: L L L L B B L B B L B B B L L L L L L B B B B L B B B L B L B B B B B L B B L L L B L L B L B L B L L L B B L B L B B L B B B B B L B B L L B B L L L L B B B B B L L B B B B L B L B B

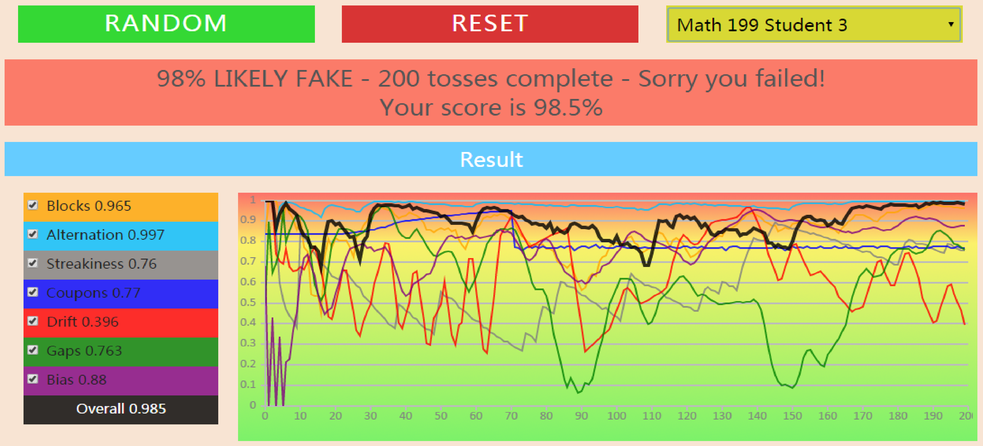
B2: L B L B B B L L L L B L B L L L B B B B L B B L B B L L L B L L B B B L B L B L B L B L L B L B L B L L B B B L B L B L L L L L B B L L L L L L B B L L L L B L L B L B B B B L B B B L B B B L B B B B B

Rainy/Dry days in Champaign, January–April, 1999:

C1: D R D D D R R R D D R R R D D D R D D D R R R D D D D D D D R D R D D D D R D D D R R D D R D D D R R D D D D D D D R R D R R R D D R D D R D D R R D R R D D D D D D D D D D D D D D D D D D D D D D R R D D D R R R D D D R R R D R R D D D D R R D D D

C2: D R R D D D D D D R D D D R D R D R D D D D D D D D D D D R D R R R D D R R D R R R D D D D R R D R R D D D D D D R R D R R R D D D D D D D R R D R R D D D D D D D R R D R R R D D D D D D D R R D R R D D D D R D D D R D D D R D R D D D D R R R D D D R D D D R D R R D D R D D D D

The Fake Coin Toss Detector: www.math.illinois.edu/fakerandomness



Results: Human-Generated Data versus Computer-Generated Data

The table below shows the results of the "Fake Coin Toss Detector" for five strings of 200 heads and tails generated by Math 199 CHP students instructed to mimick true randomness, along with 5 computer-generated random strings of the same length. Note that the overall scores for computer-generated strings are spread over the fulll interval $[0, 1]$, while those for human-generated strings are all .985 or above, corresponding to a 98.5% likelihood that the sequence is fake.

Test	Student					Computer				
	#1	#2	#3	#4	#5	#1	#2	#3	#4	#5
Blocks	0.999	0.999	0.965	0.999	0.994	0.625	0.665	0.585	0.495	0.415
Alternation	0.999	0.999	0.997	0.998	0.155	0.868	0.165	0.285	0.440	0.665
Streakiness	0.665	0.000	0.760	0.999	0.665	0.780	0.823	0.932	0.725	0.710
Coupons	0.205	0.999	0.770	0.966	0.045	0.230	0.485	0.165	0.695	0.445
Drift	0.202	0.986	0.396	0.526	0.852	0.170	0.638	0.747	0.698	0.422
Gaps	0.999	0.999	0.763	0.474	0.995	0.785	0.122	0.454	0.276	0.322
Bias	0.133	0.851	0.880	0.976	0.997	0.633	0.407	0.067	0.807	0.304
Overall	0.999	0.999	0.985	0.999	0.988	0.455	0.325	0.645	0.255	0.135

Analyzing Real-World Sequences

A key goal of this project is to analyze large sets of real-world sequences for deviations from randomness. We are currently focusing on the following data sets:

- **NBA scoring sequences:** Scoring sequences for all NBA games during the period 2007–2012. This data set includes some 7500 sequences, representing close to one million scoring events.
- **MLB win/loss sequences:** Win/loss sequences for all MLB teams for the period 1990–2014. The data set includes some 700 sequences.
- **Weather-related sequences:** Daily precipitation data for Champaign-Urbana for the period 1890–2014.
- **Human-generated sequences:** Sequences generated by students in class experiments and at Open House events.

How to Detect Fakes

A variety of statistical tests have been developed to test random number generators (Knuth, 2005; Marsaglia, 1996). We have some of these tests for our purposes and developed additional tests. Our current implementation employs 11 statistical tests to measure different characteristics of a sequence and to identify deviations from random behavior.

- **Alternations:** Measures frequencies of H/T and T/H "flips" in the sequence. Human-generated "fake" coin flips tend to have significantly more alternations than random sequences, while weather-related sequences tend to have fewer alternations.
- **Streakiness:** Measures frequencies of "streaky" blocks such as HHHHH. Weather-related sequences exhibit more streakiness than random sequences, while scoring sequences in basketball games tend to exhibit less streakiness than a random sequence
- **Drift:** Measures the variability in the relative frequencies of H's. Weather-related sequences and sports sequences show significant drift.
- **Gaps:** Measures the lengths of the gaps between H terms in the sequence.
- **Bias:** Compares the frequencies of heads and tails with those of a random coin toss. This test is easiest to "beat" by a human.

References

- Bakan, P. Response-tendencies in attempts to generate random binary series. *American Journal of Psychology*, 1960, **73**, 127-131
- Knuth, Donald Ervin. *The art of computer programming.* Pearson Education, 2005.
- Marsaglia, George. "DIEHARD: a battery of tests of randomness." (1996).

Answers to Quiz

A1, B2, C1 are the "real" sequences.