METEOR®: A Dice-Based Method for Uniform Random Sampling of Geographic Coordinates

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Abstract

METEOR® is a dice-based method for generating approximately uniform random geographic coordinates across the Earth's surface. A coin toss or D2 and four D10 digits select a signed value whose arcsine gives latitude; a D36 and four D10 digits select longitude in one of 36 ten-degree sectors. Under fair, independent dice rolls, longitude and the sine of latitude are each approximately uniform on their discrete grids, with a duplicated zero outcome in each. The finite resolution and the World Geodetic System 1984 (WGS84) ellipsoidal shape of the Earth place limits on exact surface-area uniformity. The method is transparent and suitable for GIS demonstrations, spatial sampling and tabletop applications.

1 Introduction

Random sampling of geographic coordinates is useful in GIS, spatial statistics, simulations and games. Uniform latitude across $-90°$ to $90°$ oversamples polar regions on a sphere. The appropriate spherical construction instead samples $u = \sin\phi$ uniformly and calculates $\phi = \arcsin u$. METEOR® implements a finite-resolution version with physical dice.

2 Methodology

Dice required

One D2 (or coin toss), four D10 rolls for latitude, one D36, and four D10 rolls for longitude. Every D10 is read as a digit 0–9. Rolls are assumed fair and independent.

2.1 Latitude: spherical surface sampling

Roll the D2: 1 specifies north and 2 specifies south. Let the four D10 digits be a, b, c, d, and form

$$m = 1000a + 100b + 10c + d, \qquad u = \begin{cases} m/10000, & \text{north}, \\ -m/10000, & \text{south}. \end{cases} \qquad \phi = \arcsin(u).$$

The calculator or software must return degrees. For example, north with digits 2,3,4,0 yields $u = 0.2340$ and $\phi \approx 13.53°$ N; south with digits 7,5,0,0 yields $u = -0.7500$ and $\phi \approx 48.59°$ S. The range of u is -0.9999 to 0.9999, and exact poles are excluded. The two signed rolls for $m = 0$ both produce the same geographic latitude of zero; every other signed u value has one dice sequence. Thus zero has twice the probability of each other individual latitude value. This tiny discrete effect is distinct from the continuous ideal $u \sim \text{Uniform}(-1, 1)$.

For a sphere, an infinitesimal band has area proportional to $\cos\phi\, d\phi = du$, explaining the arcsine transformation. WGS84 is an ellipsoid, so the spherical transformation is not exactly uniform by ellipsoidal surface area.

2.2 Longitude: 36 ten-degree sectors

Roll D36, obtaining n from 1 to 36. Rolls 1–18 indicate east and 19–36 west. Let the four D10 digits be a, b, c, d, and calculate the offset

$$q = a + \frac{b}{10} + \frac{c}{100} + \frac{d}{1000} \qquad (0.000 \le q \le 9.999).$$

Calculate the signed longitude

$$\lambda = \begin{cases} 10(n-1) + q, & 1 \le n \le 18, \\ -[10(n-19) + q], & 19 \le n \le 36. \end{cases}$$

For example, n = 18 and digits 3,4,5,6 yield 170 + 3.456 = 173.456° E. With n = 36 and the same digits the result is 173.456° W. Each side has 180,000 equally likely dice sequences at 0.001-degree spacing. Both n = 1 and n = 19 with q = 0 produce longitude zero. Thus 360,000 sequences yield 359,999 distinct longitudes: zero has probability 2/360,000 and each other longitude has probability 1/360,000. Longitude 180° is excluded.

3 Uniformity and validation

Latitude samples a regular grid in the sine of latitude, and longitude samples a regular angular grid. Both distributions are approximately uniform: zero has twice the probability of any other individual value on its respective grid. These are mathematical properties of the mapping under the stated fairness assumption. No simulation data, statistical test results or reproducible simulation protocol are supplied, so no empirical validation claim is made. Finite grid spacing and the ellipsoidal Earth also limit exact global surface uniformity.

4 Illustration of sampling bias

Figures 1 and 2 illustrate why uniform latitude angles are biased toward the poles and why sampling the sine of latitude corrects that bias for a sphere.

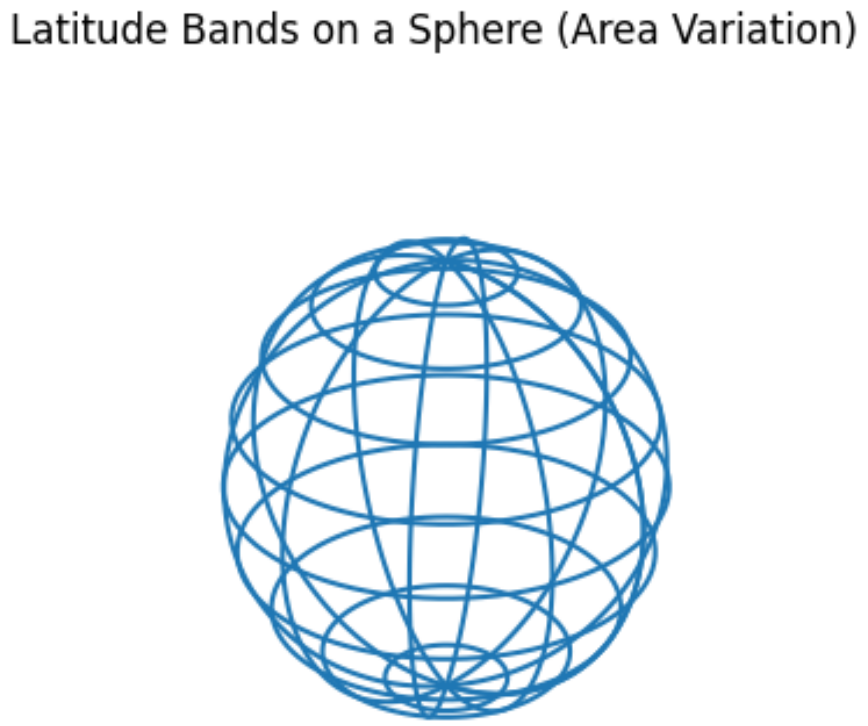


Figure 1: Latitude bands on a sphere. Equal angular intervals correspond to different surface areas.

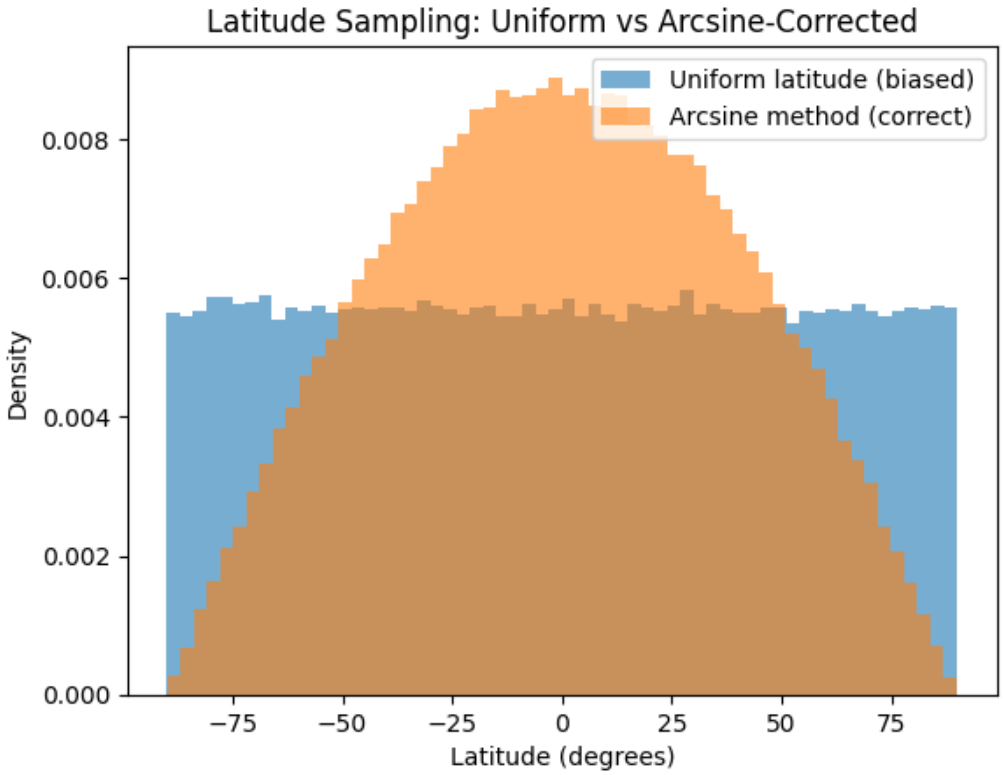


Figure 2: Comparison of uniform angular latitude sampling and spherical equal-area latitude sampling.

5 Resolution and precision

The input grid has a spacing of 0.0001 in u, but latitude *angle* spacing is not constant: approximately 0.00573° (about 637 m north–south) near the equator, increasing sharply toward the largest reachable latitudes. Longitude spacing is 0.001°, about 111 m east–west at the equator and proportionally less at higher latitudes. These are grid spacings, not measurement accuracy or guaranteed positional precision.

6 Applications and discussion

The method supports GIS testing, Monte Carlo demonstrations, education and tabletop world generation. Physical rolls provide an auditable source of random digits, while the arcsine conversion requires a calculator or software. A practical test of dice fairness and a comparison with target surface-area distributions would be needed to quantify real-world bias.

7 Conclusion

METEOR® provides a practical physical procedure for generating geographic coordinates. It samples longitudes approximately uniformly on a discrete grid and approximates uniform spherical surface sampling through the sine-of-latitude transformation. The duplicated zero outcomes in both coordinates, finite grid spacing and the ellipsoidal Earth are explicit limits on exact surface-area uniformity.

Categories

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Secondary: stat.AP

Keywords

Geographic sampling, GIS, Monte Carlo methods, analogue RNG, spherical distribution

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