Trident? Nah, Tri-ing not to lose my mind :)

5/29/2025

Introduction

Welcome! I decided to make this little analyzing games thing into a series. Basically how this will work is whenever I am annoyed at the probability of a part of a game, or with a game in general, I will withdraw and write a paper on it(nerdy, I know), but its fun so deal with it :). In honor of this starting based on my annoyance for Sudoku, I am going to call this series Annoyance Analysis.

This papers Annoyance Analysis (I love the name already) was inspired by my good friend BOB and I's Minecraft world. See, coming off a demanding first year at university, we thought 'what better way to relax and decompress over the summer then to start a nice Minecraft world?'. Now for those of you without a childhood, Minecraft is a block based game in which you explore, mine, build (hence Mine-Craft), travel to different dimensions, mercilessly slaughter thousands of animals, pillage and raid villagers, trapping the inhabitants to trade farms in which they get a 1 $\times$ 1 hole to stand in for the rest of their lives, invade other dimensions to kill their leader and steal its egg.... and its somehow called a children's game(confusion). But hey! you can tame a dog!! Anyways, in the game there is a zombie like mob called a drowned, some of which have a weapon called a trident (very cool). As BOB and I were peacefully boating along, I suddenly got hit in the head by one of them. Now since I had no weapons strong enough to kill it and had no food as it is, we fled in terror. Now you might be asking, TOM, what does this have to do with nerd math??? I'm getting there, be patient.

That moment had me wondering how many drowned I would have to kill in order to get a full durability trident. So for todays Annoyance Analysis, I will be analyzing the math behind getting a trident in the game Minecraft.

That was a very long introduction, I apologize :).

Information From The Minecraft Website

We are assuming you are starting in a ocean biome, where drowned are most common, we are also assuming that you posses no

- **Getting a Trident:** probability of a Drowned spawning is 6.25%, and the probability of it dropping a trident is 8.5%. Thus, the probability of a drowned spawning and dropping a trident when you kill it: $0.085 \cdot 0.0625 = 0.0053125$, or about 0.53%
- **We are assuming no buffs:** i.e. looting or any mods that make drops more likely, but we can add a variable to correct for it, called b, into the probability model.
- **The durability of the trident changes:** We want to get a full durability trident, so we must find the average durability of the dropped tridents so that we may combine them. If X is the durability of the trident when dropped, and the actual durability is a random value between 1 and 250, then $X \sim$ Unif$(1, \ldots, 250)$. To find the average, we need the first moment, or the expectation of X. Since it is a uniform distribution model, we know:

$$\mathbb{E}[X] = \frac{a+b}{2} = \frac{1+250}{2} = 125.5$$

However, Minecraft seems to dislike statistics, because the only tridents I have ever gotten have been below 10%, so uh.... Mojang please fix this...

Axioms of Minecraft

From the information above, we are able to construct the following axioms that influence the rest of this paper. These are proven, unalterable values and concepts that provide the backbone for all derivations of all formulas, theorems and corollaries laid out in this section.

- **(A1) Spawn Rate Axiom:** The probability of a drowned spawning when eligible is fixed and equal to 0.0625 (i.e., 6.25%).
- **(A2) Trident Drop Axiom:** The probability that a drowned drops a trident upon death is fixed and equal to 0.085 (8.5%), independent of other factors unless otherwise specified.
- **(A3) No Buffs Axiom:** There are no external influences such as Looting enchantments or game modifications. All probabilities are in their base vanilla form unless a buff factor b is explicitly introduced.
- **(A4) Durability Distribution Axiom:** A trident that drops will have durability uniformly distributed over the integers 1 to 250, i.e., $X \sim \text{Unif}\{1, 2, \ldots, 250\}$.
- **(A5) Full Trident Objective Axiom:** The goal is to obtain a full-durability trident (250/250), which may be achieved through combining multiple damaged tridents in an anvil.
- **(A6) Independence Axiom:** The spawning and trident-dropping behavior of each drowned is independent of all other drowned.

Theorems and Corollaries

Theorem 1.1 (Drowned I.I.D. Theorem): The probability of getting a trident dropped is the same across all drowned, and the list is Independent and Identically Distributed (I.I.D.).

Proof. From Axiom A6 (Independence) and A1–A2, each drowned spawn and drop is a Bernoulli trial with fixed probabilities. Hence, the sequence of drowned encounters forms an i.i.d. process. □

Corollary 1.1.1 (Expected Tridents per Kill): The expected number of tridents obtained from killing n drowned is $n \cdot p$, where $p = 0.0053125$.

Proof. Direct application of the linearity of expectation on i.i.d. Bernoulli trials with success probability p. □

Theorem 1.2 (Expected Kills for One Trident): Let T be the number of drowned you must kill to get one trident. Then $\mathbb{E}[T] = \frac{1}{p} = \frac{1}{0.0053125} \approx 188.2$.

Proof. This follows from the expectation of a geometric distribution with success probability p. □

Theorem 1.3 (Durability Expectation Theorem): Let X be the durability of a dropped trident. Then $\mathbb{E}[X] = 125.5$.

Proof. By Axiom A4, X is uniformly distributed over $\{1, 2, ..., 250\}$. The expected value of a uniform distribution over $\{a, a+1, ..., b\}$ is $\frac{a+b}{2}$. □

Theorem 1.4 (Expected Total Durability After n Tridents): The expected total durability from n trident drops is $125.5n$.

Proof. From Theorem 1.3 and linearity of expectation: $\mathbb{E}[\sum_{i=1}^{n} X_i] = \sum_{i=1}^{n} \mathbb{E}[X_i] = 125.5n$. □

Corollary 1.4.1 (Expected Tridents Needed for Full Durability): To reach a total durability of at least 250, the expected number of trident drops needed is:

$$n = \left\lceil \frac{250}{125.5} \right\rceil = 2$$

Proof. Set $125.5n \geq 250$, solve for n. □

Theorem 1.5 (Expected Kills for Full Durability Trident): The expected number of drowned that must be killed to collect enough tridents to combine into one full trident is:

$$\mathbb{E}[K] = 2 \cdot \frac{1}{p} \approx 376.4$$

Proof. From Theorem 1.2 and Corollary 1.4.1, multiply the number of required tridents by the expected kills per trident. □

Theorem 1.6 (Looting Amplification Theorem): If the looting buff modifies the trident drop probability by a multiplier $b > 1$, then the new expected kills per trident is $\frac{1}{bp}$.

Proof. The drop probability becomes bp, and the expected number of trials in a geometric distribution becomes $\frac{1}{bp}$. □

Corollary 1.6.1 (Expected Kills with Looting for Full Trident): With looting modifier b, the expected number of drowned kills to obtain enough tridents for a full-durability one is:

$$\mathbb{E}[K_{\text{loot}}] = 2 \cdot \frac{1}{bp}$$

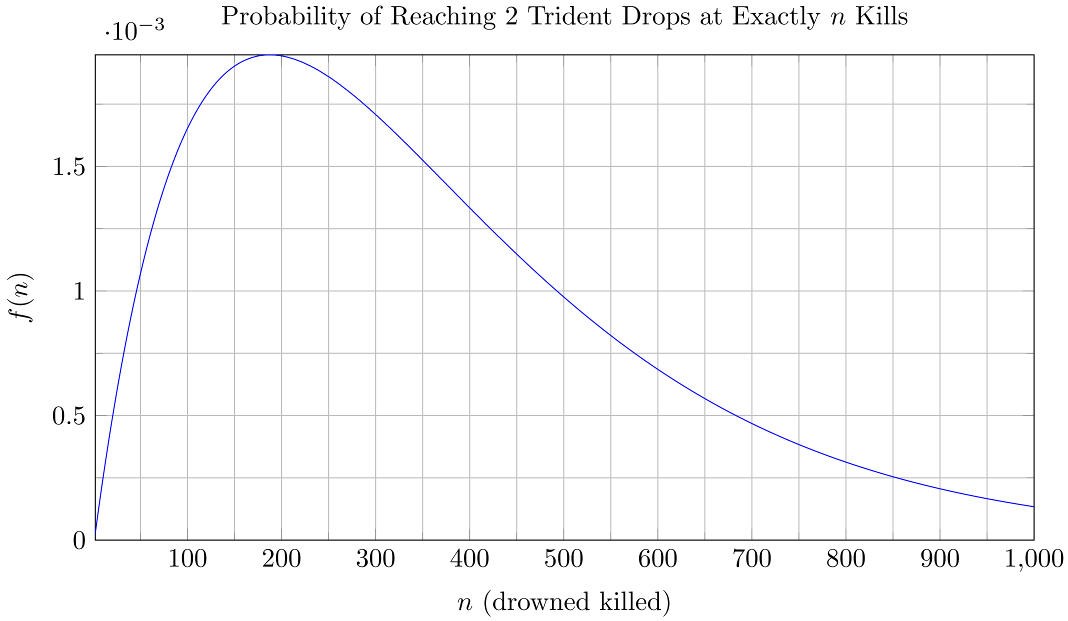
Proof. As in Theorem 1.5, replacing p with bp. □

Graphs and Models

Let us now suppose that you wish to test your luck by looking at the how the probability shifts if you set a maximum number of drowned you are willing to hunt. We will define a new random variable $T \sim NegBin(2, 0.0053125)$. We can create a new function $f : \mathbb{Z} \to \mathbb{R}$ by mapping $n \mapsto P(\text{A5})$, where P(A5) is the probability of obtaining our objective of a full durability trident.

$$f(n) = \binom{n-1}{r-1} p^r (1-p)^{n-r}$$
$$f(n) = \binom{n-1}{2-1} (0.0053125)^2 (0.9946875)^{n-2}$$
$$f(n) = \binom{n-1}{1} (0.0053125)^2 (0.9946875)^{n-2}$$

where $f(n)$ is the probability of getting the full trident off of n drowned killed.
Below we graph this function for $n \in [2, 1000]$:



Conclusion and Analysis

Though I am not a professional Minecraft player, I find the probabilities, coding, and concepts behind the game to be quite fascinating.//
Using assumptions from the base game (no buffs or enchantments), we found the following:

- The chance of getting a trident from a drowned kill is only **0.53125%**.
- On average, you need to kill about **188.2 drowned** to get a single trident.
- Because each trident is damaged and averages **125.5 durability**, you'll likely need **two tridents** to combine and reach full durability.
- This means the expected number of drowned kills for a full trident is around **376.4**.
- If you add a looting modifier (e.g., $b = 2$), you can cut that number in half, which dramatically improves efficiency.

We also modeled the probability distribution using the negative binomial framework, which allowed us to compute the chance of reaching the trident goal within a specific number of kills. The shape of this distribution is heavily right-skewed, meaning there's a significant chance you'll be grinding for hundreds of kills without success.

From a gameplay perspective, this analysis justifies the frustration players experience when hunting for tridents. With drop rates so low and durability so limited, the trident becomes one of the more elusive weapons in vanilla Minecraft. It also highlights the real power of enchantments like Looting and the value of repair mechanics like the anvil.

Finally, on a meta level, this exploration showcases how even games designed for fun contain rich systems governed by probability, expectation, and discrete mathematics. It turns out that trying to "relax" with Minecraft can accidentally result in writing a math paper, and honestly, I'm not even mad about it.

Stay tuned for future entries in Annoyance Analysis, where we'll keep using math to justify irrational levels of gaming rage. Until then, may your mobs be plentiful and your drop rates ever in your favor.