ARENA™

Simulation Analysis & Design

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Introduction

Since 1996, children and even some adults around the world (but mostly Japan) have been captivated by the world of Pokémon. Pokémon is a creature training game. It fosters an environment which promotes “strategic thinking and, in many cases, basic math skills” [1]. We want to take that to the next level. We want to use simulations and statistical analysis of their outputs to analyze the best strategies in Pokémon to become true Pokémon masters.

The insights gathered from optimal strategies have important implications for the balance of Pokémon. Game developers must ensure their game is being played in interesting ways by users rather than with a fixed strategy. If the mean completion time of a major task in Pokémon given a certain strategy is found to be statistically significantly better than all other strategies it will nullify the diversity and strategic thinking that the game developers aim for.

In particular, it is common for trainers to level up their starting Pokémon first before completing major objectives in the game since this is a rather easy and highly rewarding task. We are looking to compare the mean times needed to level up each starter Pokémon. If a certain starter is easier, it will likely be selected by most trainers causing diversity issues.

Original System

The first generation system for Pokémon was the Nintendo Game Boy. This system is not efficient to perform simulations on due to manual button inputs. It’s also quite a rare system, being released in 1989. Game emulators exist to simulate this environment, but performing simulations on these environments still requires manual inputs. Some people have created programs to directly play the game through code, but performing analysis on the results is limited and would involve lots of custom code. Using Arena will be able to give us automatic reports on mean times for training. Furthermore, statistical analysis on these means is also an available feature which is highly desirable.

Pokémon works on a highly nuanced battle and movement system. Attack and defence stats are used to calculate damage done by one Pokémon to another. Various factors such as move sets, items and even hit probability can be used to vary this damage done. Additionally type or move type matching can greatly affect the damage multipliers calculated by the game. Furthermore Pokémon can only be encountered in specific areas of the game and the species of Pokémon that you encounter is randomized within a certain set within a region.

Data

Input

Input information for the simulation model was based off real Pokémon Red game dynamics and equations. These dynamics were simplified under the most basic assumptions. Simplified game dynamics included:

Game Dynamics

As a Pokémon gains experience points from battle, it levels up by passing experience point thresholds much like a stepwise function. The simulation model has been created with a set of decision nodes that determine which level the Pokémon is at based on its experience. Each node corresponds to the amount of in game points actually required for a Pokémon of that type to reach each level. Rate of experience gained from a particular battle depends on the Pokémon defeated. It is calculated via the following approximation which holds well for low levels:

$$\Delta_{Experience} = \left(\frac{50}{7}\right) * Level$$

Level	Experience Threshold
5	*Start*
6	44
7	101
8	179
9	284
10	425

Upon leveling up, a Pokémon's attack, defense, and health points (HP) stats are increased proportionally. The process nodes of the simulation increment the Pokémon's based on real in game rates. The attack and defense increments upon leveling have been approximated to 1 or 2 points increase with a 50/50 chance, while the heath point increase has been approximated to a constant increase of 2. These attack, defense and health points are used to authentically model Pokémon battles, wherein health point damage dealt with an attack is calculated via the following equation:

$$Damage = 40\left(\frac{2 * Level_{Attacking} + 10}{250}\right)\left(\frac{Attack_{Attacking}}{Defence_{Defending}}\right) + 2$$

This equation states that the amount of damage of done in health points is dependent on the level of the level of the attacking Pokémon, its attack level and the defence level of the defending Pokémon. For each turn, it is assumed that the user takes 3 seconds to decide on and perform an attack, ultimately deciding on an attack with a strength multiplier of 40 each time. The computer generated opponent

Pokémon takes approximately 1 second to "decide upon" and perform their attack. Thus the time that battles take depends on the amount of turns that it takes for either the player or the computer generated opponent to die.

In order to find a Pokémon to battle, the player must walk in a certain area wherein the likelihood of encountering a Pokémon with each step is a probability of 10/187.5 or 0.053. Given that each step takes 0.255 seconds the Pokémon encounter rate can be determined with an exponential function with parameter 0.208 probability of encounter per second.

Lastly, Pokémon can be healed by visiting the "Pokémon center". This will recover their health points back to their max health point level but it takes a constant amount of time to travel from the Pokémon center back to the battle area. This constant amount of time has been approximated to 15 seconds each way. If a player "dies" or his/her health points are less than or equal to zero, they will restart at the Pokémon center. Thus there is a 15 second penalty for dying and a 30 second penalty for healing.

Simulation Model

Objective

The specific objective is to simulate how long it would take for a gamer (Pokémon trainer) to use their initial game state (starting Pokémon) to achieve 5 level ups (from level 5 to level 10). We wish to compare the length of time taken on average by each of the three potential starting strategies in the game (based on the starting Pokémon selected).

Entities

Entity Name
My Pokémon

Variables

Variable Name	**Initial Value**
Level	5
Total Experience	0

Attributes

Name	**Initial Value (Power) for {**Charmander, Squirtle, Bulbasaur**)**
Max HP	Initially {20, 20, 21}
Enemy Level	Randomly generated between 2-5

MyHP	Equivalent to Max HP and is manipulated in battle
MyAttack	12 for all Pokémon
MyDefence	{10, 13, 10}
Opponent HP	14, held constant as an approximation
Opponent Attack	7, held constant as an approximation
Opponent Defence	11, held constant as an approximation

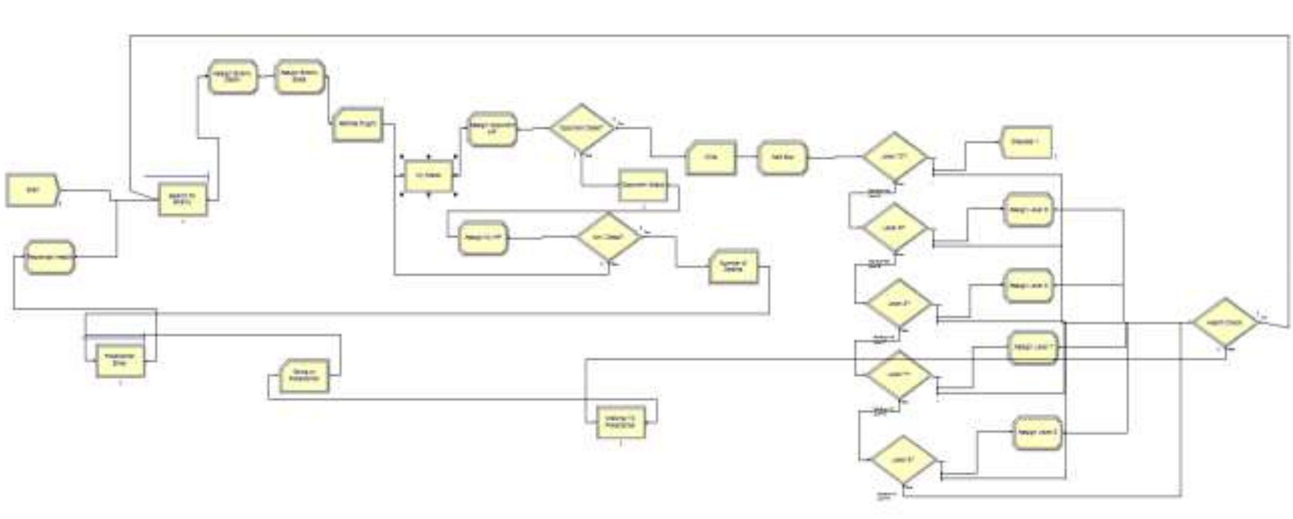
Events

Event Name	**Delay (seconds)**
Enter Pokémon Center	15 to include healing
Walk to Pokémon Center	15 (arbitrarily assigned)
My Attack in Battle	3 based on human decisions
Opponent Attack in Battle	1 since AI decide instantly

Activities

Activity Name	**Delay(seconds)**
Search for Enemy	Approximately exponentially distributed with parameter 2.1

Arena Implementation



As seen in the simulation model, statistics are collected on every death event and killing event. Statistic is also tracked when deciding whether on not to go back to searching for opponents or to go to the base to heal. There is also a timer to keep track of the time the simulation is taking.

Event Execution

<u>Start</u>

1. Search for enemy (Exponentially distributed, based on constant probability of encounter and constant movement)
2. Assign enemy a random level and universal (HP, Attack, Defense) vector as an approximation
3. Begin battle upon arrival
    a. Attack opponent, deterministically changing its HP based on stats
    b. If enemy HP < 0, add a deterministic amount of XP based on enemy level
        i. Check if trainer leveled up; if so Update(HP, Attack, Defense, Level)
        ii. Check if trainer needs to go to Pokémon center based on HP threshold
            1. If so go back to 1. after a set amount of time
            2. Else go back to 1 to find the next battle
    c. If not dead, the opponent attacks, deterministically changing HP of trainer
        i. If trainer HP < 0, the trainer dies
            1. If so go back to 1 after a set amount of time

Healing Strategy Analysis

The most important factor when trying to reach level 10 is deciding when to keep fighting and when to go back to the base to heal since this is the only real decision the player can make. Player has no control of the enemies he finds and cannot predict how long the battle will last or how much damage is done prior, therefore he/she needs to decide at what threshold they will go back to the base to regenerate their health.

This threshold is identified by the "Health Check" decision after every battle. By experimenting with various thresholds for Charmander, we found that if the player returns to base when the health drops below 14, they will never die. The results of the experiment can be found in Figure 1.0 below.

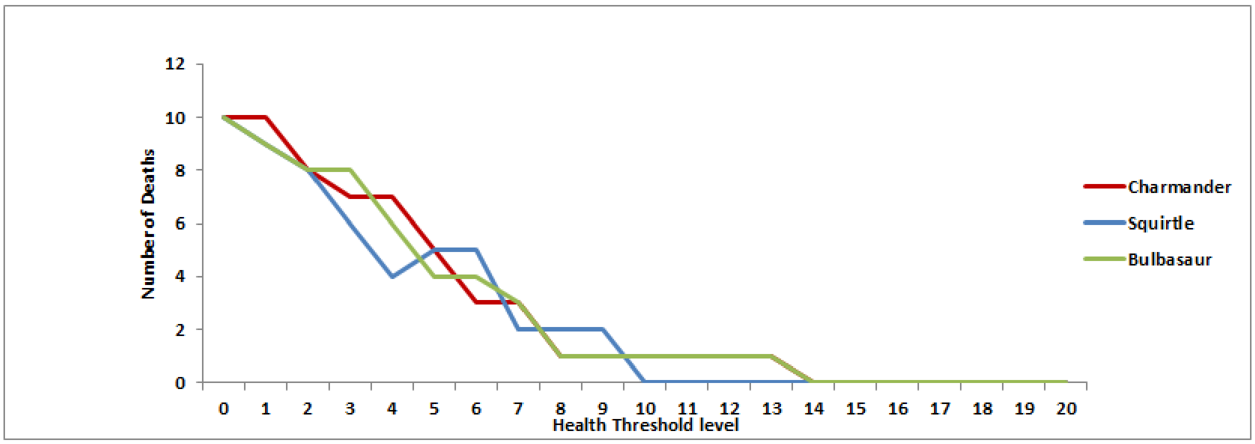


Figure 1.0: Various thresholds for healing and the associated number of deaths that result.

The simulation was repeated for Squirtle, Charmander and Bulbasaur to see which of these Pokémon takes the least time to reach level 10, while attempting to ensure that they don't die in the process. The results suggested that Squirtle requires a threshold of at least 10 and Charmander and Bulbasaur need at least a threshold of 14 to avoid dying through the whole process, likely due to their lower defense. There is an enticement for gamers to avoid dying as every death results in a loss of coin. The coin was not used for this model as it does not provide any benefits to the user until after level 10.

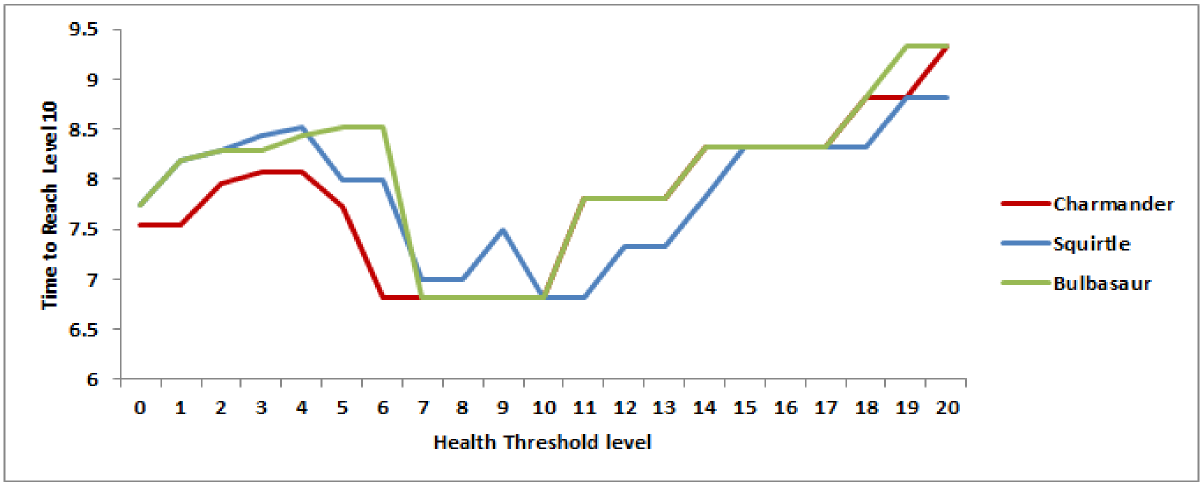


Figure 2.0: Various thresholds for healing and the associated time to reaching level 10.

For the same experiment, the time to completing the activity was measured for each Pokémon. These are depicted in Figure 2.0 above. The results were used to find time ranges required for each Pokémon to reach level 10 depending on the playing style of the gamer. If the gamer plays conservative and heals after every battle, the results display that it could take up to 10 minutes to reach level 10 due to the long time it takes to walk to the base to heal after every battle. Similarly, if the gamer plays aggressive and never heals until they die they reach level 10 in around 8 minutes. That is because time is wasted battling enemies that the Pokémon cannot win due to their lack of health. The simulation results suggest that the ideal threshold for going back to heal is if your health falls below 10 for all 3 of the Pokémon. However Charmander is more lenient with a range of 6 to 11 with Bulbasaur having a range of 7 to 10 and Squirtle having a range of 10 to 11. The results also show that it is impossible to reach level 10 in less than 6.8 minutes due to the time it takes to search and fight Pokémon and either dying or healing.

Comparing Performance

The results of 1000 repetitions of leveling a Pokémon from level 5 to 10 showed that Squirtle is far superior compared to other Pokémon in the beginning, as illustrated in Figure 3.0. Furthermore, Charmander and Bulbasaur were within each other's confidence intervals, varying only slightly in their means and standard deviations. Results were obtained by using Output Analyzer as part of Arena.

<u>Confidence Interval on Average Time to Completion</u> (Confidence = 95%)

	Avg	**Std Dev**	**Half-Width**	**Min**	**Max**
Bulbasaur	9.24	1.45	0.0897	6.26	16
Charmander	9.25	1.43	0887	6.26	15.5
Squirtle	7.75	0.808	0.0502	6.18	11.2

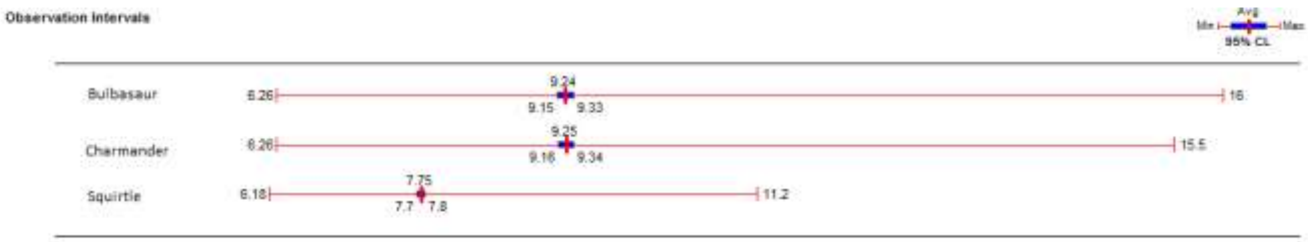


Figure 3.0: Confidence intervals for the time to completion for each Pokémon.

Conclusions & Recommendations

"Charzard is super strong, so what's the point of math?"

In conclusion, we now know why Bulbasaur is nobody's favourite.

In terms of time to completion, Bulbasaur takes just as long as Charmander, with a lousy 1 HP difference in starting stats. On the other hand, Charmander can be played highly aggressively with a minimum HP strategy lower than Bulbasaur's, thus saving time for a smart player.

Also, Blastoise looks pretty cool, so that's another perk to choosing Squirtle. Just sayin'.

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