

Bachelor Thesis

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Design, Implementation and evaluation of different strategies for playing Pokémon battles

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Abstract

...

Zusammenfassung

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1. Introduction

1.1. What is Pokémon

To Be Done (TBD)

1.2. Basic rules

ToDo (Game is turn based)
 ToDo (Each player has 6 Pokémon)
 ToDo (If a Pokémon has no HP left, it faints)
 ToDo (If all Pokémon of a player fainted, the player loses) (Game states in Pokémon are high-dimensional and the majority of its features are both categorical and partially observable)
 ToDo

1.3. Battling

One of the key aspects of the Pokémon game is to battle other Pokémon. In the mainline games, you can have up to six Pokémon in your team, also known as party. There is the option to swap a Pokémon with another Pokémon, but you can't have more than six Pokémon at any point in your team. When playing the original Games, you can explore the world to find more Pokémon and use your team to defeat wild Pokémon and other Pokémon trainer. This thesis however focus on random battles taking place on Pokémon Showdown. In a random battle, both you and your opponent get a team of six random Pokémon. At the start of the battle, you know each of your six Pokémon but only the currently active enemy Pokémon.

Every turn, both players can choose to either use a Move of their currently active Pokémon or switch their active Pokémon to another Pokémon. Moves can either deal direct damage to the enemy Pokémon or yield other advantages like increasing the damage dealt by the next move. Moves will be covered in more detail in section 1.3.2. Each Pokémon has an amount of hit points (hp). The hp of a Pokémon can be dropped by attacking it with a Move. If the hp of a Pokémon drops to zero, it faints and can't be used in this battle anymore. A player wins, if all Pokémon of the enemy are fainted.

Note: In the mainline games there is the possibility to heal or even revive a fainted Pokémon during battle using *Healing Items* like *Revive* or *Hyper Potion*. In competitive Play, only *Held items* like *Leftovers* are allowed. Items will be explained in depth in section 1.3.5.

1.3.1. Types

Pokémon implements a *Rock-Paper-Scissors*-like system. Each Pokémon has either one or two of 18 types. For example, a *Fire*-type Pokémon is weak against *Water*-type Pokémon whereas a *Water*-type Pokémon is weak against *Grass*-type Pokémon. Lastly, a *Grass*-type Pokémon is weak against *Fire*-type Pokémon. The figure 1.1 shows how different Pokémon types interact with each other. It is important to note, that the type modifiers will be multiplied if a Pokémon has two types. For example, a *Fire*-type attack will deal 4 times the damage against *Parasect* as *Parasect* has the types *Grass* and *Bug* [2].

1.3.2. Moves

Moves can be split up into three categories: *Physical*-, *Special*- and *Status*-Moves. While *Physical*- and *Special*-moves usually deal damage to the opponent Pokémon, *Status*-Moves can for example change the weather, which plays a role in damage calculation explained in section 1.3.7, inflict status effects, raise or lower the stats of a Pokémon. Just as Pokémon, each Move has one of the 18 possible types.

1.3.3. Pokémon

As stated in 1.3, each Pokémon has a given amount of hp. However, two Pokémon of the same *species*, meaning two Pokémon with the same name, can have different starting hp values. The figure 1.2 shows the different *stats* for the Pokémon *Charizard*.



Figure 1.1.: Pokémon type chart [1]

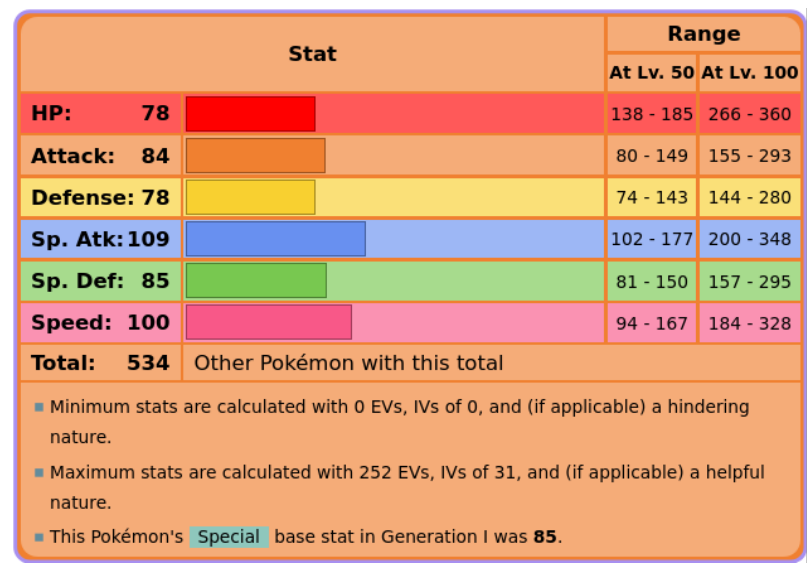


Figure 1.2.: Charizard’s stats [3]

Explanation of stats

HP: The hp determines how much damage a Pokémon can receive before fainting.

Attack: The attack stat (atk) determines how much damage a Pokémon will deal when using a *Physical-Move*.

Defense: The defense stat (def) determines how well a Pokémon can resist against physical attacks.

Sp. Atk: The special Attack stat (spa) determines how much damage a Pokémon will deal when using a *Special-Move*.

Sp. Def: The special Defense stat (spd) determines how well a Pokémon can resist against special attacks.

Speed: The speed stat (spe) determines how fast a Pokémon can act. This is important as instead of both Pokémon moving at the same time, the Pokémon with the higher spe will move first. After the faster Pokémon moved, the slower Pokémon will move. Therefore, the faster Pokémon is usually at an advantage. **(Cover priority moves and trickroom)**
(Cover evasion / accuracy, context to showdown)

ToDo
ToDo

Status condition

A Pokémon can have a status condition, this affects the Pokémon negatively. Status conditions are inflicted by moves. The most important status conditions are

- **Burn:** If a Pokémon suffers from the status condition burn (brn), it will lose 1/8 of its total hp every turn. In addition to that, a burned Pokémon will only deal half as much damage when using a *physical* move.
- **Freeze:** If a Pokémon suffers from the status condition freeze (frz) it won't, with a few exceptions, be able to use moves
- **Paralysis:** If a Pokémon suffers from the status condition paralysis (par) it won't be able to use the selected move 25% of the time and their Speed is halved.
- **Poison:** If a Pokémon suffers from the status condition poison (psn) it will, with a few exceptions, take damage equal to 1/8 of its total hp at the end of every turn. A Pokémon can also be *badly poisoned*. Badly poison initially inflicts damage equal to 1/16 of the Pokémon's maximum hp, with the damage inflicted increasing by 1/16 each turn. This means that the Pokémon will take 2/16 damage on the second turn, 3/16 on the third turn.
- **Sleep:** If a Pokémon suffers from the status condition sleep (slp) it won't be able to use moves, except *Snore* and *Sleep Talk*. In the mainline games, sleep lasts randomly between one and three turns. However, in Pokémon Showdown a Pokémon will *always* be asleep for exactly two turns.

At any point, a Pokémon can only suffer from one status condition at a time, this means that a *burned* Pokémon can't fall asleep.

Determination of stats

The total stat of a Pokémon is calculated as described in equation 1.1 and equation 1.2 [4].

$$HP = \left\lfloor \frac{(2 \times Base + IV + \lfloor \frac{EV}{4} \rfloor) \times Level}{100} \right\rfloor + Level + 10 \quad (1.1)$$

$$OtherStat = \left\lfloor \left(\frac{(2 \times Base + IV + \lfloor \frac{EV}{4} \rfloor) \times Level}{100} + 5 \right) \times Nature \right\rfloor \quad (1.2)$$

Base: Refers to the base stat of a Pokémon. Two Pokémon of the same species will always have the same base-stats. As seen in figure 1.2, a *Charizard* will always have a base-atk of 84.

Level: As mentioned in section 1.3, the goal of the mainline games is to create a team of six Pokémon and to make that team stronger by fighting other Pokémon. If a Pokémon defeats enough other Pokémon, it grows a Level. The maximum level of a Pokémon is 100. If the level of a Pokémon increases, so will its stats. For each level gained (ignoring Nature), stats will increase by $1/50$ the base stat value, and $1/100$ the combined individual values (iv) and effort values (ev) values [4]. In Pokémon Showdown, the level of a Pokémon is set at the start of the battle and won't increase [5].

Nature: A Pokémon has a nature. Most natures enhance the growth of one stat, while hindering the growth of another. After all other calculations are finished, the stat that the Nature enhances will be 100% of what it would be without the Nature, and the stat hindered will be 90% of its normal value [4]. Nature can be neglected in this thesis as all Pokémon in random battles have a neutral nature, meaning no stat is enhanced or hindered [5].

IV: Refers to the iv of a Pokémon. These cause two Pokémon of the same species to have different Stats [4]. Pokémon in Pokémon Showdown will always have the best possible iv stat, 31, unless it is a disadvantage for the Pokémon, then it will be zero [5].

EV: These are the ev of the Pokémon. ev are what causes a trained Pokémon to have higher stats than an untrained counterpart of the same level. For every 4 ev gained, a level 100 Pokémon will have 1 extra point in the given stat. A Pokémon can earn up to 510 ev, but can't have more than 255 ev in a single stat [4]. Random Pokémon on Showdown will always have 85 ev in each stat, or 0 in the case that having a high stat being detrimental [5].

1.3.4. Switching

Instead of using a move with the current Pokémon, the player also has the option to switch out the active Pokémon for another Pokémon in his party. Switching always takes place before the execution of moves. However, the player does not know whether the opponent is switching or using a Move. Therefore, if the player decides to switch out a non-fainted Pokémon, the enemy gets to use his move on the new Pokémon. If a Pokémon faints, the player has to switch in a new Pokémon and then the next turns start. This means that the opponent gains a one turn advantage if the player decides to switch out a healthy Pokémon, but won't get to attack an additional time if the Pokémon was defeated.

1.3.5. Items

A Pokémon can also hold an Item that yields benefits in battle. There are various purposes that items can fulfill. For example, the item *Life Orb* boosts damage dealt by the holder's damaging move by 30%¹, but the holder takes damage equal to 10% of its maximum hp after it uses a damaging move² [6]. *Leftovers* restore $1/16$ of the holder's maximum hp³ at the end of each turn whereas the item *Air Balloon* makes the holder *ungrounded*, which means that the holder is immune to *Ground*-type moves as well as several related effects[7]. The items generated in Pokémon Showdown are described in more details in 1.5.2.

¹This boost is approximated as $5324/4096 \approx 1.29980$

²Rounded down, but not less than 1

³Rounded down, but not less than 1

Important items

In this section, a quick introduction to the most important items is given.

- **Choice Band:** When held by a Pokémon, this item boosts the atk by 50%, but only allows the use of the first move selected. This effect resets when the holder is switched out [8].
- **Choice Scarf:** When held by a Pokémon, this item boosts the spe by 50%, but only allows the use of the first move selected. This effect resets when the holder is switched out [9].
- **Choice Specs:** When held by a Pokémon, this item boosts the spa by 50%, but only allows the use of the first move selected. This effect resets when the holder is switched out [10].
- **Leftovers:** Restores 1/16 of the holder's maximum hp at the end of each turn [11].
- **Life Orb:** Boosts the damage dealt by the holder's damaging moves by 30%, but the holder takes damage equal to 10% of its maximum hp after it uses a damaging move [6].
- **Heavy-Duty Boots:** The holder is unaffected by the effects of entry hazards. Entry hazards are described in 1.4. If a *grounded Poison*-type Pokémon enters the field while holding this item, it will cause *Toxic Spikes* to be removed [12].
- **Assault Vest:** Raises the holders spd by 50%, but also prevents the holder from selecting any status move⁴ [13].
- **Focus Sash:** If the holder has full hp and is hit by an attack that would otherwise cause fainting, it survives with 1 HP [14].

1.3.6. Field effects

There are multiple *field effects* that affect combat.

Terrain

Terrain is set up by the respective move with identical name and last for five turns. All of them are beneficial to *grounded* Pokémon. A Pokémon is *not grounded* if any of the following conditions apply:

- The Pokémon has the *Flying*-type
- The Pokémon has the Ability Levitate
- The Pokémon is holding the item *Air Balloon*
- The Pokémon is under the effect of *Magnet Rise* or Telekinesis.

Grounded Pokémon are with a few exceptions those Pokémon, that are not *ungrounded*. A Pokémon will be grounded if any of the following conditions apply:

- The Pokémon is holding an *Iron Ball*
- The Pokémon is under the effect of *Ingrain*, *Smack Down* or *Thousand Arrows*.
- The *Field effect Gravity* is in effect.

More information about grounding can be found at [15] There are five different possible *terrain*-states.

⁴Except *Me First*

- **None:** The default state, no other effects are applied.
- **Electric Terrain:** Grounded Pokémon can't fall asleep and the power of *Electric*-type moves is also by 50%.
- **Grassy Terrain:** The HP of grounded Pokémon is restored by 1/16 of their maximum HP at the end of each turn. In addition, the power of *Grass*-type moves is increased by 50% and the moves *Earthquake*, *Magnitude* and *Bulldoze* halve in power.
- **Misty Terrain:** protects all grounded Pokémon from status conditions (including confusion). The power of *Dragon*-type moves is halved while in effect.
- **Psychic Terrain** prevents grounded Pokémon from being hit by high-priority moves (such as **Quick Attack** or *Sucker Punch*). The power of *Psychic*-type moves is also increased

It is important to note, that only one *terrain* can be active at a time, yet, *terrain* can coexist with other *field effects* like *weather*.

Weather

1.3.7. Damage calculation

The damage dealt by a move mainly depends on the *level* of the Pokémon that uses the move, its effective Attack or Special Attack stat, the opponent's effective Defense or Special Defense stat and the move's effective power.

Precisely, the damage is calculated as follows[16]:

$$\text{Damage} = \left(\frac{\left(\frac{2 \times \text{Level}}{5} \right) \times \text{Power} \times A / D}{50} + 2 \right) \times \text{Targets} \times \text{Weather} \quad (1.3)$$

$$\times \text{Badge} \times \text{Critical} \times \text{random} \times \text{STAB} \times \text{Type} \times \text{Burn} \times \text{other}$$

The only exception for this are moves that deal direct damage. A list of these moves can be found at [17].

Level

Level refers to the level of the attacking Pokémon[16]. In Pokémon Showdown, the level is displayed next to the name of the Pokémon. **(Mainline games leveling)**

ToDo

A / D

A is the effective Attack stat of the attacking Pokémon if the used move is a physical move, **(Reference to physical moves)**

ToDo

or the effective Special Attack stat of the attacking Pokémon if the used move is a special move. **(Reference to special moves)**

ToDo

D is likewise the effective Defense stat of the target if the used move is a physical move, or the effective Special Defense of the target if the used move is a special move[16].

There are four moves that use stats from different categories, more Information can be found at [18].

Power

Power is the effective power of the used move. **(When is the power not equal to the base power)** The *Base Power* of a move in Showdown can be seen when hovering over a move in the move list.

Note: The same move will always have the same base power. For example, *Fire Punch* will always have a base power of 75[19].

Weather

The *Weather* modifier is 1.5 if a *Water-type* move is used during *rain* or a *Fire-type* move during *Harsh Sunlight*. The modifier is 0.5 if a *Water-type* move is used during *Harsh Sunlight* or a *Fire-type* move during *rain* [16]. **(Reference to weather section)**

Critical

In the latest Generation, a critical hit (crit) deals 1.5 times the damage compared to a normal hit. If the crit rate is not increased, the chance of landing a crit is 1/24 [20]. Increasing crit rate, as well as other stats, will be explained in chapter 1.3.8.

Note: In earlier games, crits worked different, see [20] for more details.

Random

Random is a random integer percentage between 85% and 100%. Because of this, the same move may deal different damage in the same scenario [16].

STAB

STAB stands for *Same Type Attack Bonus*. It is a multiplier of 1.5 if the used move is of the same type as the attacking Pokémon. Otherwise, it is 1.0 [16].

Type

This is the in section 1.3.1 described type modifier [16].

Burn

Burn is 0.5 if the attacking Pokémon is burned, and the used move is a physical move⁵. Otherwise, it is 1.0 [16].

Other

The *other* modifier is usually 1. A list of exceptions can be found at [16].

1.3.8. Effective Stats

Boosting

(Boosting critical rate)

1.4. Hazards

An *entry hazard* is a condition that affects a side of the field that causes any Pokémon that is sent into battle on that side of the field to be afflicted by a negative effect. Entry hazards are created by moves, usually status moves [21].

(This paragraph is copied word by word from Bulbapedia)

⁵This does not apply if the attacking Pokémon has the Ability *Guts* or the used move is *Facade*

1.4.1. List of entry hazards

Currently, there are five moves that create an entry hazard

Spikes

Spikes is a *Ground*-type entry hazard that causes the opponent to lose 1/8% of their maximum hp when they enter the field. This effect can be stacked up to three times. Two layers of spikes will deal 1/6% and three layers will deal 1/4% of the enemies maximum hp.

(Removal and Immunity of Spikes) Spikes are created by the move *Spikes*[22].

ToDo

Stealth Rock

The move *Stealth Rock* sets an entry hazard around the target Pokémon causing Pokémon on the target's field to receive damage upon being switched in. The amount of damage inflicted is affected by the effectiveness of the type *Rock* against the target. Unlike Spikes, this entry hazard does not stack. The damage taken from the victim's maximum is denoted in table 1.4.1[23]. *Note*: Stealth Rocks can also be created by the move *G-Max Stonesurge*.

Type effectiveness	Damage (Max. hp)
0.25x	3.125%
0.5x	6.25%
1x	12.5%
2x	25%
4x	50%

Table 1.1.: Damage dealt to Pokémon by Stealth Rocks[23]

This damage-dealing Water-type G-Max move is exclusive to Gigantamax Drednaw [24].

(Does this move exist in Showdown)

ToDo

Sticky Web

The entry hazard set by the *Bug*-type move *Sticky Web* lowers the opponents speed stat by one stage upon switching in [25].

(Pokémon that are not affected by this)

ToDo

Poison spikes

Poison Spikes set by the *Poison*-type move *Toxic Spikes* cause the opponent to become poisoned. If two layers of spikes are set, the Pokémon instead becomes badly poisoned [26].

(Pokémon not affected)

ToDo

(Explain (badly) poisoning)

ToDo

Sharp steel

This entry hazard works very similar to Stealth Rock described in 1.4.1. However, Sharp steel can only be set by the *Steel*-type move *G-Max Steelsurge* which is the exclusive G-Max Move of Gigantamax Copperhead. The damage dealt by Sharp steel does not stack, the amount of damage dealt is based on the Type effectiveness of the *Steel*-type against the target. Exact damage modifiers can be found in table 1.4.1 [27]. **(Unaffected Pokémon)**

ToDo

Type effectiveness	Damage (Max. hp)
0.25x	3.125%
0.5x	6.25%
1x	12.5%
2x	25%
4x	50%

Table 1.2.: Damage dealt to Pokémon by Sharp Steel[27]

1.4.2. Hazard counterplay

There are some moves that can remove entry hazards. *Rapid Spin* [28] removes entry hazards from the user's side of the field and *Defog*[29] removes entry hazards on both sides of the field⁶. In addition, *Court Change*[30] will exchange the entry hazards on each side of the field, along with other one-sided field conditions. **(What other one-sided field conditions are there?)** If a grounded⁷ *Poison*-type Pokémon enters the battle, it will remove Toxic Spikes, described in 1.4.1, from its side of the field. Lastly, Pokémon holding the item *Heavy-Duty Boots*[12] are unaffected by entry hazards, but grounded *Poison*-type Pokémon can still remove Toxic Spikes even if they hold the boots[21]. There are various exceptions and special cases to hazards. **(Special cases of hazards)**

1.5. Showdown random battles

(Write introduction to this) (This has to include that the same species has different movesets)

1.5.1. Sets

As described in section 1.3.3, Pokémon created for random battles usually have 85 evs and 31 iv in every stat with a neutral nature, meaning a nature that does neither boost nor hinder any stat [5]. There are some cases where a high stat is not beneficial, an example would be the move *Gyro Ball*. Unlike most moves, the *Base Power* of this move described in the damage calculation described in 1.3.7 is not a fixed value. It is determined as described in 1.4 [31].

$$BasePower = \min(150, \frac{25 \times CurrentSpeed_{target}}{CurrentSpeed_{user}}) \quad (1.4)$$

As the damage dealt by *Gyro Ball* gets bigger, the lower the spe of the attacker, Pokémon using this move have 0 ev and 0 iv in the spe stat.

Note: Being able to outspeed the opponent is extremely valuable, but the only two Pokémon using *Gyro Ball*, *Stakataka* and *Ferrothron*, already have a very low spe stat and are slower than almost all other Pokémon in random battles. A complete list of Pokémon with their respective spe stat can be found at [32].

This knowledge can be exploited to gather additional information about the enemy, section 3.1.2 describes how this is achieved.

⁶In older games *Defog* would only remove Hazards on the target's side of the field. But as we only investigate the latest version, this won't be covered in detail.

⁷The term *grounded* is used to describe a Pokémon that can't be affected by damaging *Ground*-type moves and several other associated effects[15].

1.5.2. Items

Items in random battles are procedurally generated by showdown and depend on the Pokémon's moves, base stats and ability. As stated in [5], the exact implementation is „changed frequently with the intention of optimizing set generation“, yet, item assignment follows these rules:

- Pokémon with 2 or fewer attacking moves will get *Leftovers*, or *Black Sludge* if *Poison*-type.
- Pokémon with 3 attacking moves will get **Life Orb**, if the sum of their base hp, def and spd is less than 275. Otherwise, these Pokémon get *Leftovers* or *Black Sludge*.
- Pokémon with 4 matching attacks get a *Choice* item which follows these rules:
 - Pokémon with four physical attacks or four special attacks, a base spe between 60 and 108 and base atk or spa of 100 or more can get a *Choice Scarf* 2/3 of the time. If the Pokémon doesn't meet one of the stat qualifications or doesn't get the 2/3 chance, they'll get *Choice Specs* or *Choice Band* instead.
 - Pokémon with 3 special attacks and the move *U-turn* always get *Choice Specs*. *U-turn* is a physical, *Bug*-type move that switches the user out after damage is dealt [33].
 - Pokémon with *Trick* [34] or *Switcheroo* [35], both moves that allow to switch items with the opponent, they will always get a choice item. If they meet the above-mentioned speed range, they will always get a *Choice Scarf*. Otherwise, they will always get *Choice Specs* or *Choice Band*.
 - Having priority moves will always prevent a *Choice Scarf* from being generated in all situations. **(Either explain priority moves or explain them here)**
- Pokémon with 4 attacks that don't qualify for choice items, will get an *Assault Vest* if their $hp + def + spd \geq 235$. Otherwise, *Expert Belt*, *Leftovers* or *Life Orb* is generated.
- Pokémon that are weak to Rock will get *Heavy-Duty Boots* if they don't get a higher priority item, such as *Assault Vest* or a choice item. Pokémon that are four times weak to *Rock*, such as *Charizard*, will always get *Heavy-Duty Boots*. This is done as these Pokémon would otherwise lose up to 50% hp to the entry hazard *Stealth Rock* described in 1.4.1. The only exception is *Scyther*, which can get *Eviolite*.
- Pokémon in the lead slot will get *Focus Sash* if their $hp + def + spd < 255$, and they would otherwise get *Leftovers* or *Life Orb*.
- Pokémon that get a Speed-boosting move will be given a *Weakness Policy* if their $hp + def + spd \geq 300$, and they aren't four times weak to *Ground*. This item boosts the atk and spa by two stages each if hit by a super effective move. After that, the item breaks [36].

ToDo

There are also some species that will always roll the same item, either because it's their signature item or because doing so supports a niche ability or set. For example, *Pikachu* always has *Light Ball*

1.6. Pokémon Matchups

Due to the typing system, there is no best Pokémon that is the best option in all situations. Therefore, we have to determine how good a Pokémon is against another Pokémon in a given situation. In this case, the *situation* refers to the current state of both Pokémon like current hp and status conditions as well as field effects like weather.

1.6.1. Check and Counter

ToDo

There are multiple definitions of *check* and *counter* (**Cite multiple definitions**). In this thesis, we refer to a Pokémon *checking* another Pokémon if it can beat the enemy Pokémon in every scenario and can safely be switched in at any point. A *counter* is also capable of defeating the enemy Pokémon but may lose in some situations. The most notable being if switched in without the previous active Pokémon fainting as this grants the opponent an additional attack.

The key difference between *check* and *counter* is, that a check is also stronger if it takes damage once more while a counter is not guaranteed to win in this situation.

Note: Every *check* to a Pokémon is also always a *counter* while *counter* could also be a *check*, but is not guaranteed to.

2. Related Work

(This won't go into)

ToDo

2.1. Pmariglia

The developer *Pmariglia*[37] created a sophisticated battling bot for Pokémon Showdown. This implementation is open source and can be found at <https://github.com/pmariglia/showdown>. On the repository, you can find two different approaches:

Safest

The *Safest* approach searches through the game-tree for two turns and selects the move that minimizes the possible loss for a turn. As Pokémon battles make heavy use of random number generation (rng), the author takes a weighted average for all possible end states. This is explained in more detail in (Link to section where we take miss chance into account).

ToDo

Nash-Equilibrium (experimental)

In game theory, the *Nash-Equilibrium* is the most common way to define a solution of a non-cooperative game involving two or more players. In a Nash equilibrium, each player is assumed to know the equilibrium strategies of the other players and no player has anything to gain by changing only their own strategy [38].

2.2. Showdown AI Competition

The authors of the *Showdown AI Competition*[39] compared many simple AI implementations with each other. (Does not describe how damage is calculated)

ToDo

Breath-first search

Given a root battle object representing the current game state, breadth-first search (bfs) explores the outcomes of all possible choices, treating these resultant states as child nodes. This algorithm traverses the game tree until it finds a state in which the enemy Pokémon is fainted. As a non-adversarial algorithm, the agent assumes that the enemy does not move at all [39].

Minimax

ToDo

This variant of the *Minimax*-Algorithm deals with adversarial paradigms by assuming that each player acts in their best interest. In this decision tree, each node represents the worst case scenario that would occur as a result of the current choice. The agent also uses alpha-beta pruning, ignoring any node in which the agents Pokémon faints. **(We take the average outcome. We don't prune fainting paths (explosion))** The tree itself is traversed using a greedy strategy, which terminates under the same conditions as bfs2.2. Both the traversal order and worst-case evaluation are performed using the evaluation function 2.1 [39]:

$$Eval = \frac{\text{current hp}_{\text{Own Pokémon}}}{\max \text{hp}_{\text{Own Pokémon}}} - 3 \cdot \frac{\text{current hp}_{\text{Enemy Pokémon}}}{\max \text{hp}_{\text{Enemy Pokémon}}} - 0.3 \cdot \text{depth} \quad (2.1)$$

Q-learning

The authors also implemented a *Q-learning* algorithm. Two agents using *Q-Learning* were developed: A single layer perceptron as well as a multi layer perceptron. Both agents were used to output the expected reward of all current moves and switches. Based on this, the best action was picked. Both agents were rewarded for defeating opponents Pokémon and punished for allowing one of its own Pokémon to faint. Because decisions made tend to have long term consequences, weights are updated using the last three (State, Action) pairs rather than the most recent pair only. Additionally, in order to promote exploration, the agent employs an epsilon-greedy selection policy, causing it to randomly override its decision with a probability of 0.1. The single layer perceptron was trained using the Delta Rule, while the multilayer perceptron was trained using Delta Rule plus Backpropagation[39].

One Turn Lookahead

One Turn Lookahead is a heuristic based agent designed to encapsulate a greedy strategy that prioritizes damage output. The agent operates by estimating the damage dealt by all usable moves, including those usable by the agent's inactive but usable Pokémon. If the highest damaging move belongs to the active Pokémon, the agent will use that attack. If the most damaging move belongs to an inactive Pokémon, the agent will switch to that Pokémon [39].

Type Selector

This is a variation of the *One Turn Lookahead*-Agent that utilizes a short series of if-else statements in its decision-making. At first, if the current Pokémon knows a move that drains the opponents hp to zero, this move is selected. Otherwise, the favorability of the current matchup is evaluated. If the current type matchup is undesirable, the agent will switch to the Pokémon with an acceptable type matchup. If no such Pokémon exists, the agent will default to the most damaging move [39].

Pruned Breadth-First Search

This agent is designed to demonstrate a simple way to utilize domain knowledge as a cost-cutting measure. This algorithm does so by making modifications to the Breadth First Search agent. First, the algorithm does not simulate any actions that involve using a damaging move with a resisted type, nor does it simulate any actions that involve switching to a Pokémon with a subpar type matchup. Additionally, rather than selfishly assuming the opponent skips their turn in each simulation, the agent assumes its opponent is a One Turn Lookahead agent and simulates accordingly **(This is copied word by word)**[39].

ToDo

Evaluation

The authors demonstrated how very basic approaches already yield interesting results in the field of competitive Pokémon battles. As this thesis will demonstrate, simple approaches can yield even better results if more key-aspects of the game like *Hazards* ([Link to Hazards](#)), *Field Effects* ([Link to Field effects](#)) and especially *Status Effects* ([Link to Status effects](#)) and *Stat Boosts* are taken into account. This thesis furthermore introduces a variation of the *Minmax*-Algorithm that allows for long term planning.

ToDo
ToDo
ToDo

2.3. Self-Play Policy Optimization Approach

The approach described in [40] uses a reinforcement learning approach and performs on par with the state of the art search-based Pokémon AI described in 2.1. Similar to OpenAI's Dota AI [41], the agent is represented using an actor-critic neural network. Actor-critic RL methods ([This is the same source as in the paper](#)) [42] combine policy-based and value-based RL methods by predicting both policy and value for a given state, and then using the value prediction, the „critic“, as an estimate of expected return when updating the policy prediction, the „actor“. The authors represent both actor and critic using a two-headed neural network which is trained via self-play RL [40].

ToDo

Neural Network

Input to the neural network is the current state of the game, from the point of view of the player, represented as multi-level tree-like structure:

1. The *battle* consists of two *teams*, along with weather effects.
2. Each *team* consists of six *Pokémon*, along with side conditions described in ([Link to side conditions](#))
3. Each *Pokémon* has many features. Table 2.1 contains a partial list¹

Feature	Type	Dims	Description
<i>species</i>	categorical	1×1023	e.g. Pikachu
<i>item</i>	categorical	1×368	e.g. Leftovers, Choice Band
<i>ability</i>	categorical	4×238	e.g. Rough Skin, Shadow Tag
<i>moveset</i>	categorical	4×731	e.g. Flamethrower, Surf
<i>lastmove</i>	categorical	1×731	The last move used
<i>stats</i>	continuous	6	hp, atk, def, spa, spd, spe
<i>boosts</i>	continuous	6	Temporary boosts for stats
<i>hp</i>	continuous	1	Current number of hp
<i>maxhp</i>	continuous	1	Number of hp at full health
<i>ppUsed</i>	continuous	4	# times a move was used
<i>active</i>	indicator	1	1 if Pokémon is active, else 0
<i>fainted</i>	indicator	1	1 if Pokémon has no hp, else 0
<i>status</i>	indicator	28	e.g. slp, brn, par
<i>types</i>	indicator	18	e.g. Bug, Fire
<i>volatiles</i>	indicator	23	e.g. Leech Seed, Perish Song

Table 2.1.: Features used to describe a single Pokémon battle [39]

¹The authors state that this list is not complete but no additional information is provided.

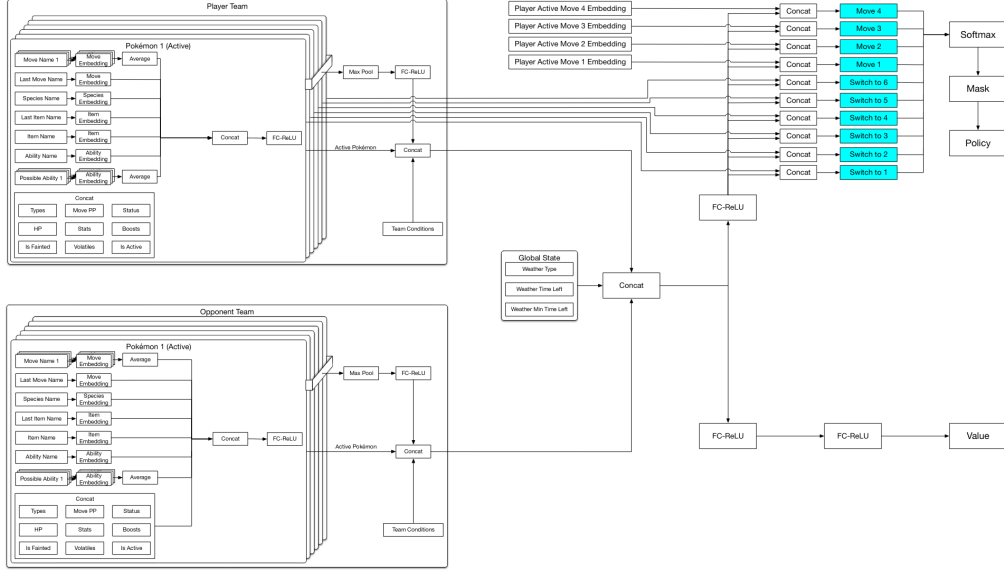


Figure 2.1.: The actor-critic neural network used by the authors in [39]

The network has two outputs: a probability distribution $\pi \in \mathbb{R}^n$ over actions to take, and an estimate of player strength in the current state $v \in \mathbb{R}$. The probability distribution π is computed as follows:

1. The network outputs an intermediate vector $p \in \mathbb{R}^n$. Each of the colored cells in figure 2.1 correspond to an element of p
2. A probability distribution $\pi' \in \mathbb{R}^n$ is computed by using the softmax function: $\pi' = \frac{\exp(p_i)}{\sum_i \exp(p_i)}$
3. As not every action is valid in every state, for example, a switch to a Pokémon is invalid if that Pokémon is already fainted, the authors ensure their agent has zero probability of taking invalid actions. To do this, they take a mask $s \in \{0, 1\}^n$ as part of the input, and renormalize probabilities to obtain $\pi : \pi_i = \frac{s_i \pi'_i}{s^T \pi'}$

The authors point out the following two key design decisions: First, a 128-dimensional entity embedding layer for each of the categorical variables is used. This enables capturing similarities between different moves, species and abilities without having to directly model their, often complicated, effects. Second, the parameters for computing p from above are shared among all n actions. The resulting network is described by figure 2.1 and contains 1,327,618 parameters in total [39].

Training the network

Training was done serially: After $m = 7680$ games per iteration, the neural network parameters are updated using the $2m$ self-play matches as training data to obtain new neural network parameters. A reward of +1 for a win and -1 for a loss are assigned at the end of the match. To speed up learning, a dense reward signal using reward shaping was constructed. Auxiliary rewards are assigned based on events that occur over the course of the match. For example, a reward of -0.0125 is added when a Pokémon of the agent faints, and a reward of +0.0025 whenever the player's Pokémon makes a super effective move.

To update the neural network, the authors use *Proximal Policy Optimization*, which optimizes an objective function that combines expected reward, accuracy of state value prediction, and a bonus for high entropy policies. To reduce the variance of policy gradient estimates, *Generalized Advantage Estimation* is used (Link Paper to both).

ToDo

After 500 iterations of the training loop, 3,840,000 self-play matches had been played by the neural network. Training was performed using Google Cloud Platform over the course of 6 days with an approximated cost of \$91 USD.

3. Approach

(Switching highest Priority, always first) (Players move at the same time, unlike in chess.)

ToDo
ToDo

3.1. Implementation

3.1.1. Communication with Pokémon Showdown

The communication with Pokémon Showdown is handled using the python library *Poke-Env* [43]. This library provides a lot of the core functionality needed, like accessing the current Pokémon in battle as well as switch and move options. However, it does not provide functionality for damage calculation. We use the *Pokémon Damage Calculator* [44], a node library written by the smogon-team for that. Communication between the two libraries is implemented by capturing stdout and stdin using the *subprocess* python library.

3.1.2. Gathering Information about the enemy Pokémon

As mentioned in 1.5, the same Pokémon can occur in various different builds, meaning the combination of moves, abilities and items. Knowing the exact enemies build is very important for decision-making. Consider the following example:

- **Player1** has an active *Charizard* with *Heavy-Duty Boots* and 150hp remaining on the field.
- **Player2** has just sent out a *Drapion* with 160hp remaining.
- The *Charizard* is faster but can't kill the enemy *Drapion* in one turn as his move *Fire Blast* deals between 127 and 151 damage to the *Drapion*.
- Therefore, if **Player1** decides to attack, *Drapion* is guaranteed to survive this turn and can attack *Charizard* as well.

In this scenario, the optimal play for **Player1** depends heavily on the move set of the enemy *Drapion*. Possible moves for *Drapion* are:

- *Aqua Tail*: A damaging *Water*-type move
- *Earthquake*: A damaging *Ground*-type move
- *Knock Off*: A damaging *Dark*-type move

- *Poison Jab*: A damaging *Poison*-type move
- *Swords Dance*: A move to raise the own atk by two stages
- *Taunt*: A move that makes the afflicted Pokémon unable to use status moves
- *Toxic Spikes*: A move that sets an entry hazard.

Hereby it is important to note, that *Drapion* only knows the move *Aqua Tail*, if it knows four total damaging moves. In the given scenario, **Player1** should switch out his *Charizard* if the enemy *Drapion* knows the move *Aqua Tail* as this attack would kill *Charizard*. We can determine whether the enemy knows *Aqua Tail* based on his item:

- If *Drapion* rolls two status moves, it will have the item *Black Sludge* and therefore doesn't know *Aqua Tail*. Because *Drapion* is already damaged, we know that it has this item if it healed 1/16% of his max hp in his last turn.
- If *Drapion* rolls one status move, it will have the item *Life Orb*. If *Drapion* already attacked, we know if it has a *Life Orb* or not as this item causes it to lose 10% of his maximum hp after an attack.
- If *Drapion* has neither *Black Sludge* nor *Life Orb*, it has to have a *Choice Band* and as this item will only generate if the Pokémon knows four matching attacks, and therefore has to know the move *Aqua Tail*.

Implementation details

The first step to predicting enemy sets is to determine all possible sets as well as how likely each individual set is. In order to achieve this, I wrote a script that to start a battle between an information gathering player and a random agent. In the next step, the script extracts all builds of all Pokémon and stores them, then, it forfeits, and a new battle is started. Once enough battles are played, the script will store the builds as well as how often they appeared in text files, one file for each Pokémon.

In actual battles, if a new Pokémon enters the enemy side, we assume it to have the most likely build for this species. Once more information becomes available on items, moves and abilities, we rule-out non-matching builds and always assume the enemy to have the remaining most likely build.

3.1.3. Scoring the current game state

In Order to not only rate the current board state, but also individual Pokémon, we implement the following scoring algorithm:

$$score(e_{i,j}) = \text{Expected Damage that Pokémon } i \text{ will deal to Pokémon } j \quad (3.1)$$

The expected damage is the damage dealt if both Pokémon behave optimal in the amount of turns that the bot looks into the future. Section 3.1.5 covers how the optimal moves are determined. 3.1

$$val(i) = \sum_{j \in \text{Enemy Pokémon}} score(e_{i,j}) \quad (3.2)$$

Using this, we can also introduce a *value* for each of our Pokémon where a higher value implies a more important Pokémon. It is important to note, that scores are determined independently of each other meaning that we do not take into account damage taken by the attacker. This does explicitly mean that this metric does not determine how good the Pokémon is if it has to battle *all* enemy Pokémon but rather against how many other Pokémon it *could* be used. This is done as the order in which a Pokémon battles multiple Pokémon plays a huge role. The reasoning behind this as well as the determination of

ToDo

an optimal order is explained in (Ref to MinMax). This metric also has multiple flaws as it only takes the damage dealt to the enemy into account, other important factors like damage received, healing, the availability of status moves and hazards is not taken into account.

Similarly, we can determine the *thread level* as shown in equation 3.3

$$thread_level(j) = \sum_{i \in \text{Own Pokémon}} score(e_{j,i}) \quad (3.3)$$

Combining the *value* and *thread level*:

$$board_rating = \sum_{i \in \text{Own Pokémon}} val(i) - \sum_{j \in \text{Enemy Pokémon}} thread_level(j) \quad (3.4)$$

(Maybe use `can_defeat` with 0 / 1 instead here) Therefore, a positive rating indicates that the board is favorable for the player, a negative rating indicates that the board is unfavorable for the player and a value close to zero indicates that no player currently has and advantage over the other.

ToDo

3.1.4. Stages of the game

We divide the game into two phases, the first one being the *Discover*-Phase whereas the second phase is called *Defeat*-Phase. Our goal and therefore our play style, is different in both phases.

Discover Phase

At the beginning of the game, we play safely until we know our opponents entire team. Therefore, we try to gather information about the enemy team while sacrificing as little hp as possible. In this stage, we act following these rules:

1. Kill the opponent if we are guaranteed to kill him this turn. This either leads to us defeating the enemy Pokémon, or possibly new information if the enemy switches.
2. Healing our Pokémon. If we have a healing move that will heal us more than the expected damage we receive this turn, and we are not at full hp we will heal our Pokémon. Doing so will force the enemy to switch as we are otherwise gaining an advantage over him.
3. If we have a hazard setting move available, we will use this move as they will help us in the *Defeat*-Phase. Other beneficial side-conditions like *Light Screen* will be set as well.
4. Using moves that inflict status to the opponent like *brn*.

If none of these conditions apply, we decide whether to switch out our Pokémon or not. If our current Pokémon is a *check* or *counter* against the enemy Pokémon, we won't switch. Otherwise, we switch to a *check*, or *counter* if present. Next, we check if the current matchup is very unfavorable. This applies, if the enemy is expected to survive the current matchups for two turns longer than we do, meaning that our Pokémon would not be able to defeat the enemy, if it was allowed to attack two additional times. If this is the case, we determine the next action as follows:

We start by determining the *score* of each of our Pokémon as described in 3.1 and exclude our two most valuable Pokémon from the next steps. This is done as we assume to depend heavily on these Pokémon to defeat other enemies. Next up, we pick the Pokémon with the lowest *score* that fulfills the following criteria:

- The Pokémon has to survive for at least three turns against the enemy
- The Pokémon has to fulfill at least one of these criteria:
 - It is able to set a *hazard* or other beneficial field effect that is not already present.
 - It can inflict a status condition on the enemy.

If not Pokémon matches these criteria, the Pokémon with the lowest score is picked instead. In any other case, the currently active Pokémon will use the best move calculated in 3.1.5.

Defeat Phase

The *Defeat*-Phase starts as soon as we know all enemy Pokémon. At the beginning of this stage, we have to create a match plan for defeating the enemy. The main goal is to figure out, which Pokémon to use against which enemies, especially the best order to send them into battle. Figure 3.1 shows a possible end-game scenario. In this simple example, we

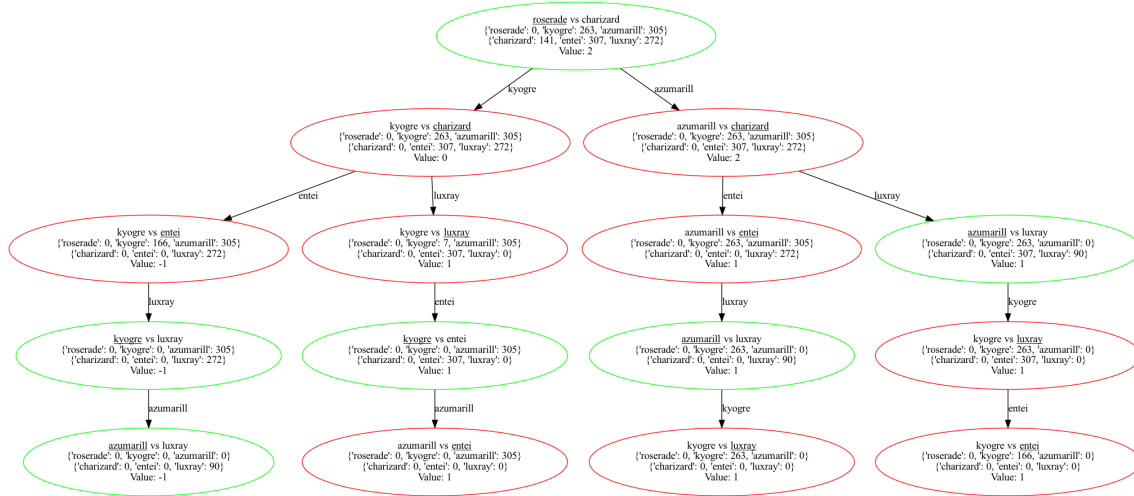


Figure 3.1.: Possible end game scenario

assume both players to each have three Pokémon with full hp and no status conditions. Each circle represents two Pokémon battling each other. Therefore, the circle in the top center indicates, that our *Roserade* is currently fighting against the enemy *Charizard*. As *Charizard* is a *Fire*-type Pokémon which has a type advantage against his enemy, our *Roserade* will faint in this matchup, indicated by the underlined name. This means, that now Player 1 has to switch in a new Pokémon. A green circle around a node indicates that the first player has to make a turn as his Pokémon fainted, and a red circle marks a decision for Player 2. The first line below the names of the two opposing Pokémon displays the amount of hp the first team has left after this battle took place. As *Roserade* fainted, it has zero hp left whereas the other two Pokémon in his team are still at full health. Below that, the remaining hp of the second team is displayed. *Charizard* is *expected* to survive the battle with an *expected* amount of 141 hp remaining. Next, we have two possible options remaining, we can either send *Kyogre* or *Azumarill* to defeat the enemy *Charizard*. Taking a look at the leaves of the tree, the *value* of a leaf node is -1 if the enemy wins the battle and 1 if we win the battle. The value of a non-leaf node is the sum of the values of the children nodes. The *value* of two means that we expect to win the battle. As a result of this, the best choice in our example scenario is to use *Azumarill* to defeat the already damaged *Charizard*.

ToDo (Explain why MinMax Tree is correct. Pokemon don't have expected items / moves!)

3.1.5. Determining matchups

In order to determine whether to attack or to switch, we need to determine how the optimal moves for a Pokémon against another Pokémon are calculated. As stated before, the amount of possible combinations combined with the non-deterministic nature of the game makes it unfeasible get the optimal move combination by simulating every possible combination of actions and reactions over the span of multiple turns. Therefore, we determine the optimal moves for a Pokémon using this simplified method:

We start by generating all possible move combinations for a Pokémon with a given length. Then, we simulate the outcome of the battle, if the attacking Pokémon would use these moves in the defined order given the enemy would not do anything¹ Here, we also take boosting, items, status effects and the possibly changing field state into account **(Reference to further work with things that do not work like recognizing focus items)**. In the early game. Then, the combination resulting in the lowest amount of turns until the enemy faints is selected. It is important to note that this is not necessarily the move that the bot will use in the next turn as in the *Discover*-Phase healing, status and other beneficial effects are prioritized.

ToDo

¹The option of not doing anything in a turn does not exist in Pokémon, if possible, the player is always forced to either select a move or switch.

4. Evaluation

(Lee-Paper: MinMax requires simulation)

ToDo

4.1. Challenges for evaluation

Different researchers use different metrics to evaluate the performance of their agents. There are multiple factors that increase the difficulty of properly evaluating the performance.

4.1.1. Randomness of battles

As teams are generated random, one player often ends up with a slightly better team than his opponent. In very extreme cases, one player may not even have a chance at winning the battle. While battling our agent during the evaluation process, one particular game stood out as the first Pokémon of Player one was capable of defeating the entire enemy team.

The Pokémon of Player one was a *Volcarona* with the following moves:

- *Fire Blast*, a damaging *Fire*-Type move
- *Quiver Dance*, a *Bug*-Type move that boosts the user's spa, spd and spe by one stage each.
- *Bug Buzz*, a damaging *Bug*-Type move
- *Roost*, a move that restores half of the user's maximum hp

This Pokémon was able to defeat the entire enemy team with little to no possible counter play: The first enemy Pokémon, *Leafeon*, a *Grass*-Type Pokémon was killed in one hit using *Fire Blast* after damaging *Volcarona* using *X-Scissor*.

Next, *Glalie*, an *Ice*-Type was sent into battle. *Glalie* uses his best move, *Earth Quake* which brings *Volcarona* to 52% hp. As the enemy doesn't pressure *Glalie* much, Player1 decided to boost using *Quiver Dance*. Now, *Volcarona* is faster than his enemy and kills it again in one hit using *Fire Blast*.

Then, *Mr. Mime (Galar)* is sent into battle. As he fails to pressure *Volcarona* as well, Player1 can heal his Pokémon using *Roost* and further boost using *Quiver Dance*. After defeating *Mr. Mime (Galar)*, *Volcarona* is back to 84% HP and boosts of 2.5 spa, 1.5 spd and 2.5 spe.

Boosted this high, *Volcarona* can one shot both the enemy *Volcarona*, *Pheromosa* and the dynamaxed *Scraggy* using *Fire Blast*.

To eliminate the impact of these very extreme cases, evaluation of agents against other agents should be done using multiple hundred, better thousands of games against each other. **(Metrik von Markus, wie viel ist denn unfair?)**

ToDo

4.1.2. Evaluation against baseline agents

A good way to get a rough idea on how well an agent performs can be to compare it against a baseline agent. There are two very popular baseline agents, the *RandomPlayer* and the *MaxDamagePlayer*. While the *RandomPlayer* always chooses either a random move or a random switch, the *MaxDamagePlayer* always picks the move with the highest base power. If no move is available, the agent will switch to a random Pokémon. This is roughly equal to the skill level of an inexperienced beginner human. **(Similar performance here, yet getting crushed later)**

ToDo

4.1.3. Evaluation against human opponents

As described in **(Link Showdown chapter)**, Pokémon Showdown allows researchers to use bots on the ranked ladder.

ToDo

4.2. Results

4.2.1. HerrDonner and HerrGewitter

Opponent	Wins	Losses
<i>RandomPlayer</i>		
<i>MaxDamagePlayer</i>		
<i>HerrGewitter</i>		

Table 4.1.: Results of HerrDonner

Opponent	Wins	Losses
<i>RandomPlayer</i>		
<i>MaxDamagePlayer</i>		
<i>HerrDonner</i>		
<i>Pmariglia</i>	273	727

Table 4.2.: Results of HerrGewitter

5. Conclusion

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Listings

Acronyms

TBD To Be Done

hp hit points

atk attack stat

def defense stat

spa special Attack stat

spd special Defense stat

spe speed stat

crit critical hit

iv individual values

ev effort values

brn burn

frz freeze

par paralysis

psn poison

slp sleep

rng random number generation

bfs breadth-first search

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Appendix

A. First Appendix Section

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Figure A.1.: A figure

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Ich versichere, dass ich die vorstehende Arbeit selbstständig und ohne fremde Hilfe angefertigt und mich keiner anderer als der in den beigefügten Verzeichnissen angegebenen Hilfsmittel bedient habe. Alle Textstellen, die wörtlich oder sinngemäß aus Veröffentlichungen Dritter entnommen wurden, sind als solche kenntlich gemacht. Alle Quellen, die dem World Wide Web entnommen oder in einer digitalen Form verwendet wurden, sind der Arbeit beigefügt.

Weitere Personen waren an der geistigen Leistung der vorliegenden Arbeit nicht beteiligt. Insbesondere habe ich nicht die Hilfe eines Ghostwriters oder einer Ghostwriting-Agentur in Anspruch genommen. Dritte haben von mir weder unmittelbar noch mittelbar Geld oder geldwerte Leistungen für Arbeiten erhalten, die im Zusammenhang mit dem Inhalt der vorgelegten Arbeit stehen.

Der Durchführung einer elektronischen Plagiatsprüfung stimme ich hiermit zu. Die eingereichte elektronische Fassung der Arbeit ist vollständig. Mir ist bewusst, dass nachträgliche Ergänzungen ausgeschlossen sind.

Die Arbeit wurde bisher keiner anderen Prüfungsbehörde vorgelegt und auch nicht veröffentlicht. Ich bin mir bewusst, dass eine unwahre Erklärung zur Versicherung der selbstständigen Leistungserbringung rechtliche Folgen haben kann.

Place, XX. Month 20YY

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(Julian Schubert)