**Part A**

**A screenshot of a cell phone

Description automatically generated**

**Part Bi**

1. All roads lead to a different location than their starting point and all roads allow travel in both directions.
2. Cities are always bigger than towns and towns are always bigger than villages.
3. Every location is either a city, a town or a village.
4. There is at least one city.
5. There is no more than one city.
6. There are at least two towns.
7. Either a location is a city or it has a road to a larger location.
8. Villages only have one road to another location.
9. Every town has at least three roads that lead to different locations.
10. Every location has no more than 3 roads leading to other locations.

**Pokémon Knowledge Base – Part C**

This knowledge base represents some of the facts and rules regarding Pokémon, Pokémon types, and specific instances of hypothetical Pokémon characters which could enact various scenarios when interacting with each other (mostly through combat).

**Facts**

Firstly, it was necessary to start with a hierarchical structure of the Pokémon: all characters in this domain were considered Pokémon, so Pokémon was the superclass. Subclasses of Pokémon included different types of Pokémon, such as ‘fighting’, ‘fire’, or ‘poison’. For each type of Pokémon, there are many different species each character can be, such as a ‘Pikachu’ or a ‘Bulbasaur’, and so another set of facts was created to represent some of the Pokémon species. A set of 15 specific characters was then created, each given in the format “[‘name’, is, ‘species’].” The various ages of the characters were specified using “is\_age”. Characteristics such as Legendary and Starter Pokémon were also included.

Some of the Pokémon characters in the domain were of the same family group; for simplicity, we chose just a few characters to have children. To initiate the battles, facts using ‘X attacks Y’ were used to demonstrate who attacks who in our scenario. Furthermore, we decided that some Pokémon would be armed with defence equipment and used ‘armed’ to demonstrate this.

**Rules**

It was then necessary to create the ruleset from which inferences could be made. We started with general logic and set-theoretic rules, which included the transitive nature of the subclass relation, for example.

Taxonomic relationships included basic family relationships, such as the fact that a parent of a parent of a character is a grandparent to that character, and that a grandparent of a character is a grandchild.

Semantic relations helped elucidate who – intuitively – could not beat another in an attack (for example, if a Pokémon is neutral to another, or beaten by another, they cannot beat them). We considered these semantics since these conclusions naturally follow from their antecedents.

Domain-specific rules were included, such as strength and weakness rules for attacks according to Pokémon type. This mostly adheres to Pokémon convention, with some types excluded for brevity. It should be noted that weakness rules are their own category and are not directly correlated with strength rules (If X is stronger than Y when attacking, Y is not necessarily weaker than X when initiating the attack).

Other rules included evolution (the fact that starter Pokémon above a certain age have the ability to evolve), rules for attacking (such as who becomes vulnerable or resistant when involved in an attack), rules for protective parents (parents will get angry when their child is attacked by someone stronger than them, will want to intervene if they have the strength to, and will definitely intervene if their child is also very young). Finally, a set of defence rules was established for methods of defence (such as being armed or being saved by another Pokémon, such as a parent).

Certain default rules were needed; for example, to be able to deduce when a Pokémon would beat another in an attack, since it was necessary to ensure that first the other Pokémon was in a vulnerable position and with no established means by which to defend themselves and no ability to evolve. The final set of rules determines the consequences of battle.

**Limitations**

One of the limitations we encountered during the creation of the knowledge base was that pre-existing facts and rules could not be overwritten once established. Therefore, we were unable to express, for example, a Pokémon starting out as one type and evolving into another type, as we could not render their initial type obsolete. We were only able to state that they evolved, adapting the Pokémon convention to allow evolution within types. We were also unable to express time effectively, and so we had to construct a static environment of relationships, attacks, and defence.

**Inferences**

One interesting inference is that the Pokémon character ‘emma’ does not attack the Pokémon character ‘zoe’: “ **– [emma, attacks, zoe]**”. This is interesting because it is also inferred that emma wants to attack zoe: “ **[emma, wants\_attack, zoe]**”, but does not end up doing so. The table below demonstrates why.

|  |  |  |  |
| --- | --- | --- | --- |
| **Inference** | **Facts/Previous Inferences used** | **Rules used** | **Explanation** |
| [zoe, stronger\_than, sarah] | [zoe, is, machop]  [machop, subclass\_of, fighting]  [sarah, is, eevee]  [eevee, subclass\_of, normal] | Strength: [[X, is, fighting], [Y, is, normal]] ==> [X, stronger\_than, Y]).  Logic: [[X, is, C1], [C1, subclass\_of, C2]] ==> [X, is, C2] ). | zoe is stronger than sarah because sarah is of type ‘normal’ and zoe is of type ‘fighting’. ‘Fighting’ is stronger than ‘normal’ in an attack. |
| [sarah, vulnerable\_to, zoe] | [zoe, stronger\_than, sarah]  [zoe, attacks, sarah] | Attack: [[X, stronger\_than, Y], [X, attacks, Y]] ==> [Y, vulnerable\_to, X]). | sarah is vulnerable to zoe because zoe is attacking her and zoe is stronger than her |
| [emma, angry\_at, zoe] | [sarah, vulnerable\_to, zoe]  [emma, parent\_of, sarah] | Angry: [[X, vulnerable\_to, Y], [Z, is\_parent\_of, X]] ==> [Z, angry\_at, Y]). | emma is angry at zoe because her child is being attacked by zoe and is vulnerable |
| [emma, stronger\_than, zoe] | [emma, is, mew]  [mew, subclass\_of, psychic]  [zoe, is, machop]  [machop, subclass\_of, fighting] | Strength: [[X, is, psychic], [Y, is, fighting]] ==> [X, stronger\_than, Y]).  Logic: [[X, is, C1], [C1, subclass\_of, C2]] ==> [X, is, C2] ). | emma is stronger than zoe because emma is of type ‘psychic’ and zoe is of type ‘fighting’ |
| [emma, wants\_attack, zoe] | [emma, stronger\_than, zoe] | Angry: [[X, angry\_at, Y], [X, stronger\_than, Y]] ==> [X, wants\_attack, Y]). | emma wants to attack zoe because emma is angry at zoe and also stronger than her |
| *Not inferred:* [emma, wants\_defend, sarah] | [sarah, is\_age, 18]  (18 > 8)  [sarah, is\_child\_of, emma] | Angry: [[Z, is\_child\_of, X], [Z, is\_age, A], test(A<8)] ==> [X, wants\_defend, Z]). | It is not inferred that emma wants to defend her child sarah in the attack because sarah is older than 8, (and so she has left her to deal with the fight herself) |
| **Conclusion:**  **-[emma, attacks, zoe]** | [emma, wants\_attack, zoe]  [zoe, attacks, sarah]  Not inferred: [emma, wants\_defend, sarah] | Default: [[X, wants\_attack, Y], [Y, attacks, Z], \+[X, wants\_defend, Z]] ==> -[X, attacks, Y]). | emma does not attack zoe because, although emma wants to attack zoe (because she is angry at her), we have not inferred that she wants to defend sarah in the attack. |

Another inference found at level three is the “alex is attacked by jonny” inference. This inference demonstrates what happens when a start Pokémon that is over the age of 8 is attack by a Pokémon which it is vulnerable and would normally result in the attacked party being beaten.

First, we infer that alex is a charmander which is a subclass of the fire type which is a subclass of Pokémon. As charmander is a starter Pokémon it is then inferred that alex is a starter Pokémon. Next it is inferred that alex as a fire type is stronger than a water type Pokémon but weaker than a ground or water type Pokémon.

Jonny attacks alex which infers that alex is attacked by jonny. Alex is vulnerable to jonny as jonny is a water type and therefore stronger than alex. As alex is over the age of 8 his parent will not come to defend him despite being attacked and vulnerable. However, as alex is a starter Pokémon, when he is attacked and vulnerable, he can evolve and stop the attacker from beating him. So alex “evolves” and prevents jonny from beating him. As no one is beat no one faints or gains exp.

Other inferences are made regarding taxonomy but in this instance plays no big role in determining the outcome of this inference.

The final fact that we consider that the knowledge base inferred at level 3 was “mary is attacked by sarah”.

The initial facts from the knowledge base required for this eventual inference can be split into five groups. First is the Pokémon type of each character involved, so sian is a Bulbasaur, mary is a Butterfree and sarah is an Eevee. Second is that Butterfree is stronger than Bulbasaur and Eevee is stronger than Butterfree. The final three groups only have one necessary fact in each, mary attacks sian, sarah is sian’s parent and sian is 3 years old.

From these facts, after one level of inference, the following facts are also available. First is that we get the Pokémon type for all Pokémon involved from the logic rules, so sian is grass, mary is flying and sarah is normal. From a taxonomy rule we find that sian is a child of sarah, and from a semantic rule we have that sian is attacked by mary. We also have that sarah wants to defend sian, as sian is under the age of 8 and a child of sarah. Finally, we have that sarah is stronger than mary and mary is stronger than sian from the strength rules.

Another layer of inference can now be considered, from one of the semantic rules we have that sian is vulnerable to mary. By this and the initial fact that sarah is sian’s parent, via the angry rule, we get that sarah is angry at mary. Another angry rule with this and the fact that sarah is stronger than mary, from the first inference level, gives us that sarah wants to attack mary. Finally, as sarah wants to defend sian, mary attacks sian and sarah wants to attack mary, it follows by one of the defend rules that sarah attacks mary.

At the final layer of inference, a single use of one of the semantic rules and the fact from the previous inference level that sarah attacks mary, we have that mary is attacked by sarah.