I. Linear Temporal Logic Semantics

The semantics of LTL are defined inductively as

\[(q_i, p_i) \models \neg \varphi \iff (q_i, p_i) \not\models \varphi\]

\[(q_i, p_i) \models \varphi_1 \land \varphi_2 \iff (q_i, p_i) \models \varphi_1 \land (q_i, p_i) \models \varphi_2\]

\[(q_i, p_i) \models \varphi_1 \lor \varphi_2 \iff (q_i, p_i) \models \varphi_1 \lor (q_i, p_i) \models \varphi_2\]

\[(q_i, p_i) \models \bigcirc \varphi \iff (q_{i+1}, p_{i+1}) \models \varphi\]

\[(q_i, p_i) \models \varphi_1 \mathcal{U} \varphi_2 \iff \exists j \geq i, \text{s.t.} (q_j, p_j) \models \varphi_2\]

\[\text{and } (q_k, p_k) \models \varphi_1, \forall i \leq k \leq j\]

In these definitions, the notation \(\bigcirc \varphi\) represents that \(\varphi\) is true at the next “step” (i.e., next position in the sequence), \(\square \varphi\) represents \(\varphi\) is always true (i.e., true at every position of the sequence), \(\Diamond \varphi\) represents that \(\varphi\) is eventually true at some position of the sequence, \(\Diamond \Box \varphi\) represents that \(\varphi\) is true infinitely often (i.e., eventually become true starting from any position), and \(\Diamond \Box \varphi\) represents that \(\varphi\) is eventually always true (i.e., always becomes true after some point in time in the sequence).

II. An Additional LTL Specification For Keyframe State

If \(\bigcirc e = \bigcirc e_{hd}\) (i.e., hugeDownward), the level of degree for next keyframe state increases by one or two units, either from step length or apex velocity. The only exception is when \(q = q_{l-t}\), next step state \(q\) can only maintain \(q_{l-t}\).

\[\square ((q_{s-s} \land \bigcirc e_{hd}) \Rightarrow \bigcirc (q_{n-s} \lor q_{s-n} \lor q_{s-t} \lor q_{n-t})) \land \bigcirc ((q_{s-n} \land \bigcirc e_{hd}) \Rightarrow \bigcirc (q_{s-t} \lor q_{n-n} \lor q_{n-t}))\]

\[\ldots\]

\[\land \bigcirc ((q_{n-n} \lor q_{n-t} \lor q_{l-t}) \land \bigcirc e_{hd}) \Rightarrow \bigcirc q_{l-t}) \land \Diamond ((q_{swing} \lor q_{stop}) \land \bigcirc e_{hd}) \Rightarrow \bigcirc (q_{s-n} \lor q_{n-n} \lor q_{n-t})\]

where, if \(q = q_{s-s}\), \(\bigcirc q\) increases the level of degree by one, i.e., \(q_{s-n}\) and \(q_{n-s}\), or by two, i.e., \(q_{n-n}, q_{l-t}\) and \(q_{s-t}\). Special cases are \(q_{l-n}, q_{n-l}\) and \(q_{l-t}\) where \(\bigcirc q = \bigcirc q_{l-t}\) is the only choice. Unexpected events are those in (S5).