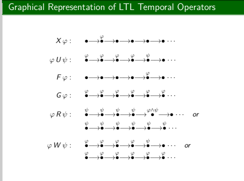
Graphical Representation of LTL Temporal Operators



Note that missing formula stands for *true*.

Note that a system satisfies an LTL formula iff **all** its runs satisfy it.

LTL examples

LTL examples

- X *rain*
- F *rain*
- *pick-up* R *kin-gar*
- $G(\textit{drop-off} \implies (\textit{kin-gar}\ U\ \textit{pick-up}))$
- $G\,(\neg(cs_1 \wedge cs_2))$
- $G\,(req \implies F\ resp)$ ... Does it guarantee that $\#_{req} = \#_{resp}$?
- $G\ F\ chocolate$
- $(G\ F\ req) \implies (G\ F\ resp)$
- $sin \implies (F\ G\ hell)$
- $F(sin \wedge (\neg confession\ U\ death)) \implies (F\ G\ hell)$

- $X\ rain$ - it will rain tomorrow
- $F\ rain$ - it will rain eventually
- *pick-up* R *kin-gar* - pick-up releases a child from kindergarten
- $G(\textit{drop-off} \implies (\textit{kin-gar}\ U\ \textit{pick-up}))$ - contrary to the previous one *pick-up* can be out of *kin-gar*
- $G\,(\neg(cs_1 \wedge cs_2))$ - mutual exclusion (in critical sections)
- $G\,(req \implies F\ resp)$ ... Does it guarantee that $\#_{req} = \#_{resp}$? - no
- $G\ F\ chocolate$ - chocolate infinitely many times
- $(G\ F\ req) \implies (G\ F\ resp)$ - only infinitely many requests cause i. m. responses
- $sin \implies (F\ G\ hell)$ - *sin* causes *hell*
- $F(sin \wedge (\neg confession\ U\ death)) \implies (F\ G\ hell)$ - improved with confession

LTL properties - example

You have two fishes, say Alice (A) and Bob (B). There is an aquarium divided into two parts: left (L) and right (R). Both fish start on the right side of the aquarium and do the following sequence of steps (independently): They move to the left, eat, move back to the right. Formulate using LTL:

- Whenever Alice eats, she is on the left.
- Whenever Bob is on the left, he will eat eventually.
- Whenever Bob eats, he will immediately go to the left.
- If Alice do not eat before Bob, she will never eat.
- Alice and Bob will never be on the same side from some point.
- Bob chases Alice until they both eat together.

- Whenever Alice eats, she is on the left
  $G\,(ae \implies al)$
- Whenever Bob is on the left, he will eat eventually
  $G\,(bl \implies F\,be)$
- Whenever Bob eats, he will immediately go to the left
  $G\,(be \implies X\,bl)$
- If Alice do not eat before Bob, she will never eat
  $((\neg ae)\,U\,be) \implies G\,(\neg ae)$
- Alice and Bob will never be on the same side from some point
  $FG((al \land br) \lor (ar \land bl))$
- Bob chases Alice until they both eat together
  $((al \implies X\,bl) \land (ar \implies X\,br))\,W\,(ae \land be)$

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└LTL properties - distributivity questions

LTL properties - distributivity questions

Is it true that ...

- $X(\varphi \vee \psi) \stackrel{?}{\equiv} X\varphi \vee X\psi$
- $X(\varphi \wedge \psi) \stackrel{?}{\equiv} X\varphi \wedge X\psi$
- $F(\varphi \vee \psi) \stackrel{?}{\equiv} F\varphi \vee F\psi$ $\qquad GF(\varphi \vee \psi) \stackrel{?}{\equiv} GF\varphi \vee GF\psi$
- $F(\varphi \wedge \psi) \stackrel{?}{\equiv} F\varphi \wedge F\psi$ $\qquad GF(\varphi \wedge \psi) \stackrel{?}{\equiv} GF\varphi \wedge GF\psi$
- $G(\varphi \vee \psi) \stackrel{?}{\equiv} G\varphi \vee G\psi$ $\qquad FG(\varphi \vee \psi) \stackrel{?}{\equiv} FG\varphi \vee FG\psi$
- $G(\varphi \wedge \psi) \stackrel{?}{\equiv} G\varphi \wedge G\psi$ $\qquad FG(\varphi \wedge \psi) \stackrel{?}{\equiv} FG\varphi \wedge FG\psi$
- $\varphi\, U\, (\psi_1 \vee \psi_2) \stackrel{?}{\equiv} (\varphi\, U\, \psi_1) \vee (\varphi\, U\, \psi_2)$
- $\varphi\, U\, (\psi_1 \wedge \psi_2) \stackrel{?}{\equiv} (\varphi\, U\, \psi_1) \wedge (\varphi\, U\, \psi_2)$
- $(\varphi_1 \vee \varphi_2)\, U\, \psi \stackrel{?}{\equiv} (\varphi_1\, U\, \psi) \vee (\varphi_2\, U\, \psi)$
- $(\varphi_1 \wedge \varphi_2)\, U\, \psi \stackrel{?}{\equiv} (\varphi_1\, U\, \psi) \wedge (\varphi_2\, U\, \psi)$

- $X(\varphi \vee \psi) \equiv X\varphi \vee X\psi$
- $X(\varphi \wedge \psi) \equiv X\varphi \wedge X\psi$
- $F(\varphi \vee \psi) \equiv F\varphi \vee F\psi$ $\qquad GF(\varphi \vee \psi) \equiv GF\varphi \vee GF\psi$
- $F(\varphi \wedge \psi) \not\equiv F\varphi \wedge F\psi$ $\qquad GF(\varphi \wedge \psi) \not\equiv GF\varphi \wedge GF\psi$
- $G(\varphi \vee \psi) \not\equiv G\varphi \vee G\psi$ $\qquad FG(\varphi \vee \psi) \not\equiv FG\varphi \vee FG\psi$
- $G(\varphi \wedge \psi) \equiv G\varphi \wedge G\psi$ $\qquad FG(\varphi \wedge \psi) \equiv FG\varphi \wedge FG\psi$
- $\varphi\, U\, (\psi_1 \vee \psi_2) \equiv (\varphi\, U\, \psi_1) \vee (\varphi\, U\, \psi_2)$
- $\varphi\, U\, (\psi_1 \wedge \psi_2) \not\equiv (\varphi\, U\, \psi_1) \wedge (\varphi\, U\, \psi_2)$
- $(\varphi_1 \vee \varphi_2)\, U\, \psi \not\equiv (\varphi_1\, U\, \psi) \vee (\varphi_2\, U\, \psi)$
- $(\varphi_1 \wedge \varphi_2)\, U\, \psi \equiv (\varphi_1\, U\, \psi) \wedge (\varphi_2\, U\, \psi)$