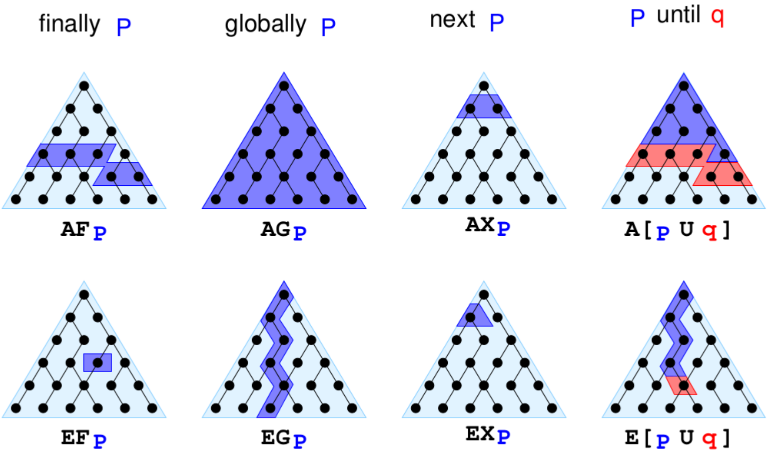
CTL intuitive recall



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Known picture drawback - the runs should form trees!

CTL examples

Express in CTL:

- A state where *a* is true, but *b* is not, is reachable.
- Whenever system receives a request *Req* then it generates an acknowledgement *Ack* eventually.
- Whenever system receives a request *Req* then it is possible that it will generate an acknowledgement *Ack* eventually.
- In every run there are infinitely many *b*.

CTL examples

Express in CTL:

- All the paths lead to Rome.
- All the time if I have not died yet, then I have a chance to survive one more day.
- All the time if I get robbed then I can react by defending myself or not defending myself.

CTL examples

Read CTL formula:

- $AG[\text{ error } \implies E(\text{repair } U \text{ operational})]$
- $AG[\text{ error } \implies AX\ A(\text{!error } W \text{ operational})]$
- $AG[\ EF(\text{restart})\ ]$
- $AG[\ EX(\text{restart})\ ]$
- $A[\ p\ U\ A(q\ U\ r)\ ]$

How to read:

- AX, EX - necessarily next, possibly next
- AF - necessarily in the future (or Inevitably)
- EF - possibly in the future (or Possibly)
- AG - globally (or Always)
- $AG(\phi \implies \psi)$ - Whenever ϕ then ψ.
- EG - possibly henceforth
- AU, EU - necessarily until, possibly until

CTL properties

- $\neg AG\varphi \equiv EF\neg\varphi$
- $\neg EG\varphi \equiv AF\neg\varphi$
- $\neg EX\varphi \equiv AX\neg\varphi$

- discuss $\neg Gp$ in LTL

- $EX(\varphi \vee \psi) \equiv EX\varphi \vee EX\psi$
- $EX(\varphi \wedge \psi) \not\equiv EX\varphi \wedge EX\psi$
- $AX(\varphi \vee \psi) \not\equiv AX\varphi \vee AX\psi$
- $AX(\varphi \wedge \psi) \equiv AX\varphi \wedge AX\psi$

CTL vs. LTL examples

Express in LTL: $EF[\ \mathrm{a} \wedge \neg \mathrm{b}]$

Compare the following formulae:

- $AG[\ EF$ restart $]$ vs. $G[\ \neg(G\neg$ restart$)\ ]$
- $AG[\ \mathrm{p} \implies AF\ \mathrm{q}\ ]$ vs. $G(\ \mathrm{p} \implies F\mathrm{q}\ )$
- $AF[\ AG\ \mathrm{p}\ ]$ vs. $FG\ \mathrm{p}$
- $AG[\ AF\ \mathrm{p}\ ]$ vs. $GF\ \mathrm{p}$
- $AF[\ AX\ \mathrm{p}\ ]$ vs. $FX\ \mathrm{p}$

Express in CTL: $(GF\ \mathrm{p} \wedge GF\ \mathrm{q}) \implies \psi$