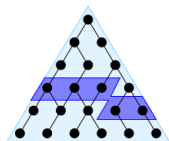


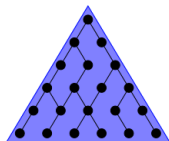
CTL intuitive recall

finally P



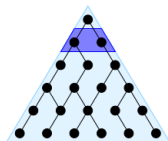
$AF P$

globally P



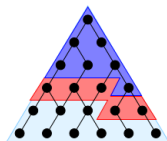
$AG P$

next P

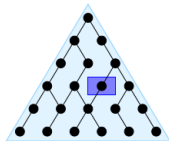


$AX P$

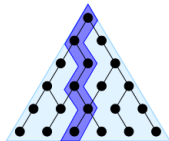
P until q



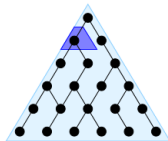
$A[P U q]$



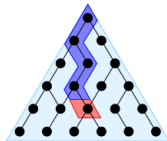
$EF P$



$EG P$



$EX P$



$E[P U q]$

(C) Alessandro Artale

Known picture drawback - the runs should form trees!

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 .

Express in CTL:

- All the paths lead to Rome.
- All the time if I did not loose, then I have a move where I do not loose.
- 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

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

- 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: $EF[a \wedge \neg b]$

Compare the following formulae:

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

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