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*.

- $EF[\ \mathrm{a} \wedge \neg \mathrm{b}]$
- $AG[\ \mathrm{Req} \implies AF\ \mathrm{repair}\ ]$
- $AG[\ \mathrm{Req} \implies EF\ \mathrm{repair}\ ]$
- $AG[\ AF\ \mathrm{b}\ ]$

CTL examples

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.

- AF Rome
- $AG[\neg \text{Loose} \implies EX \neg \text{Loose}]$
- $AG[\text{Robbed} \implies (EX \text{ Defend} \wedge EX \neg \text{Defend})]$
  do not confuse with $AG[\neg \text{Robbed} \implies EX (\text{Defend} \wedge \neg \text{Defend})]$
  or with $AG[\neg \text{Robbed} \implies EX (\text{Defend} \vee \neg \text{Defend})]$

CTL examples

Read CTL formula:

- $AG[$ error $\implies E($repair U operational$)\ ]$
- $AG[$ error $\implies AX\ A($!error W operational$)\ ]$
- $AG[\ EF($restart$)\ ]$
- $AG[\ EX($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

- Whenever there is an error, it is in a repair mode until it gets operational.
- Whenever there is an error, it stays without error until it gets operational or it stays without error forever.
  Whenever there is an error, there is no other error in the subsequent state before getting operational.
- There is always an option/possibility to restart the system eventually.
- There is always an option/possibility to restart the system immediatelly.
- All paths has to satisfy the regular expression $p^* q^* r$ in its prefix.

CTL vs. LTL examples

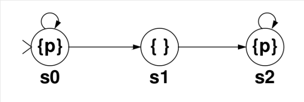
Express in LTL: $EF[\ a \wedge \neg b]$

Compare the following formulae:

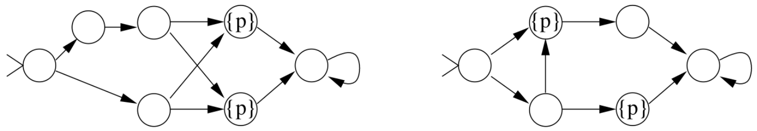
- $AG[\ EF$ restart] vs. $G[\ \neg(G$ restart)]
- $AG[\ p \implies AF\ q\ ]$ vs. $G(\ p \implies Fq\ )$
- $AF[\ AG\ p\ ]$ vs. $FG\ p$
- $AG[\ AF\ p\ ]$ vs. $GF\ p$
- $AF[\ AX\ p\ ]$ vs. $FX\ p$

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

- $AG[EF($ restart$)]$ - not expressible in LTL
- $AG[\ p \implies AF\ q\ ]$ vs. $G[\ p \implies Fq\ ]$ - the same
- $AF[AG\ p]$ vs. $FG\ p$ - different



- $AG[AF\ p]$ vs. $GF\ p$ - the same
- $AF[AX\ p]$ vs. $FX\ p$ - different



$EF[\ a \wedge \neg b]$ - not directly, we can express (and check) its negation

$(GF\ p] \wedge G[F\ q]) \implies \psi$ - fairness is not directly expressible in CTL