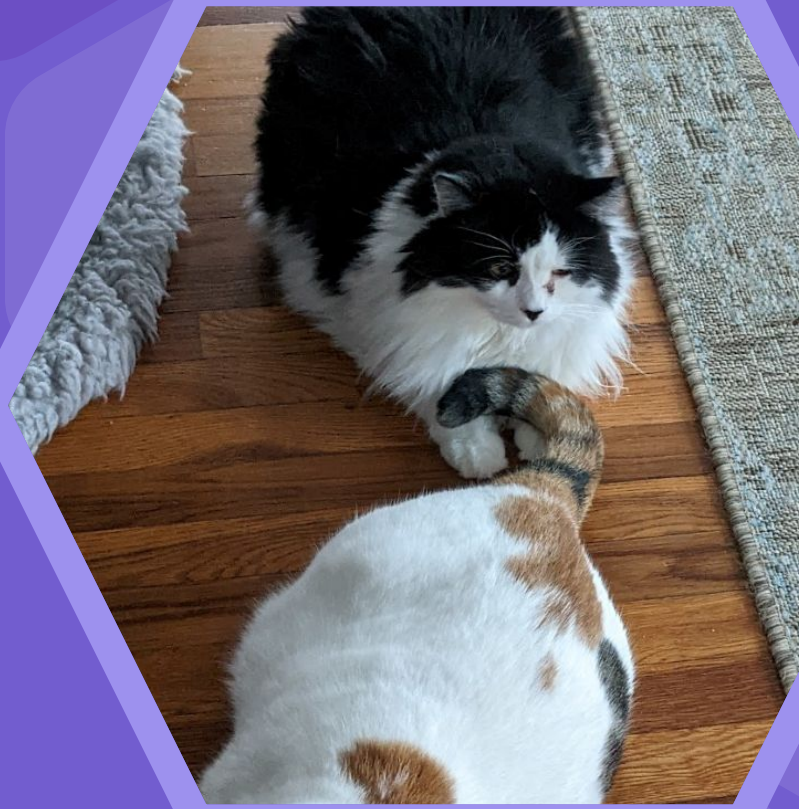
Linear Temporal Logic



Safety requirements vs liveness requirements

Safety: nothing bad *ever* happens

Liveness: something good *eventually* happens

- Means system is functioning as intended
- System requirements are often liveness requirements

What are some liveness requirements for the AC?

*How would you **monitor** that a liveness requirement is fulfilled?*

Verifying some liveness properties

Saying something *eventually* happens is the same thing as saying that it is *not* the case that it always *doesn't* happen

Can we use invariant verification to check this?

Linear Temporal Logic (LTL)

Assume you have *some* execution trace

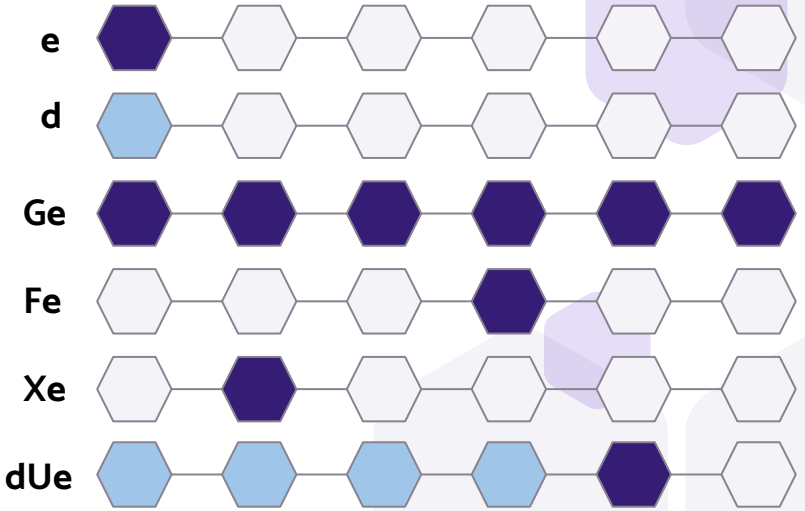
LTL operators are propositional logic operators PLUS:

G (globally/always)

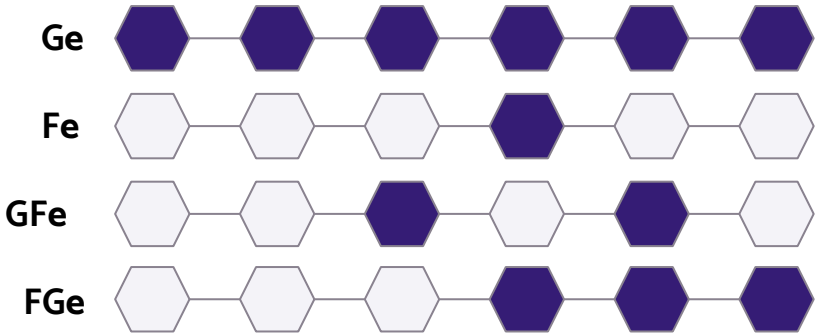
F (eventually/finally)

X (next state)

U (until)



FG vs G, GF vs F, FG vs GF



e repeats an infinite number of times for an infinite trace

LTL examples on FSMs

Safety property is an *invariant* if property p holds for all reachable states of S

Liveness property *holds* for S if it holds for all possible traces of S

Lee/Seshia Chapter 13, exercise 2

LTL means we can specify liveness properties with F. Can we specify safety properties more easily with LTL, too?

Safety properties with LTL

Use “G” to say a property holds for every state

Can use “X” to express statefulness/history without a monitor state machine

Limits of LTL

G(even(x) -> ((X-even(x)) ∧ (XXeven(x))

But if you don't know if you started a sequence with an odd number or even number, you cannot write

(even(x) ∧ X-even(x))

Automated model checking and LTL

These are covered more deeply in Alur's textbook

If interested: take CS1710!

Buchi Automata: automata that "accept" a certain LTL formula

Can be automatically constructed

Using nested DFS, show repeatability for negation of LTL formula holds

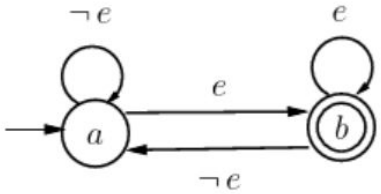


Figure 5.5: Büchi Automaton for □◊ e

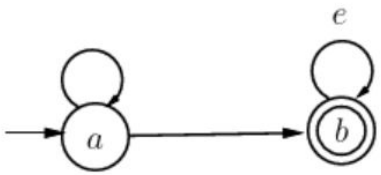


Figure 5.6: Büchi Automaton for ◊□ e

More verification techniques

Automated verification

Symbolic model checking: represents a set of states symbolically as a logic formula and does symbolic (algebraic) computation

What about timed/hybrid automata?

Symbolic reachability analysis for *linear* hybrid automata (special class of HA)

Symbolic model checking for a different kind of logic (signal temporal logic)

Assisted proof engines (differential dynamic logic)

An active area of research!

Summary: pros/cons of verification?