# CIS 4930/6930: Principles of Cyber-Physical Systems

## Project Design

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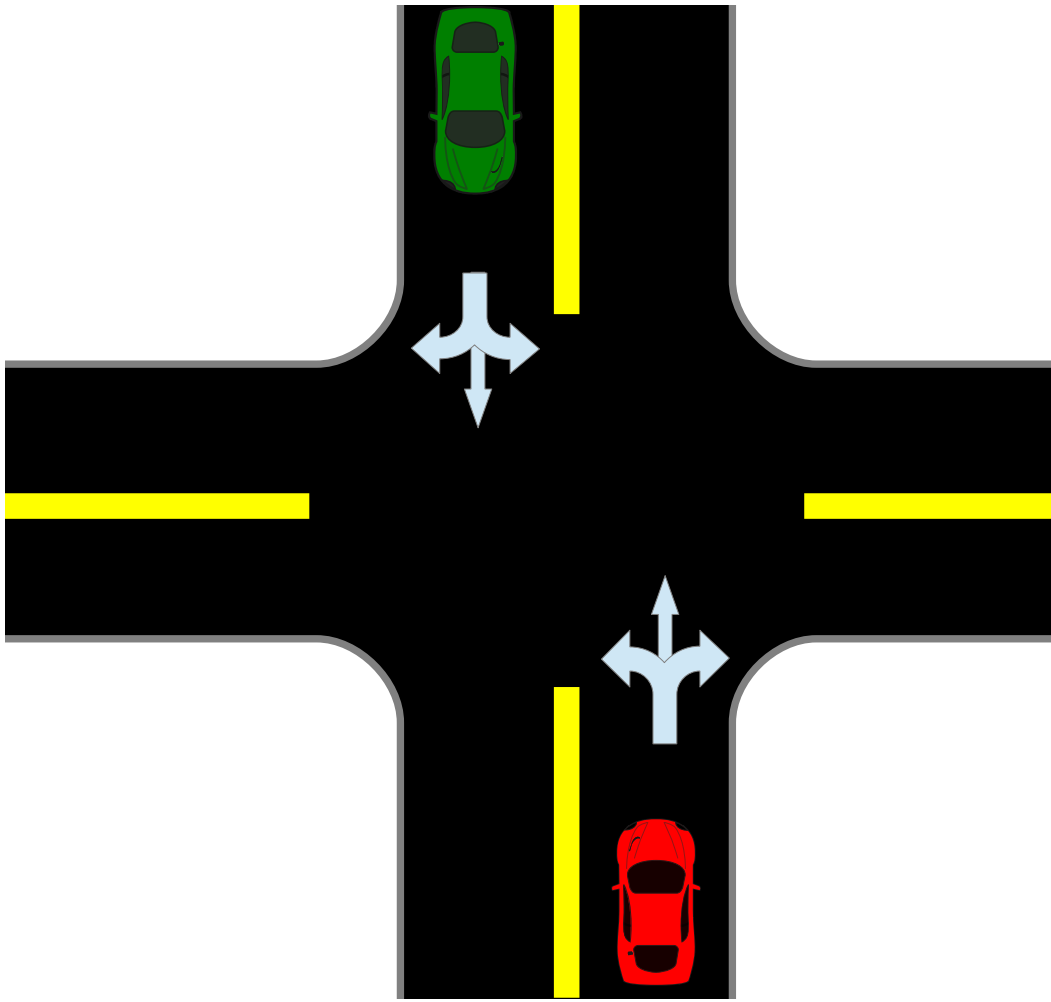
# Project 1: Discrete Modeling and Analysis

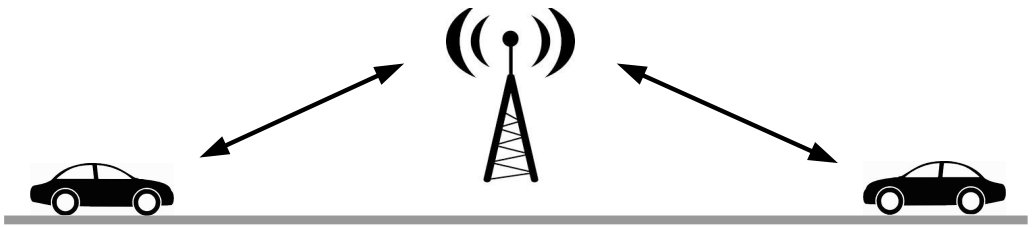
# Intelligent Traffic Control

- Goal: minimize the idle time of cross roads.
- Cars communicate with the controller – Cars' speed, position, turn/no turn, etc.
- Controller decides if it is safe for a car to access the cross, and
- Ensures a car can access the cross if it plans to.



# Intelligent Traffic Control (cont'd)

Cars are autonomous.
Cars do not operate erratically.

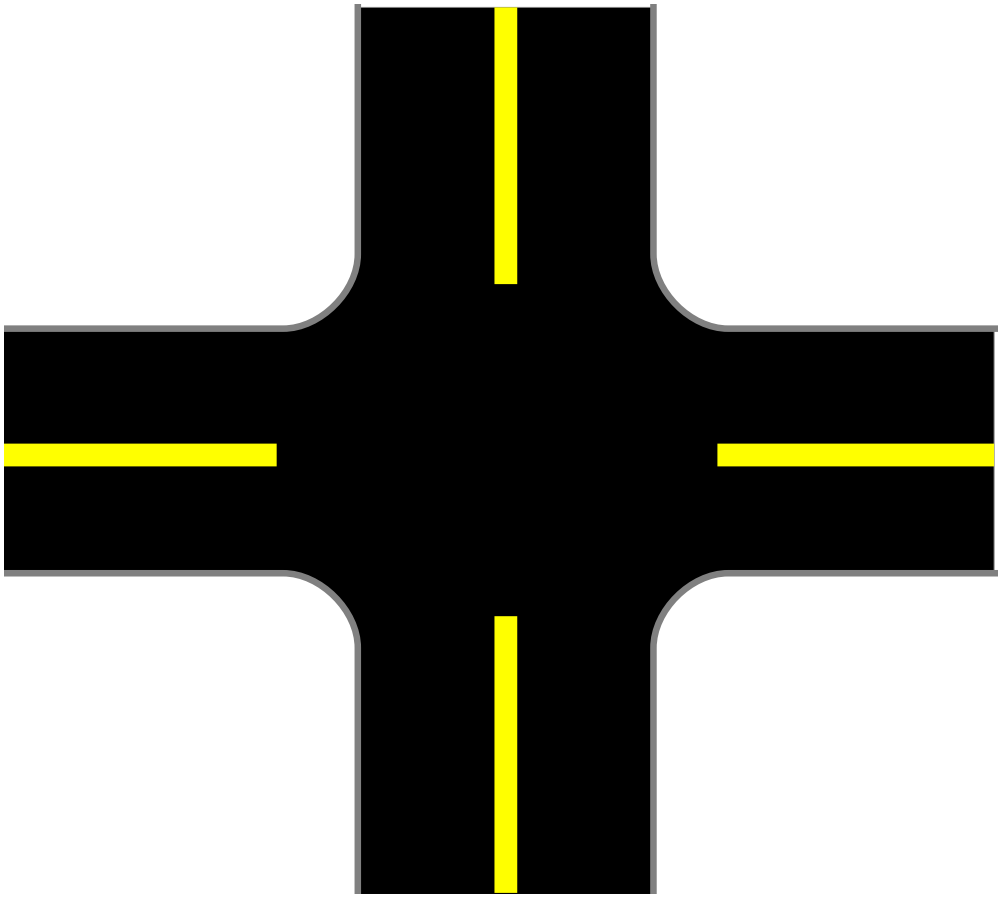


- The direction is fixed when a car approaches the cross.
- Cars maintain a fixed speed.
- Speed is reduced for turns, but not reduced if go straight.
- A car that arrives at the cross first gets the priority.
- Otherwise, a random order is selected to arrange the two cars to access the cross.
- Once the car exits the cross, its speed is back to its preset speed.

# Discrete Modeling

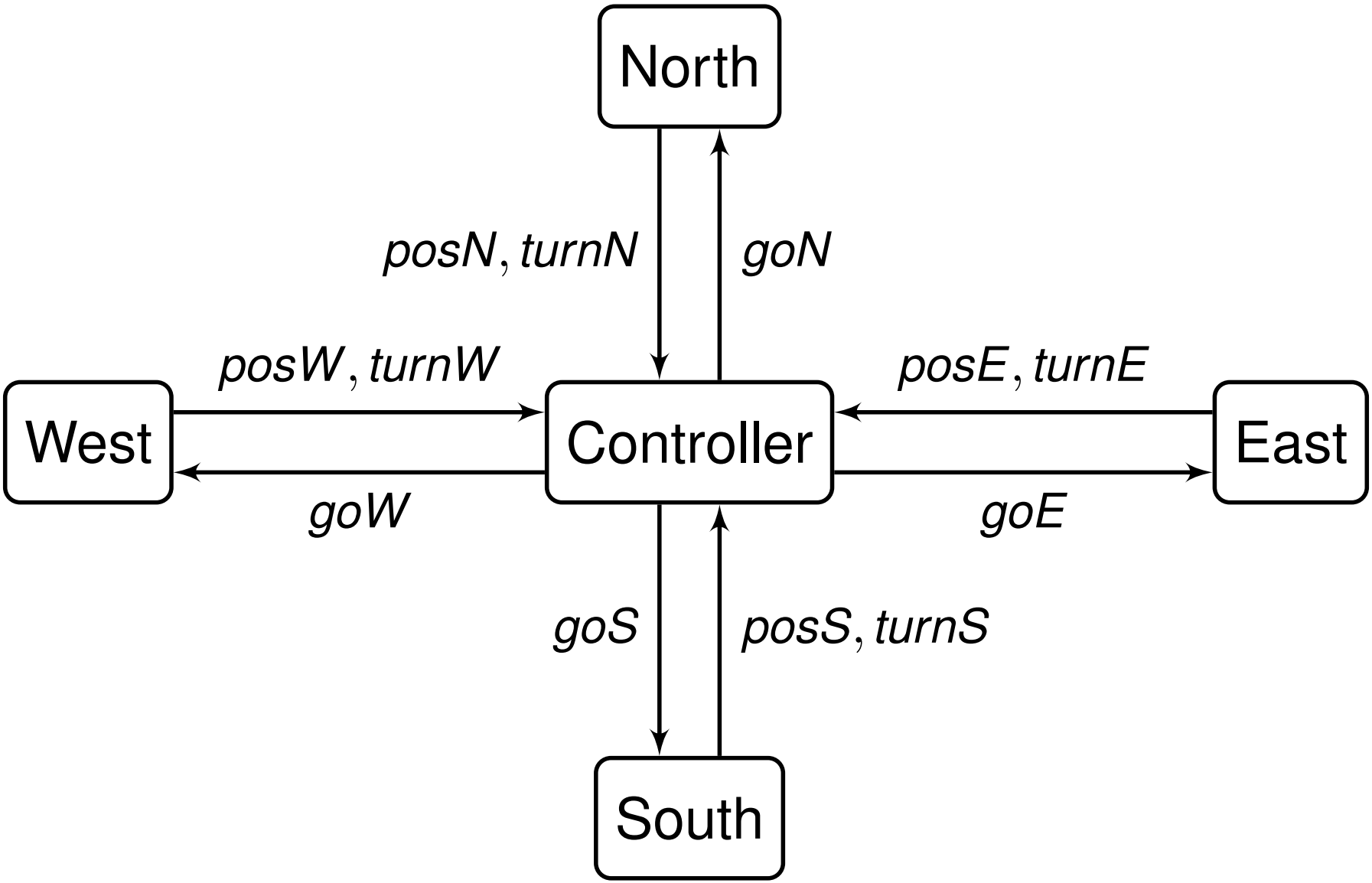
- Ignore the absolute speed.
  - How to model speed or movement?
- How to let the controller know a car's position?
  - How to model position?
- Ignore all timing delays.
  - Assume that the controller gives a command before a car enters the cross.

# How to Start



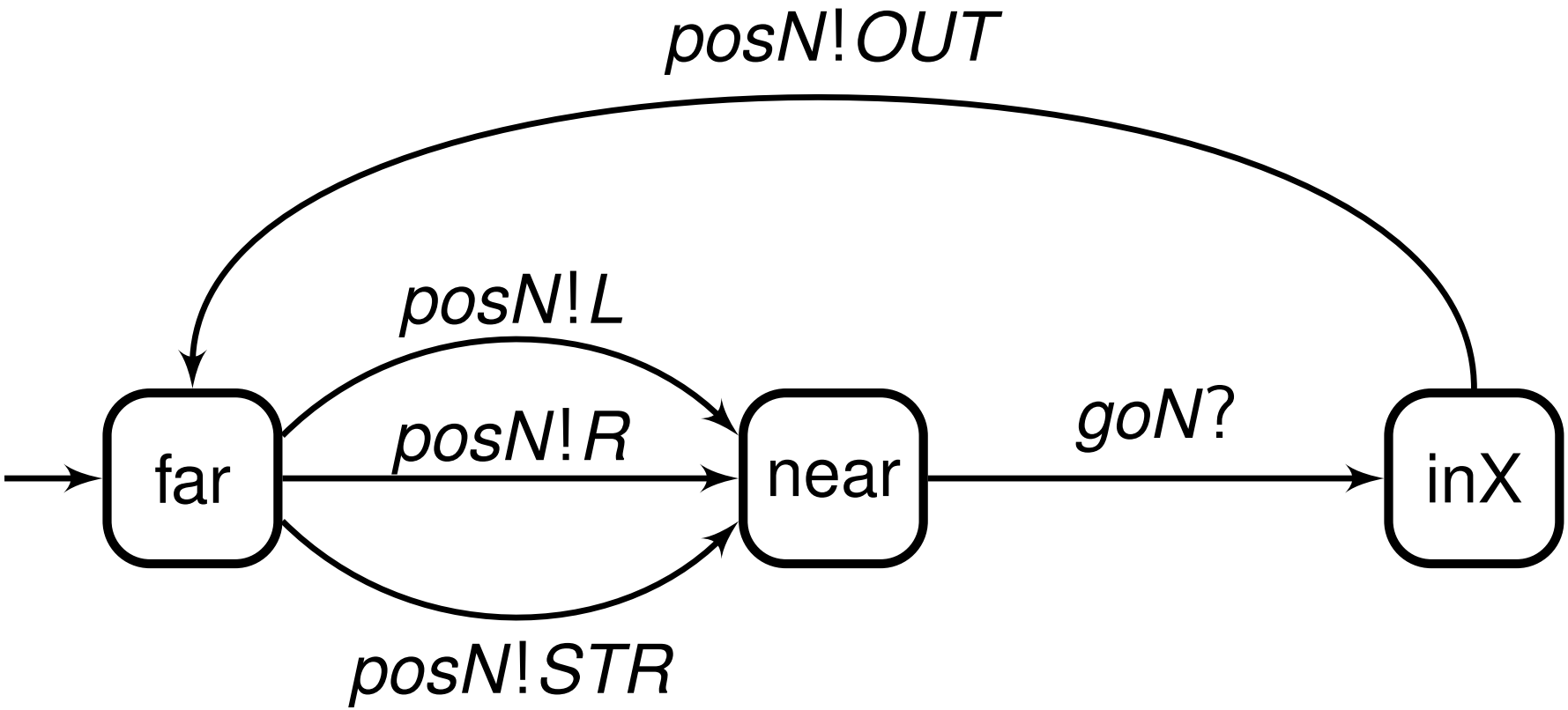
# Project 1: Post-Submission Discussion

# Actor Model


North
posN, turnN
goN
posW, turnW
posE, turnE
West
Controller
East
goW
goE
goS
posS, turnS
South

# Modeling Traffic: FSM

```
#define OUT 0 /* Out of cross */
#define L 1 /* turn left */
#define R 2 /* turn right */
#define STR 3 /* go straight */
```

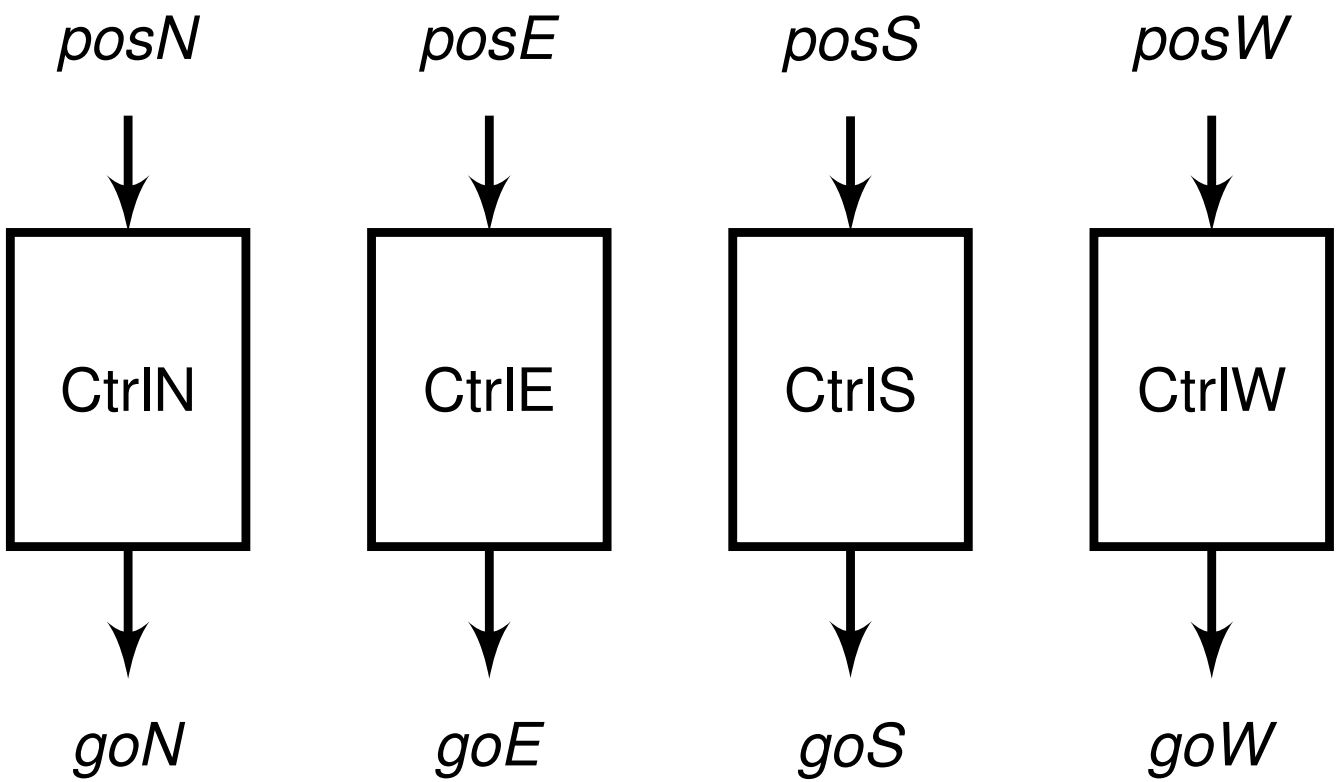


# Modeling Controller: Actor Model

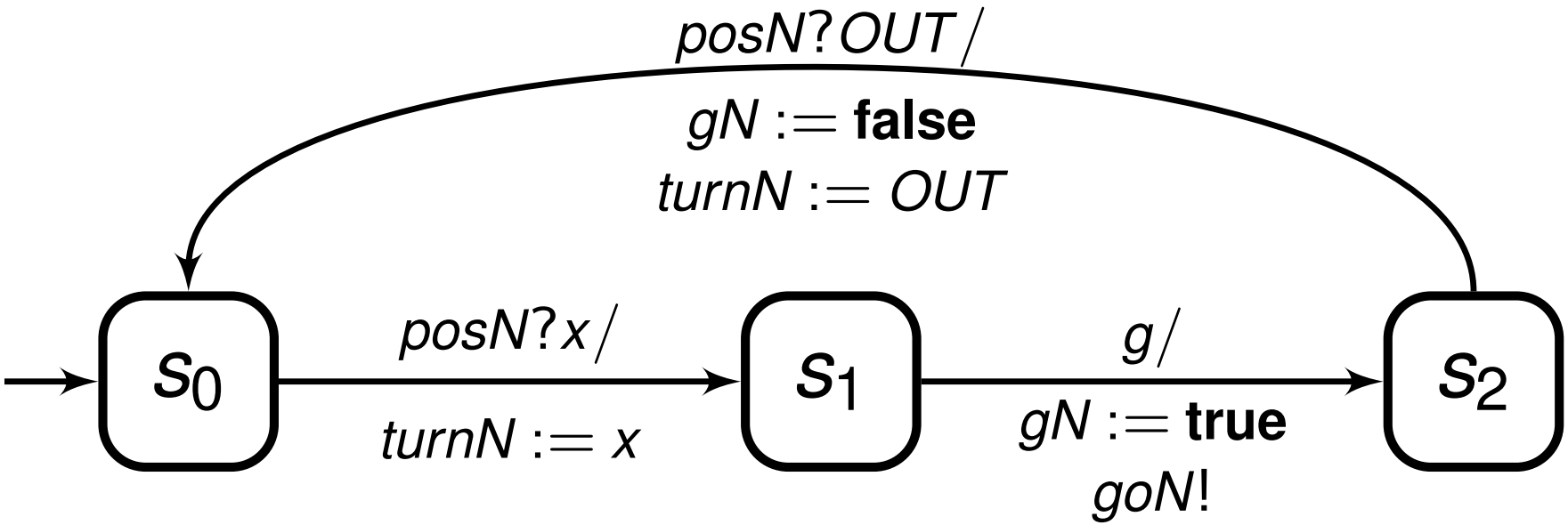
*Shared variables* :

*turnN*, *turnE*, *turnS*, *turnW* : **byte**

*gN*, *gE*, *gS*, *gW* : **boolean**



# Modeling Controller: FSM : CtrlN




$$
\begin{aligned}
g &:= ((turnN = L) \wedge g_1) \vee ((turnN = R) \wedge g_2) \vee ((turnN = STR) \wedge g_3); \\
g_1 &:= (gE \rightarrow turnE = R) \wedge (gW \rightarrow turnW = R) \wedge \neg gS \\
g_2 &:= (gE \rightarrow turnE \neq STR) \wedge (gS \rightarrow turnW \neq L) \\
g_3 &:= (gE \rightarrow turnE = R) \wedge (gS \rightarrow (turnS = STR \vee turnS = R)) \wedge \neg gW
\end{aligned}
$$

# Specification

Safety properties: no collision

$$\mathbf{G}\left(\begin{array}{lll} gN \wedge gS & \rightarrow & \neg((turnN = STR \wedge turnS = L) \vee \\ & & (turnN = R \wedge turnS = L) \vee (turnN = L \wedge (\ldots)) \end{array}\right)$$

Liveness properties

$$\mathbf{G}(turnX \neq OUT \quad \rightarrow \quad \mathbf{F}gX)$$

Performance properties:

$$\mathbf{G}(turnN = STR \wedge (turnS = STR \vee turnS = R) \rightarrow \mathbf{F}(gN \wedge gS))$$