CSCI 1106
Lecture 15

Dealing with Failure

Announcements

- Today’s Topics
  - Dealing with Failure
  - Failure and Failure Causes
  - Failure Identification
  - Failure Detection
  - Failure Recovery

Motivation

- The world is imperfect
  - Sensors give wrong readings
  - Motors turn too fast, too slow, too much, or too little
  - Wheels don’t grip the surface properly
  - Lighting conditions change
- This is normal
  - Humans deal with these kinds of problems all the time
  - We learn how to deal with failure
- How do we get robots to deal with them as well?

Dealing with Failure

- Need to do two things
  - Identify when a failure has occurred
  - Respond to the failure
- Example: Missing your exit on the highway
  - Identify that you have gone too far
  - Turn around and back track

Failure and Failure Cause

- **Def**: *Failure* is a state that is not anticipated by the design

- **Def:** *Failure cause is* the physical or functional reason for the failure
  - I.e., Why did failure occur?
  - Also known as *failure mode*
- Examples:
  - The furnace stopped working because <u>it ran out of oil</u>
  - We missed the exit because <u>we did not see the sign</u>
  - The robot missed the line because <u>it drove over it too quickly</u>
- **Key Observation:**
  - We can only deal with failures that we can foresee
  - I.e., What can go wrong?

Failure Manifestation

- **Def:** *Failure manifestation* is the detectable effect of the failure
- Examples:
  - The house is cold because the furnace is not working
  - We have driven too long because we missed the exit
  - Our arm hurts because we have broken it
- **Key Idea:** To identify failure, it must manifest itself in a detectable way

Failure Identification

- **Idea:** We can identify that a failure has occurred from its manifestation
- E.g., We identify that
  - The furnace must not be working because the house is cold
  - We must have missed the exit because we have driven too long
  - Our arm must be broken because it really hurts
- **Idea:** To identify a failure, we need to
  - Determine what can cause the failure
  - How the failure manifests

Enumerating Failures

- When designing a program we need to (attempt to) enumerate all relevant failures:
  - Assume things will go wrong
  - Ask "What can go wrong?"
  - Ask "How is failure manifested?"
- Narrow the enumeration to:
  - Failures we can deal with
  - Failure causes we understand
  - Failure manifestations we can identify
- Systems fail because designers fail to identify all relevant failure causes

Examples of Failures and Causes

- Ground proximity sensor fails to register dark / light
  - Sensor's distance to ground changed
- Horizontal proximity sensor fails to register object
  - Object has an odd shape
  - Object has an odd surface
- Horizontal proximity sensor registers ghost objects
  - Other robots nearby emitting infra-red light
- Robot does not make sufficiently precise movement
  - Tires are not properly aligned
  - Motors are rotating too fast
  - Wheels don't grip the surface properly

- In all cases the sensor or actuator may be broken
- How do we detect failures?

Mechanisms for Detecting Failure

- Unexpected external events
  - Sensors register an unexpected changes in environment
    - Sensors give false readings
    - Sensors give true readings of unexpected conditions
  - Actuators report status errors
    - Actuator fails to perform specified task
    - Actuator reports error where none has occurred
- Lack of expected external events
  - A timer expired while waiting for an expected event
    - Sensor fails to register the expected event
    - Expected event does not occur
  - Actuators fail to move the prescribed amount
    - Encounter unexpected resistance
- Unexpected (or lack there of) internal events
  - Programs run code they are not supposed to (bugs)

→ Unexpected: A difference between the anticipated and measured

Failure Response

- Once we determine that a failure has occurred, we need to respond to it
- **Def:** *Response mechanisms* are parts of the program that respond to the failure
- One approach is to put system in safe state and shut down
  - E.g., nuclear reactors
- This is not always possible if
  - System is inaccessible
    - E.g., rovers on Mars
  - System is mission critical
    - E.g., airplane
- In these cases the system must *recover* from the failures

Failure Recovery

- Recall: A failure occurs when a system enters an unexpected state
- **Def:** A *recovery mechanism* returns the system to a normal state

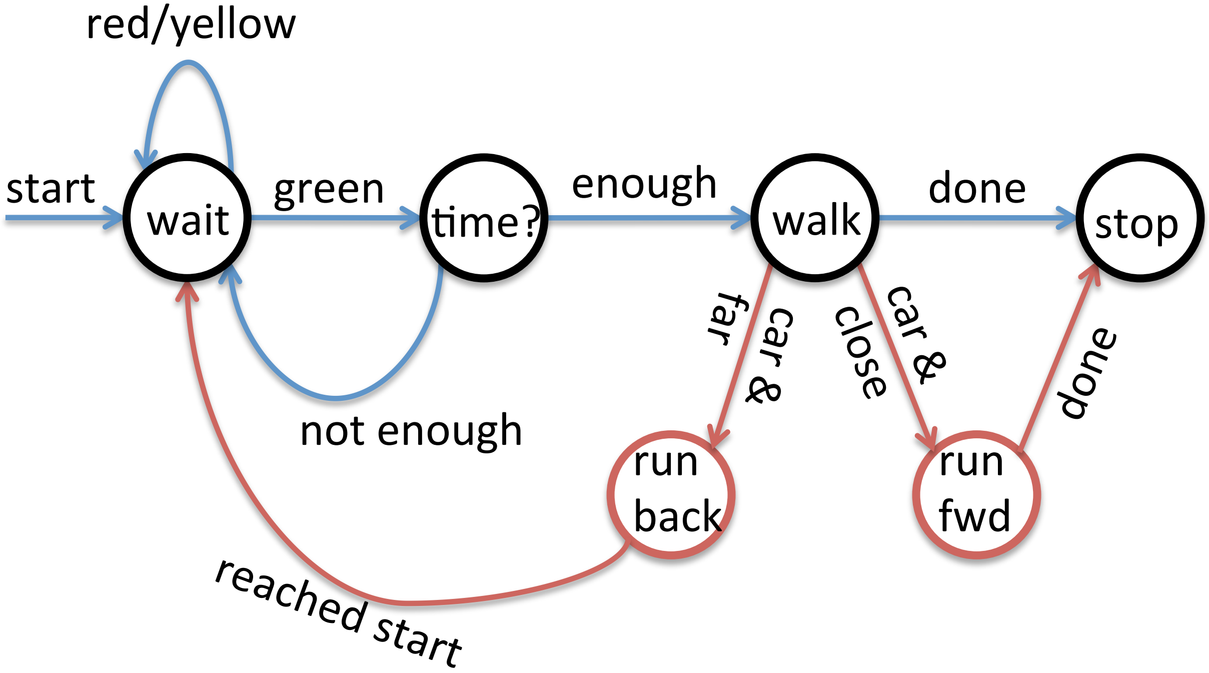
- Recovery mechanisms are specific to each failure
- Examples:
  - If an exit is missed, <u>backtrack to the exit</u>
  - If the furnace is broken, <u>call landlord</u>
  - If your arm is broken, <u>see a doctor</u>
- For our purposes: **return the robot to its last ``normal'' state**
  - Find the line if it is lost
    - Recheck sensors
    - Retry actuator operation
- If the recovery mechanism fails, we need a recovery mechanism for the recovery mechanism…

Modeling Failure Identification and Recovery

- We need to model or represent how we
  - Identify failure
  - Respond to failure
  - Recover from failure
- What should we use?

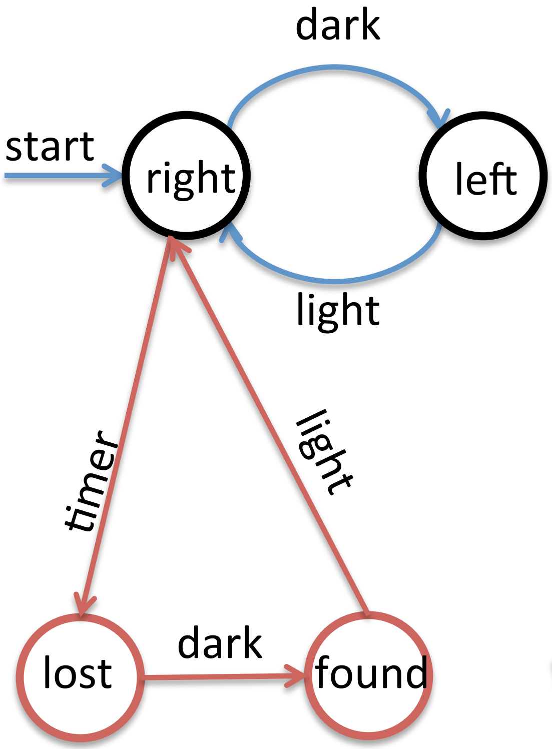
State Transition Diagrams

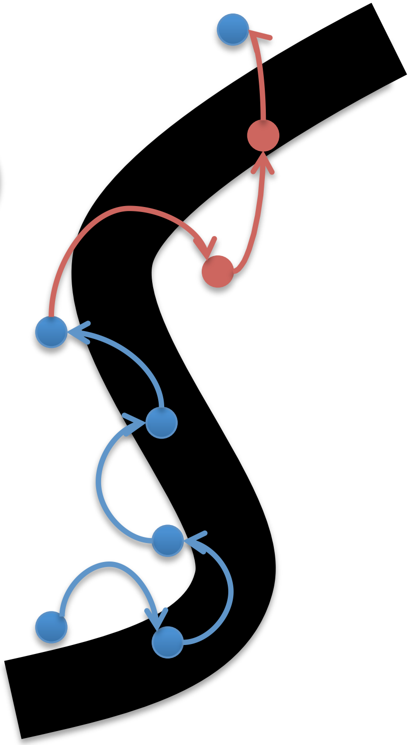
- Idea: Use state transition diagrams to represent possible failures and recovery mechanisms
- Example: Crossing the Street



A Missed Line in Follow the Line

- *Right* state
  - Sensor reports light
  - On left side of line
  - Moving to the right
  - Timer running
- *Left* state
  - Sensor reports dark
  - On the line
  - Moving to the left
- *Lost* state
  - Timer expired
  - Sensor reports light
  - On right side of the line
  - Moving to the left
- *Found* state
  - Sensor reports dark
  - On the line
  - Moving left





Observations

- Error identification and response can add much more complexity to your program
  - 80% of a typical application deals with error handling
- The error response itself may fail
- State transition diagrams are an easy way to reason about errors