Finite State Automata Lesson Plan

Summary

Computer programs often need to process a sequence of symbols such as letters or words in a document, or even the text of another computer program. Computer scientists often use a finite-state automaton to do this. A finite-state automaton (FSA) follows a set of instructions to see if the computer will recognize the word or string of symbols. We will be working with something equivalent to a FSA using a wacky fruit vendor!

Timeline

What	Time (mins)	Where
Fruit Vendor Introduction Activity – Fickle Fruit	5	FSA.pdf VendorInstructionCards.pdf
Class Discussion – FSA Syntax	5	FSA.pdf
Fruit Vendor Introduction Activity – Frustrating Fruit	10	VendorInstructionCards.pdf
Fruit Vendor Introduction Activity – Fancy Fruit (optional)	5	FSA.pdf VendorInstructionCards.pdf
Worksheet – Robot Dog	10	RobotDogWorksheet.pdf
Worksheet – Chores Robot	10	ChoresRobotWorksheet.pdf
Follow up Discussion	5	FSA.pdf
Total	50	

Materials

- ✓ One set of vendor instruction cards for each group (the instructions must be kept hidden from those trying to draw the map!)
- ✓ Fruit cards (last page of VendorInstructions). They need to be cut out, and can be laminated for future reuse. We suggest providing 8 bananas and 8 apples per group.
- ✓ Plastic silverware (spoon and fork) – one set for each group
- ✓ Each child will need pencil or pen and the following worksheets:
  - o Worksheet 1: Robot Dog
  - o Worksheet 2: Chores Robot

Lesson Preparation

- ✓ Before diving into the lesson, it is recommended that you watch “Treasure Hunt video” which can be found here: https://www.youtube.com/watch?v=8kagtp2gWhU. Although we’ll be using an alternate activity, the video provides an easy instruction to finite state automata.

Activity – Fickle Fruit Vendor

Introduction

This activity will introduce the concept of finite state automata using a fruit vendor who sells apples and bananas. Unlike what we would expect, the fruit vendors in these exercises do not always give you the fruit you ask for. The vendors DO follow a set of rules, however, so if students can figure out a pattern in the vendor's behaviors, they will be able to correctly order the fruit they want.

The three exercises in this activity are organized by level of difficulty, from easiest to hardest: Fickle, Frustrating, and Fancy.

Activity

Students should be broken up into groups of four. This will allow for each group to have one vendor and three buyers.

Select one student in each group to be the vendor. The vendor should get a Fickle Fruit Instruction Card, as well as eight apples and eight bananas (sixteen pieces total), and a spoon. The other students *should not* be able to see the instruction card, so make sure the vendors know to keep this secret!

The three buyers in the fruit market will take turns trying to buy apples and bananas. Challenge the students to come up with a sequence of requests which gets them 3 apples in a row.

While they are buying fruit, students should be trying to figure out the pattern. At this point, we have not yet introduced how to represent a FSA, so the ways students keep track of the pattern may vary. Students may occasionally get frustrated if they don't receive the type of fruit they requested; but remind them that's part of the challenge, and encourage them to really focus on what the vendor is doing.

After the majority of the groups seem to have figured out the pattern, or the vendors are out of fruit to sell, regroup as a class.

Whole-Class Discussion: Introducing FSA Syntax

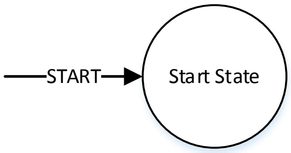
Lesson Vocabulary (you may want to write on the board):

- Finite State Automata (FSA)
- States
- Transitions

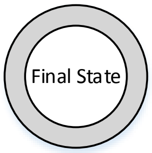
Finite State Automata (FSA) provide a visual tool for computer scientists to represent states and transitions between those states. As it turns out, FSAs are useful for modeling our fruit vendors because they follow a set pattern and set of rules.

The *syntax* (rules for correct format of the drawing) for a FSA is not too hard. Start with the basics, drawing them on the white board:

- *States* (shown below) are represented as circles with a description of the status. The states for a light bulb might be ON or OFF. The states for a music player might be PLAYING, PAUSED, STOPPED.
  - A *start state* is a circle that has a transition arrow labeled “START” pointing to that state.
  - A *final* state is a state with two circles.
- *Transitions* are represented as arrows between circles including an *event* (e.g., pushing a button) description of an *action* (e.g., music begins to play). When the event happens, the system moves to the next state. For example, pressing a Play button might cause a music player to change from STOPPED to PLAYING.



Start State



Final State

Using our newfound notation, explain to the students that we can represent the Fickle Fruit vendor using a FSA. Figure 1 shows the solution for Fickle Fruit.

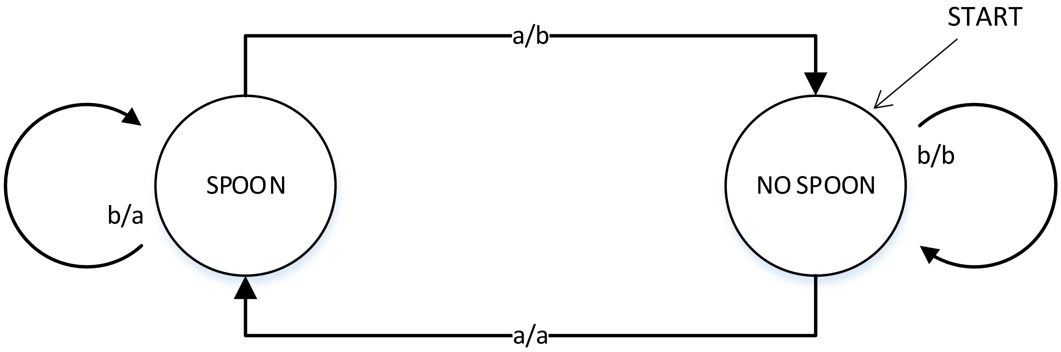


Figure 1: Fickle Fruit Vendor

The start state for this FSA is that the vendor has no spoon. There is no final state, as play continues until students have gathered 3 apples or time expires.

To engage students in drawing this FSA:

- Ask if the vendor initially is holding a spoon. Students should say no. So draw an arrow labeled START and a circle with NO SPOON.
- Ask the students what happens if a buyer asks for a banana. Students should read the Vendor Instructions and tell you the vendor gives the buyer a banana. The vendor does *not* pick up a spoon. So draw the line from NO SPOON back to NO SPOON and label it as b (asked for banana) / b (gave a banana). You can spell out the words if it makes it clearer for the students.
- Now ask the students what happens if a buyer asks for an apple. Students should tell you that the buyer gets an apple, and the vendor picks up the spoon. Draw SPOON as a state, with a line from NO SPOON to SPOON labeled a/a (or apple / apple).
- Complete the FSA by asking students what happens when the vendor is holding the spoon and the buyer asks for a banana or an apple (see Figure 1).

To reinforce the concept, you can now relate the concept of an FSA to a real life example. Ask if students have ever gone through a turnstile. What even unlocks the turnstile? [**answer**: inserting a coin] What event allows the user to pass through? [**answer**: pushing on the bar]

Draw the diagram (figure 2) on the board.

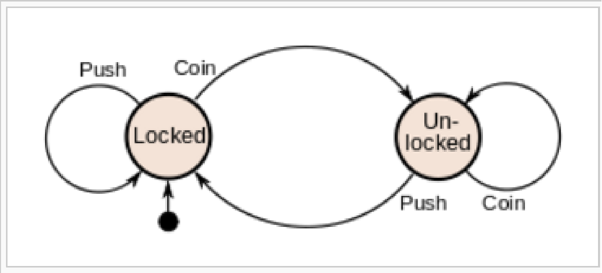


Figure 2: Turnstile FSA

Activity: Frustrating Fruit Vendor

Have students get back into their groups. Explain that they are starting a *new* exercise where the vendor will have a different pattern for selling apples and bananas. You may choose to have the same student as vendor, or select a different student within each group.

Collect the Fickle Fruit Instruction Card and distribute the Frustrating Fruit Instruction Card. Have the buyers again attempt to buy apples and bananas, but this time students should try to write the vendor's behavior as a FSA. You may ask the students to create the FSA independently, or the three buyers may work together to determine the pattern.

Ask the students whether it's possible to get 3 apples in a row [**answer**: it is not possible for this exercise].

Regroup as a class. Discuss the exercise and attempt to draw the FSA on the board, using student input. Figure 3 shows the complete FSA. You may want to leave the Fickle Fruit FSA on the board, so you can compare the two diagrams and understand why it's not possible to get 3 apples in a row [**answer**: the loop transition on the SPOON state gives a banana instead of an apple… so if the vendor is holding the spoon, the buyer will always receive a banana]

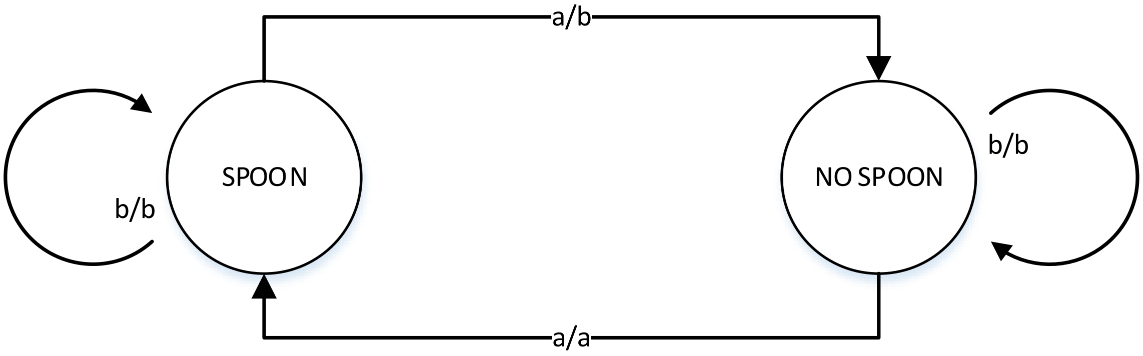


Figure 3: Frustrating Fruit FSA

Activity: Fancy Fruit (Optional Extension)

If you have enough time and the students are engaged in these exercises, you can do the Fancy Fruit activity.

Have students get back into their groups. Collect the instruction cards and pass out the Fancy Fruit card, as well as a fork. Have them repeat the buying/selling process, again trying to figure out the state diagram. This activity is a challenge and therefore should be used if time permits.

The FSA for Fancy Fruit is shown in figure 4.

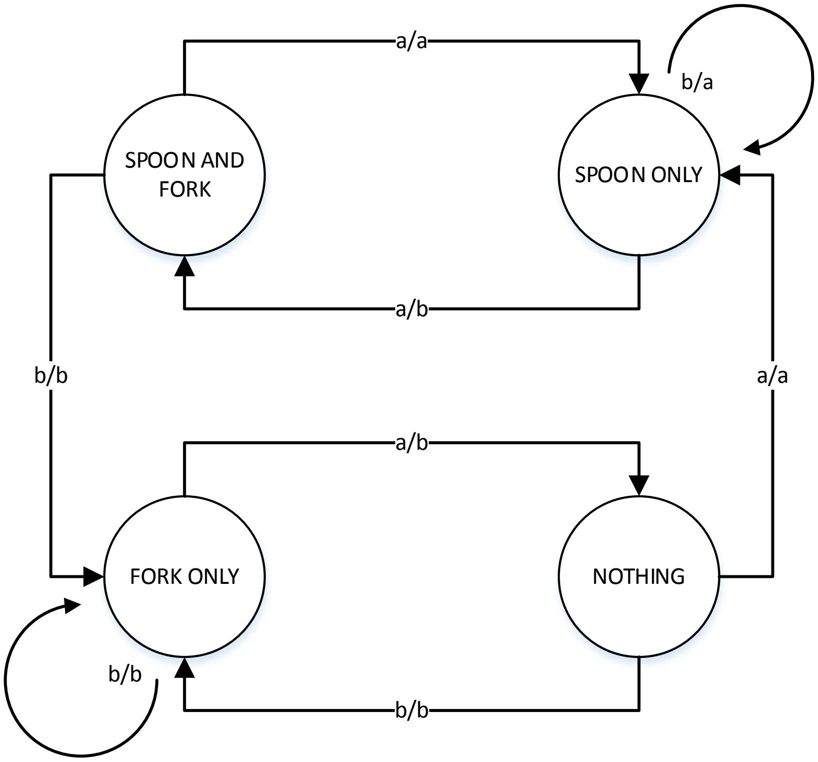


Figure 4: Fancy Fruit FSA

Optional: Notice that states "SPOON and FORK" and "NOTHING" have exactly the same transitions out of them. Namely, if you ask for a banana you are given a banana and you go to state "FORK ONLY", and if you ask for an apple you are given an apple and you go to state "SPOON ONLY". Since these two states are exactly the same, we can combine them into one called "(SPOON and FORK) or (NOTHING)". Then the diagram looks like figure 5.

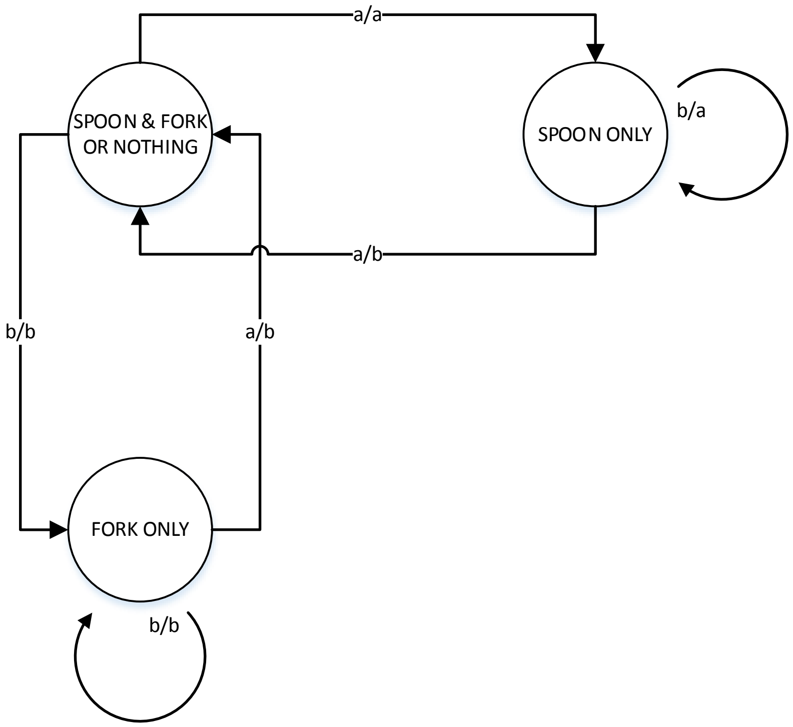


Figure 5: Alternate Fancy Fruit FSA

Activity - Worksheets

At this point, the students have seen finite state automata on the board, but have not had a chance to practice on their own. The next two worksheets should help solidify their understanding.

Robot Dog Worksheet

This worksheet will give students practice with recognize the outcomes of various FSA transitional combinations.

Chores Robot Worksheet

The purpose of this activity is to reinforce the understanding of the difference between states and transitions. This activity should also give students practice with constructing a finite state automata independently.

Solutions

Solutions for both worksheets are after the class discussion.

Class Discussion - What’s it all about?

Finite-state automata are used in Computer Science to help a computer process a sequence of characters or events.

Adult Examples. A simple example is when you dial up a telephone number and you get a message that says “Press 1 for this … Press 2 for that … Press 3 to talk to a human operator.” Your key presses are inputs for a finite state automaton at the other end of the phone. The dialogue can be quite simple, or very complex. Sometimes you are taken round in circles because there is a peculiar loop in the finite-state automaton. If this occurs, it is an error in the design of the system—and it can be extremely frustrating for the caller!

Another example is when you get cash from a bank cash machine. The program in the machine’s computer leads you through a sequence of events. Inside the program all the possible sequences are correspond to a finite-state automaton. Every key you press takes the automaton to another state. Some of the states have instructions for the computer on them, like “dispense $100 of cash” or “print a statement” or “eject the cash card”.

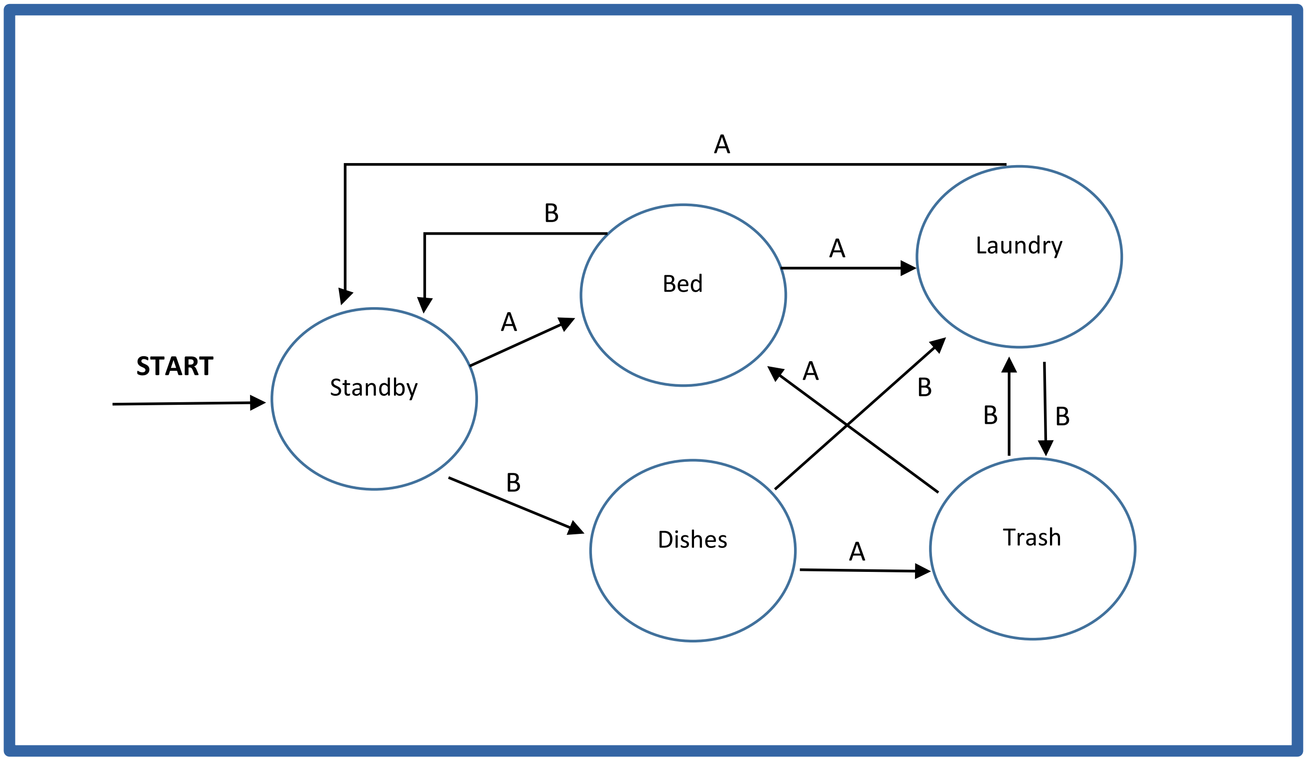
Student examples. Finite State Automata can also be applied to the concept of a vending machine. Possible transitions/actions are depositing a coin or pushing a button. States might be that more money is needed (while depositing coins) or that the item is dispensed.

A video game with a finite number of actions and levels serves as another example of a Finite State Automata. For example, in the game Mario, the character Mario can exist in multiple states. He can grow in size, shrink in size, and be able to fly or be able to throw fireballs. The various objects that Mario encounters serve as the transitions between his states. For example, if Mario eats a mushroom, he grows to large state. If Mario gets hit by an enemy who shrinks to his small state.

Chores Robot - SOLUTION

You have a robot with 2 buttons labeled A and B, if you hit these buttons it will do your chores. It can only do certain chores after it has already done other ones. Use the instructions bellow to create a FSA for your robot, remember to label all the *transitions (actions)* and **states**.

1. If your robot is on **Standby**, you can *press A* and it will **Make your bed**
2. If your robot is on **Standby**, you can *press B* and it will **do the dishes**
3. If your robot is **making your bed** you can, *press A* to get it to **do the laundry** or *press B* to make it return to **standby**
4. If your robot is **doing the dishes** you can *press A* to have it **take out the trash** or *press B* to make it **do the laundry.**
5. If your robot is **doing the laundry** *pressing A* will make it return to **standby**, and *pressing B* will have it **take out the trash**
6. If your robot is **taking out the trash**, *pressing A* will have it **make your bed**, *pressing B* will have it **do the laundry**



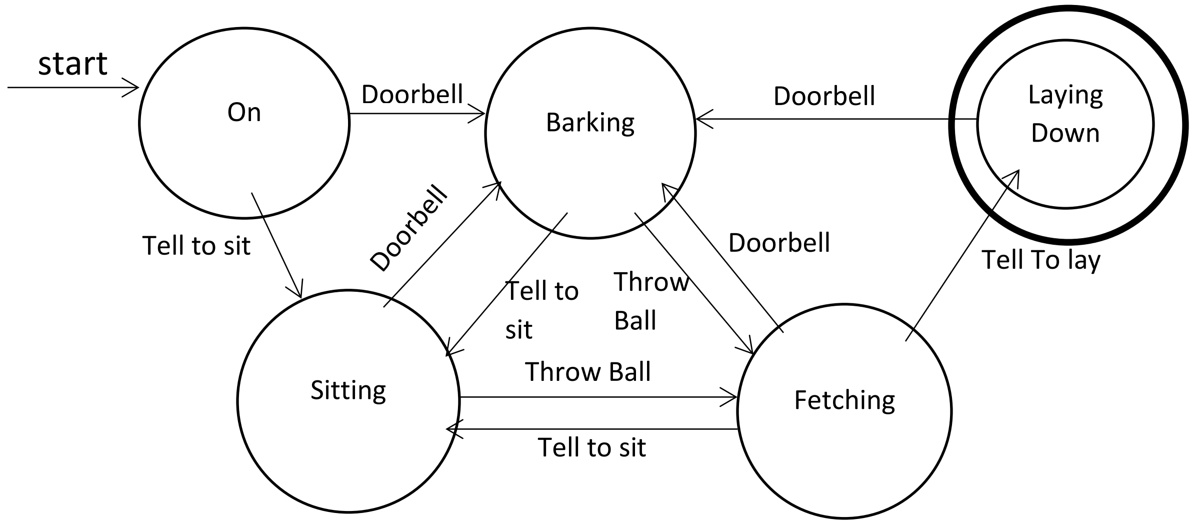
What sequence of button pushes will get your robot to do all of your chores, try to list 2 options.

1. A A A B A

A B B A B

2. B B B A **There are other possible solutions to this problem that are not listed.**

Worksheet: Robot Dog SOLUTION



1. Identify the following states

    a. Start State: <u>On</u>

    b. Stop State: <u>Laying Down</u>

2. Identify what the dog will be doing after each set of actions OR write **ERROR** if the set of actions is not valid.

    a. Doorbell, Tell to sit, Throw ball: **<u>Fetching</u>**

    b. Tell to sit, Doorbell, Tell to sit: **<u>Sitting</u>**

    c. Tell to sit, Throw ball, Tell to Lay: **<u>Lay Down</u>**

    d. Tell to sit, Throw Ball, Throw Ball: **<u>Error</u>**

    e. Doorbell, Tell to sit, Doorbell, Throw ball, Tell to sit: **<u>Sitting</u>**

3. Circle the paths from question 2 where the dog barks: **a, b, e**