

Simulations

Textbook

Simulations



Computer programs are particularly helpful for generating simulations. Simulations are helpful in many different fields. Perhaps you have seen or interacted with some simulations yourself? A [simulation](#) is an estimate of complex or random scenarios. Simulations are abstractions of more complex situations and can be very useful.

People training to become pilots often practice flying the plane in a simulated environment. Flying a plane has an infinite number of factors that can affect how the plane moves: airspeed, temperature, weight, weather, and even the positions of birds or stray balloons. Simulations allow pilots to practice responding to different scenarios in a safe space.

Medical researches have [simulations](#) to see a predicted effect a bacteria could have on a patient. These simulations allow them to work through different scenarios and practice different solutions. These are useful because they can see how different solutions work or don't work beforehand. Simulations are crucial when it comes to a high risk situation where decisions can greatly affect someone's health. Since the human body is infinitely complicated with its different systems, chemistry, biology, and interactions, it's challenging to account for every scenario that could possibly happen. But often the most likely scenarios can still be explored.

Engineers also leverage [simulations](#) in order to save a lot of time, effort, and money. Using computer programs to test out the effects of a design can help find problems before actually building it. Without simulations, engineers would have to completely construct a design and test it before finding out they need to change it. Simulations allow them to save a lot of effort beforehand.

Sports analysts also use simulations to estimate what will happen when certain teams beat other teams in a tournament.

Simulations allow us to recreate complex aspects of our world in a safe environment.

But if the real world is so complex, how do we represent it with computer programs? One approach is to use random.

Thought Question: In what ways are simulations helpful? Are there other fields that benefit from computer simulations? What are some limitations of simulations? What situations would a simulation be most helpful? Are there situations where a simulation wouldn't be adequate?

Thought Question: How might virtual reality affect simulations? In what scenarios might a virtual reality experience help improve the simulation? Are there scenarios that wouldn't benefit from virtual reality?

Bias in Simulations



When creating simulations, the researcher ends up choosing which aspects to keep and which to leave out. The real world has just too many variables to include them all, so we end up selecting the aspects of the simulation we are most interested in observing. In the bunny example, we chose to simplify the number of girl babies to exactly half. In the real world, that number varies. Depending on what the programmer is researching, they will simplify or remove certain details.

This simplification inevitably leads to [bias](#). Depending on the purpose of the simulation, certain elements can be included or left out that could possibly change the ways the simulation functions. Programmers need to be aware of this tendency and to do what they can to minimize the negative effects bias has in their simulations.

Simple Rabbit Simulator



Let's use what we've learned about random to build a simple [simulator](#). If you need a refresh on how to generate random numbers, refer to the random lesson.

This simulator will predict how many bunnies you will have after 4 generations of bunnies. Bunnies can have up to 10 babies at a time! Let's assume we start with 2 bunnies.

First, let's build our program to find a random number for the first batch of babies.

```
1 import random
2
3 babies = random.randint(0, 10)
4 print(babies)
```

Try it!

Let's make sure to add the mother and father to get the total number of bunnies.

```
1 import random
2
3 babies = random.randint(0, 10)
4
5 total = babies + 2
6 print(total)
```

Try it!

Notice how the total number of bunnies changes each time you hit "run"? That's because there's no way to know for sure how many babies your bunnies will have, so each time you hit "run", you are seeing a new possibility.

Now let's examine what happens when the bunnies babies start having babies. We need to account for the fact that only the females can have babies. For this example, let's assume that exactly half of the babies are female.

```
1 import random
2
3 babies = random.randint(0, 10)
4
5 females = round(babies / 2)
```

Try it!

Let's use round() to get a whole number to work with.

Now let's say that each of the female babies have their own babies. We don't know how many they will have, so let's assign a random value to their numbers.

```
1 import random
2
3 babies = random.randint(0, 10)
4
5 females = round(babies / 2)
6
7 grandbunnies = random.randint(0, 10)
8
9 totalgrandbunnies = grandbunnies * females
```

Try it!

This example also assumes that each female has the same number of babies. Let's leave it at that for now.

To get the grand total number of bunnies after just 2 generations we use this code.

```
1 import random
2
3 babies = random.randint(0, 10)
4
5 females = round(babies / 2)
6
7 grandbunnies = random.randint(0, 10)
8
9 totalgrandbunnies = grandbunnies * females
10
11 total = 2 + babies + totalgrandbunnies
12
13 print(total)
```


Try it!

The 2 is for the original bunnies. The variable named babies is for the first generation. The variable named totalgrandbunnies is for the second generation. Notice how each time you hit "run" you get a different total. This depends on the number of females the first two bunnies have and how many babies the females end up happening.

Further Opportunities in the Bunny Example



You might look at this example and see even more opportunities to make our [simulation](#) more accurate. For example, we assumed that exactly half of the first generation were girls, but in reality this could be any number.

Stretch Challenge: Can you adjust your code to account for a random number of females in the first batch of bunnies?

```
1 import random
2 babies = random.randint(0, 10)
3 print(babies)
4
5 females = random.randint(0, babies)
6 print(females)
```

Try it!

Another area that is more random is that each individual girl in the first generation can have a variable number of babies. Our example assumes they all have the same number.

Stretch Challenge: Can you adjust your code to account for a random number of grandbunnies for each girl in the first generation? You might consider using `random.sample()` to do this.

```

1 import random
2
3 babies = random.randint(0, 10)
4 print(babies)
5
6 females = random.randint(0,babies)
7 print(females)
8
9 totalgrandbunnies = 0
10 mylist = range(females)
11 for x in mylist:
12     grandbunnies = random.randint(0, 10)
13     x * grandbunnies
14     totalgrandbunnies = totalgrandbunnies + x
15
16 print(totalgrandbunnies)
17 total = 2 + babies + totalgrandbunnies
18 print(total)

```

Try it!

This example shows just how many areas can have a random number and how quickly a simulation can get complex. Building and maintaining quality simulations is a field of computer science with great possibilities, opportunities, and potential.

Simulations are most useful when real-world events are impractical for experiments (e.g., too big, too small, too fast, too slow, too expensive, or too dangerous).

Thought Question: Can you think of any situations where a simulation would be a better approach than doing something in the real world? Why would a simulation be better in those situations?

Analysis

When you design a program to simulate a natural phenomenon – like how water flows, how a population grows, or how a simple ecosystem changes – it's crucial to analyze and understand the algorithm that drives your simulation. Don't just focus on making the visual output look right; think deeply about *why* your algorithm produces those results. Consider how each step in your code represents a real-world process or rule of the natural phenomenon. By carefully analyzing the logic, variables, and calculations within your algorithm, you'll gain a deeper understanding of both your code and the natural system you are trying to model.

Summary

Many career fields benefit from the use of simulations because they allow us to examine information that is really fast, slow, complex, expensive, or dangerous.

Random numbers are used to represent the complex variety in the real world. [Simulations](#) are a form of abstraction. Simulations can contain [bias](#) derived from the choices of real-world elements that were included or excluded.

Summary

Many career fields benefit from the use of simulations because they allow us to examine information that is really fast, slow, complex, expensive, or dangerous.

Random numbers are used to represent the complex variety in the real world. [Simulations](#) are a form of abstraction. Simulations can contain [bias](#) derived from the choices of real-world elements that were included or excluded.

Questions (8)

1. What is a simulation?

MULTIPLE CHOICE

Choose the correct answer:

- A. Abstractions of more complex situation.
- B. An arithmetic concept.
- C. A graphic image.
- D. An iteration of a system.

2. True or False: Simulations are only used for computer science.

MULTIPLE CHOICE

Choose the correct answer:

- A. True
- B. False

3. In which situations are simulations particular useful? Situations that are... (select all that apply)

SELECT MULTIPLE

Select all that apply:

- A. If the real process is expensive.
- B. If the real process is really fast.
- C. If the real process is really slow.
- D. If the real process is really dangerous.

4. Simulations require certain aspects to be simplified or left out. This inevitably leads to what?

MULTIPLE CHOICE

Choose the correct answer:

- A. Bias
- B. Truth
- C. A simulation that cannot be useful
- D. Bugs

5. Which professions use simulations? Select all that apply.

SELECT MULTIPLE

Select all that apply:

- A. Medical professionals
- B. Engineers
- C. Sports analysts
- D. Pilots

6. What is one way that we represent complexity with computers?

MULTIPLE CHOICE

Choose the correct answer:

- A. Luck
- B. Random
- C. Libraries
- D. Sequencing

7. True or False: Medical professionals don't use simulations because the human body is too complex.

MULTIPLE CHOICE

Choose the correct answer:

- A. True
- B. False

8. True or False: Engineers use computer programs to test out the effects of a design before actually building it.

MULTIPLE CHOICE

Choose the correct answer:

- A. True
- B. False

Answer Keys & Solutions

Questions

1. What is a simulation?

MULTIPLE CHOICE

Correct Answer:

- A. Abstractions of more complex situation. ✓ Correct
- B. An arithmetic concept. ✗ Incorrect
- C. A graphic image. ✗ Incorrect
- D. An iteration of a system. ✗ Incorrect

Explanation:

Remember that simulations are representations of life situations.

2. True or False: Simulations are only used for computer science.

MULTIPLE CHOICE

Correct Answer:

- A. True ✗ Incorrect
- B. False ✓ Correct

Explanation:

Simulations are used to train pilots, conduct medical research, and generate sports predictions.

3. In which situations are simulations particular useful? Situations that are... (select all that apply)

SELECT MULTIPLE

Correct Answers:

- A. If the real process is expensive. ✓ Correct
- B. If the real process is really fast. ✓ Correct

C. If the real process is really slow.

✓ Correct

D. If the real process is really dangerous.

✓ Correct

Explanation:

Simulations are useful in many situations.

4. Simulations require certain aspects to be simplified or left out. This inevitably leads to what?

MULTIPLE CHOICE

Correct Answer:

A. Bias

✓ Correct

B. Truth

✗ Incorrect

C. A simulation that cannot be useful

✗ Incorrect

D. Bugs

✗ Incorrect

Explanation:

People with their own perspectives determine what gets left out.

5. Which professions use simulations? Select all that apply.

SELECT MULTIPLE

Correct Answers:

A. Medical professionals

✓ Correct

B. Engineers

✓ Correct

C. Sports analysts

✓ Correct

D. Pilots

✓ Correct

Explanation:

Many professions use simulations.

6. What is one way that we represent complexity with computers?

MULTIPLE CHOICE

Correct Answer:

- A. Luck ✗ Incorrect
- B. Random ✓ Correct
- C. Libraries ✗ Incorrect
- D. Sequencing ✗ Incorrect

Explanation:

Using random helps to simulate complex processes

7. True or False: Medical professionals don't use simulations because the human body is too complex.

MULTIPLE CHOICE

Correct Answer:

- A. True ✗ Incorrect
- B. False ✓ Correct

Explanation:

Medical professionals still find simulations helpful.

8. True or False: Engineers use computer programs to test out the effects of a design before actually building it.

MULTIPLE CHOICE

Correct Answer:

- A. True ✓ Correct
- B. False ✗ Incorrect

Explanation:

Engineers use simulations to check designs before building them.