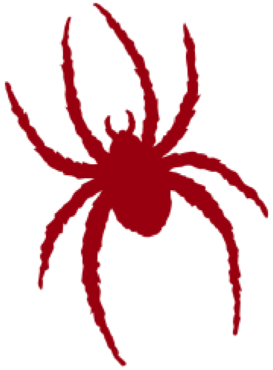
Welcome to CMSC 326!

CMSC 326 Simulation

Today

- Introductions
- Course logistics
- Motivation
- What is a Simulation?
- Environment setup
- In-class coding exercise



Introductions

Dr. David Balash

Faculty page: https://cs.richmond.edu/faculty/dbalash

Homepage: https://davidbalash.github.io

Professor Balash

"Ba-lish"

He/Him

- BS in computer engineering Iowa State
- Two-decade career as a software engineer
- MS and PhD in computer science from GW
- Research: Computer S&P

Dr. David Balash

Things I like

- Education/Learning
- Hiking
- Cycling
- Guitars
- Board games
- Programming
- Cats

Ask me anything

Assignment 1

Task: Create a personal introduction slide and post it to the introductions channel on the course Slack workspace

Due: Friday by 11:59 PM

Points: 5

Be Creative

Name

Photo

Pronunciation

Pronouns

Personal Introduction

Classroom Meet and Greet

1. Introduce yourself to a person near you

2. Introduce yourself to a different person near you

- Potential conversation topics:
  - What are some of the things that you like?
  - Who are your favorite pets?
  - Why do you want to take this class?

Student Introductions

- Name
- Pronouns (optional)
- Major
- Class year
- Favorite snack food

Course Logistics

Classroom Norms

- Questions are always welcome!!
  - Ask them at any time
- “I don’t know” is okay
- Be curious
- Treat peers and instructors with kindness and respect
- Communication is key!
- Seek support when needed

Where All Class Information Can Be Found

https://cmsc326-s25.github.io

How to Communicate With Me

- Slack workspace
  - https://cmsc326-s25.slack.com

- After class or in office hours - 223 Jepson Hall
  - Tue 4:30PM - 6:00PM
  - Thr 4:30PM - 6:00PM
  - and by appointment
- Email
  - david.balash@richmond.edu

Course Outline

- **Weeks 1-5** Introduction to C++ programming
  - Syntax, memory management, libraries, file IO
- **Weeks 6-10** Object-oriented programming
  - Abstraction, polymorphism, inheritance, encapsulation
- **Weeks 11-15** Software systems development
  - UML, design patterns, testing, debugging

Learning Outcomes

- Understand the key concepts of simulation, including discrete-event simulation, Monte Carlo simulation, and stochastic modeling
- Develop discrete-event simulations for systems involving queuing and inventory management
- Develop Monte Carlo simulations to estimate probabilities, model random processes
- Apply elementary statistics to analyze simulation outputs
- Write simulation programs using the Python programming language and libraries

Lecture

- Will usually include in-class module exercises
- In-class exercises will be due one or two weeks from when they are assigned (except during break)
- Regular attendance is expected
- Students who are sick should not attend class
- Notify me in advance of the absence, if possible

Labs

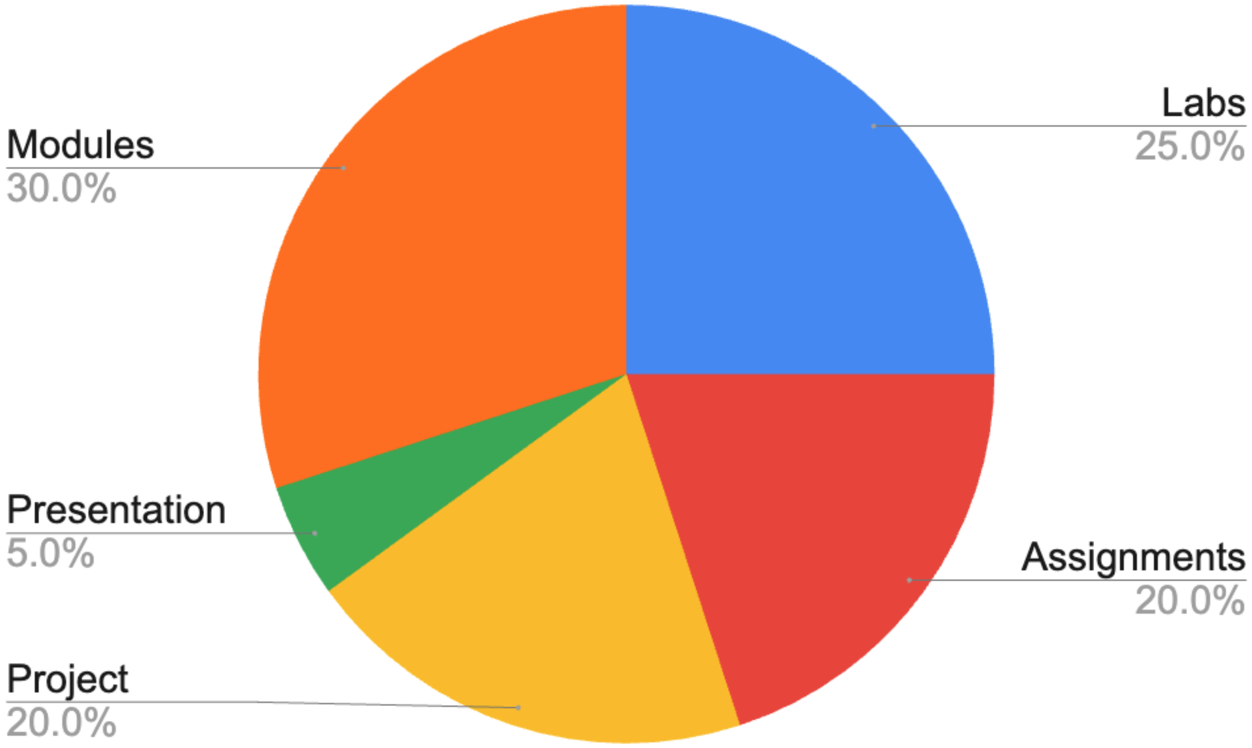
- Lab assignments done individually and in groups
  - but will always be turned in individually

- Lab assignments are typically due at 11:59 pm on the night prior to the next lab (except during break)

- Please ask for help when needed

Coursework and Grading

- Modules (In-class coding exercises)
- Lab assignments
- Programming project
- Project Presentation
- Programming Assignments



Textbook

- No textbook
- Reading materials may be assigned during the semester

Ask me a question

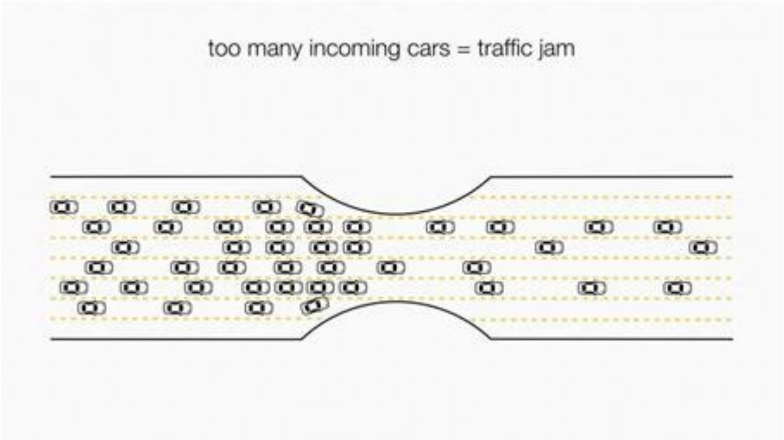
Motivation

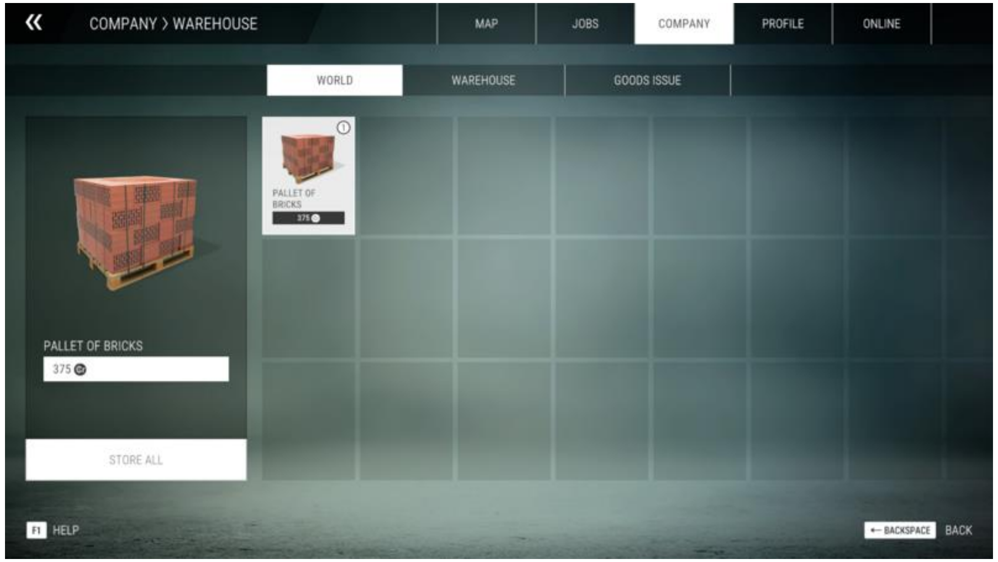
Why Take a Simulation Course?

What if you could predict the future… using code?

Why Take a Simulation Course?

What if you could predict the future… using code?





Simulations are Everywhere

- Predict customer wait times
- Simulate inventory needs for businesses
- Analyze sports strategies and improve performance
- Optimize traffic flows in cities
- Model disease spread and evaluate public health policies

Why Learn Simulation Techniques?

- Solve problems in fields like healthcare, logistics, finance, and engineering
- Analyze uncertainty and randomness in real-world systems
- Test scenarios and “what-ifs” without real-world risks or costs
- Develop skills in programming, statistics, and critical thinking

Cool Applications of Simulation

Cool Applications of Simulation

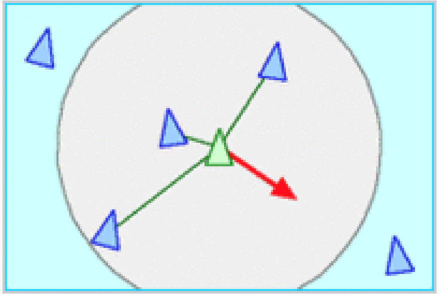
- **Boids** is an artificial life program, developed by Craig Reynolds in 1986, which simulates the flocking behavior of birds, and related group motion

- **separation**: steer to avoid crowding local flockmates

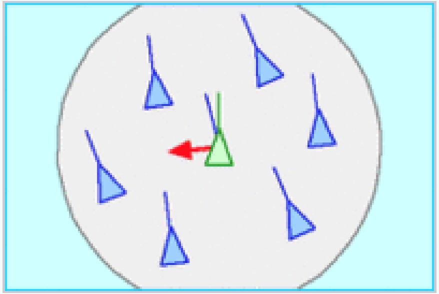
- **alignment**: steer towards the average heading of local flockmates

- **cohesion**: steer to move towards the average position (center of mass) of local flockmates

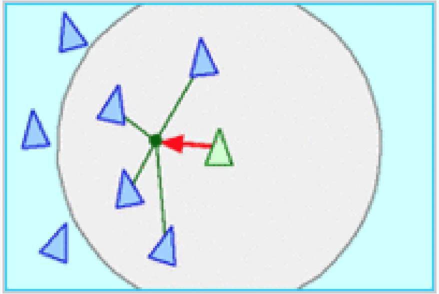
Rules applied in simple Boids



Separation

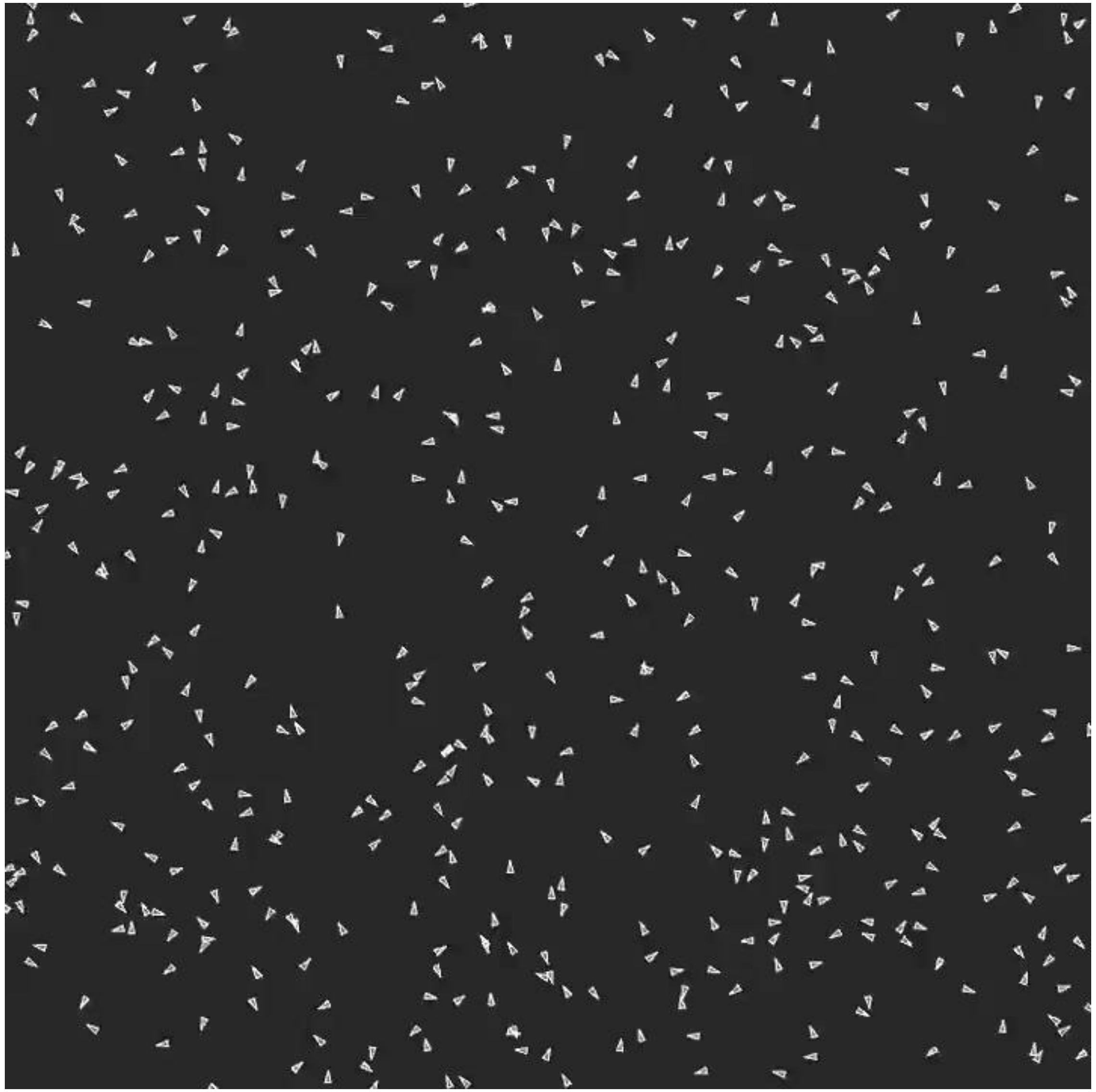


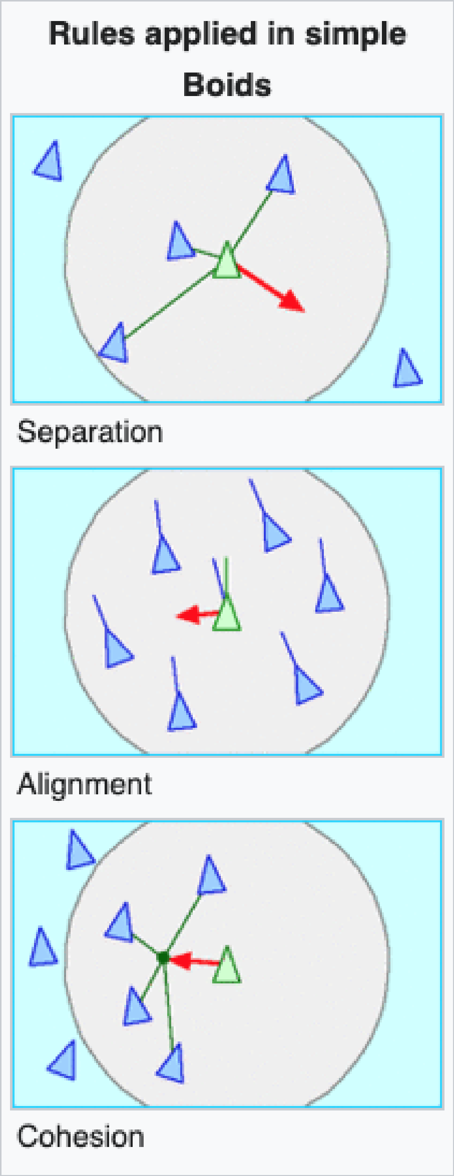
Alignment



Cohesion

Cool Applications of Simulation





Cool Applications of Simulation

- https://www.complexity-explorables.org/slides/berlin-8-am/
- https://www.complexity-explorables.org/slides/i-herd-you/
- https://www.complexity-explorables.org/slides/flockn-roll/

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What is a Simulation?

Simulation

A **simulation** is the imitation of the operation of a real-world system over time.

- It involves:
  - The generation of an artificial history of a system
  - The observation of the history to draw inferences on the characteristics of the system

Simulation Model

The behavior of a system (as it evolves over time) can be observed through a **simulation model**.

- Models help to investigate a variety of “what if” questions about real-world systems
  - What would be the impact of changes on system performance?

- Many real-world systems are so complex
  - Can be solved with computer-based simulation models

System

A **system** is a group of **objects** that are joined together in regular interaction to accomplish a **purpose**.

- For example:
  - **System**: Automobile manufacturing system
  - **Objects**: Machines, component parts, workers
  - **Purpose**: Production of vehicles

Components of a System

The following are the components of a system (Example: Bank System)

- **Entity**: Objects of interest in the system
  - Clients
- **Attribute**: Properties of an entity
  - Balance in a client's savings account
  - Credit rating
  - Account number
- **Activity**: A time period of specified length
  - Making deposits
  - Withdrawing cash

Components of a System

The following are the components of a system
(Example: Bank System)

- **State Variable**: Collection of variables necessary to describe the system at any time
  - Number of busy tellers
- **Event**: An instantaneous occurrence that might change the state of the system
  - Arrival of a client
  - Service completion of a client

Components of a System

Example: Rapid Rail System

- **Entities**: Riders
- **Attributes**: Origin, destination
- **Activities**: Traveling
- **State Variables**: Number of riders at each station, number of riders in transit
- **Events**: Arrival at a station, arrival at a destination

Components of a System

Example: Global Inventory System

- **Entities**: Warehouses
- **Attributes**: Capacity
- **Activities**: Withdrawing
- **State Variables**: Level of inventory, backlogged demand, rejected demand
- **Events**: Demand

Discrete and Continuous Systems

A system is **discrete** if the state variables are changing at a discrete set of time points

- bank, multi-level car park, board game, assembly line

A system is **continuous** if the state variables are changing at a continuous set of time points

- water dam, chemical reaction, ball rolling down a hill

The Need For a Model

We can study a system through direct experimentation on the system itself. However, this is often not an option:

- system might not exist yet
- it may be impractical to experiment with the system

Most studies require a model of the system.

Definition of Model

A **model** is a representation of a system for the purpose of studying the system.

- should consider only the aspects of the real system that affect the problem under investigation
- should be sufficiently detailed to permit valid conclusions

A model of the system has the same components as the real system (entities, attributes, etc.), **but only the ones that are relevant to the problem**

Types of Models

- A **physical model** is a larger or smaller version of a system
- A **mathematical model** uses symbolic notation and mathematical equations and inequalities to represent a system
    - A **simulation model** is a particular type of mathematical model of a system (usually in software)

Types of Simulation Models

- Static vs. Dynamic
  - **Static simulation models** represent systems at a particular point of time
    - the total newspapers sold at the end of a specific day
  - **Dynamic simulation models** represent systems as they change over time
    - the progress of newspaper sales between 9:00 AM and 4:00 PM

Types of Simulation Models

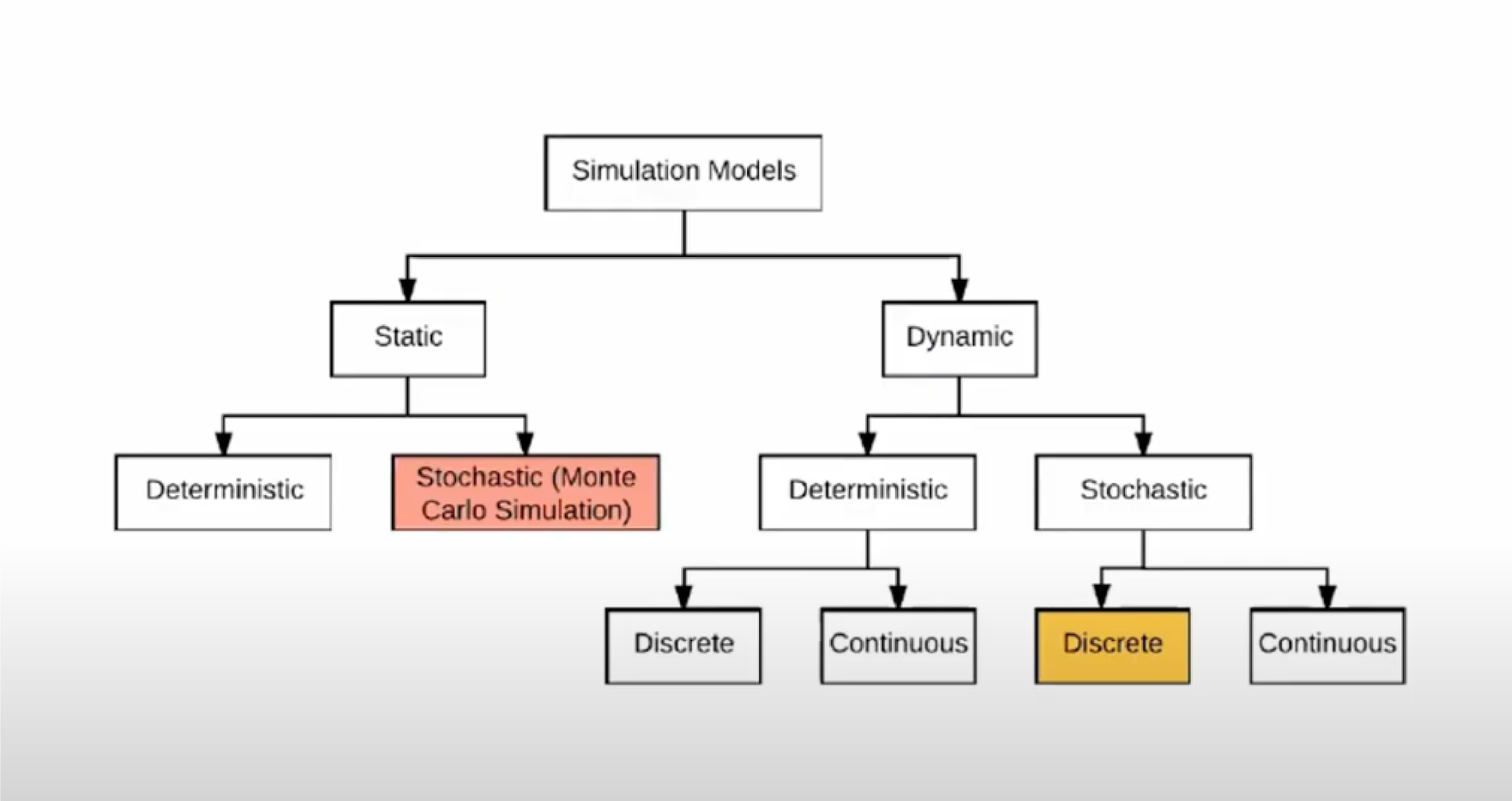
- Deterministic vs. Stochastic
  - **Deterministic simulation models** have known inputs (variables)
    - the arrivals which are based on scheduled appointment times are deterministic
  - **Stochastic simulation models** have random (probabilistic) inputs (variables)
    - random arrival and service times are stochastic

- If there is, at least, one random input in the model, then the model is stochastic

Types of Simulation Models

- Discrete vs. Continuous
  - Just like the systems are discrete or continuous, the models are either discrete or continuous
  - If there is, at least, one state variable that changes at a continuous set of time points, then the model is continuous

Types of Simulation Models



Environment Setup

In-Class Coding Exercise