VANDERBILT UNIVERSITY

INSTITUTE FOR SOFTWARE INTEGRATED SYSTEMS

C^{2}STEM: Collaborative, Computational Modeling for STEM Learning

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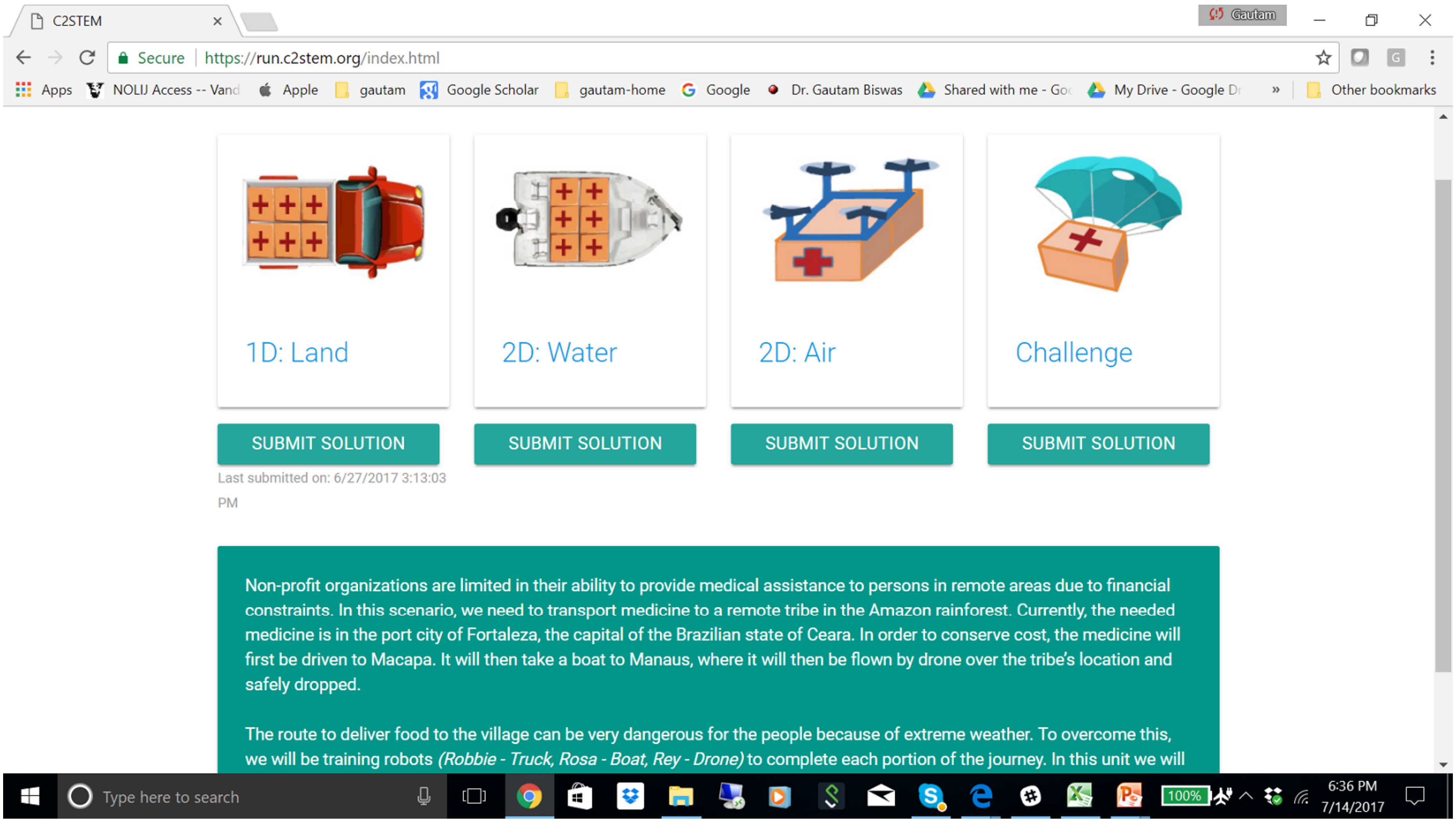
C²STEM System

- Synergistic Learning of Physics and Computational Modeling



What is the C^2STEM environment ?

- Based on NetsBlox (you worked in this environment earlier)
- Provides custom physics blocks to support your Physics-based modeling tasks
  - What is a custom Physics block?
- Modeling tasks are contextualized
  - i.e., you will apply your physics and computing knowledge to model real world scenarios

C^2STEM: Synergistic Learning

- How do we achieve synergistic learning?
  - Make the model building language match physics concepts and principles
  - Adopt computational practices that facilitate and support programming

Idea 2: Object-oriented modeling

- What is an 'object'?
  - Independent entity: existence and has behaviors
  - Operates in an environment
  - Behaviors and its existence defined by properties





Object-Oriented Programming

- Define objects – name
  - Properties
  - Behaviors (which are function of their properties and the environment)

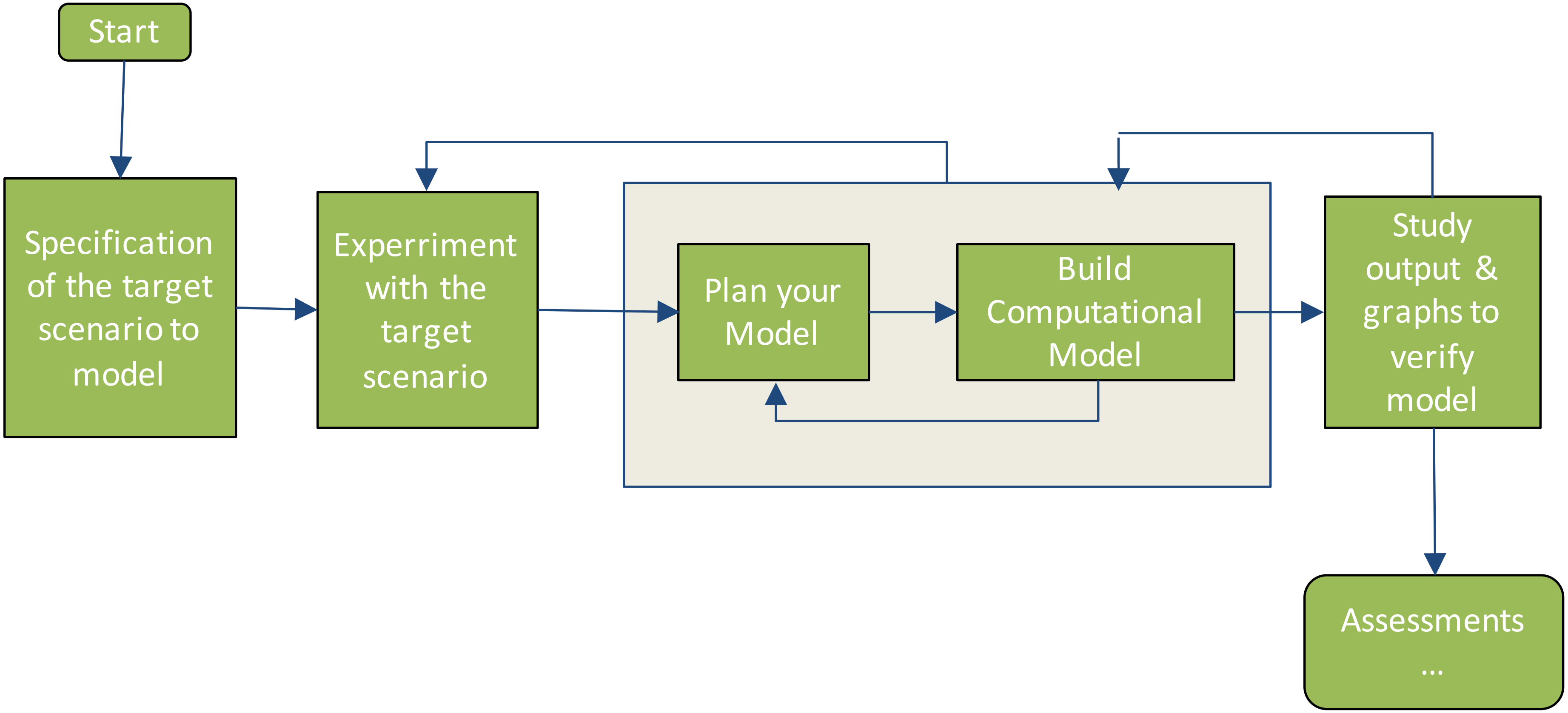
What are advantages of the object representation?

- Abstraction
  - Can only choose properties and behaviors of interest
- Can derive behavior of a system
  - In terms of the behavior of individual objects

Modeling and Simulation in C^{2}STEM

run.c2stem.org

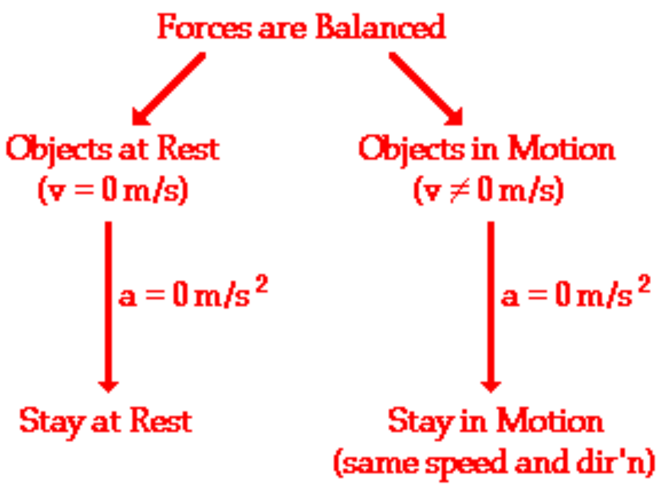
The learning-by-modeling progression

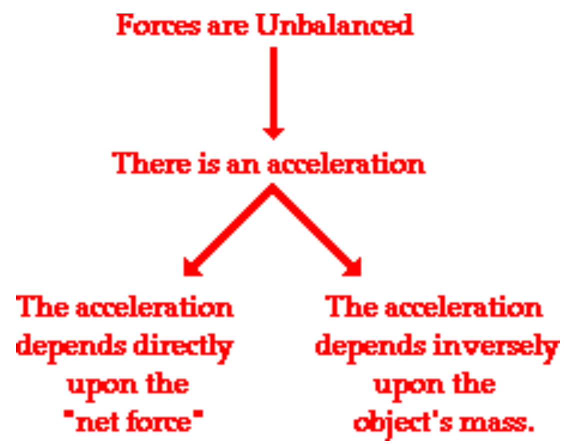


Studying Motion in Physics
Newton's Three Laws

- First law
  - An object at rest stays at rest and an object in motion stays in motion with the same speed and in the same direction unless acted upon by an unbalanced force.
- Second law
  - Newton's second law of motion pertains to the behavior of objects for which all existing forces are not balanced. The second law states that the acceleration of an object is dependent upon two variables - the net force acting upon the object and the mass of the object.
- Third law
  - For every action, there is an equal and opposite reaction.

Interpreting Newton's First and Second Laws





- Figure 1 (First law): no unbalanced forces on object, i.e., acceleration, $a = 0$

  then velocity of object, v remains unchanged
- Figure 2 (Second law): unbalanced force on object, then $a \neq 0$

A Mathematical Representation

$$a = 0 \ \ then \ \ v = constant$$

$$a = \frac{dv}{dt}; \ \ acceleration \ is \ the \ rate \ of \ change \ in \ velocity \ (speed)$$

$$v = \frac{ds}{dt}; \ \ velocity \ (speed) \ is \ the \ rate \ of \ change \ in \ distance \ traveled$$

$$where \ t \ is \ time$$

$$if \ \ v = 0 \ \ then \ object \ is \ at \ rest$$

Kinematics

- Deals with the motion of bodies, often abstracted to points
- Doesn't consider the cause for the motion (e.g., force)
- Equations of motion

$$u : initial\ \ speed\ of\ a\ body\ at\ t = 0;$$

$$a : acceleration$$

$$speed\ \ of\ body\ after\ time\ t,$$

$$v = u + a \times t$$

$$s : distance\ traveled\ by\ body\ in\ time\ \ t$$

$$s = u.t + \frac{1}{2} a \times t^2$$

Expanding the Mathematical Relations

$$a = \frac{dv}{dt} \approx \frac{v(t_2) - v(t_1)}{t_2 - t_1}$$

$$Suppose\ \ t_2 = t_1 + \Delta t$$

$$a = \frac{v(t_1 + \Delta t) - v(t_1)}{\Delta t}$$

$$v(t_1 + \Delta t) = v(t_1) + a \times \Delta t$$

If acceleration, a ≠ 0 then velocity, v changes over time

$$v = \frac{ds}{dt} \approx \frac{s(t_2) - s(t_1)}{t_2 - t_1}$$

$$Suppose\ \ t_2 = t_1 + \Delta t$$

$$v = \frac{s(t_1 + \Delta t) - s(t_1)}{\Delta t}$$

$$s(t_1 + \Delta t) = s(t_1) + v \times \Delta t$$

If velocity, v ≠ 0 then distance, s changes over time

Building simulation models

- Distance moved by body traveling at speed, *u* in time Δt : $d = v.\, \Delta t$
  - What about multiple Δt's?
    - ***Initial Step:*** $d_0 = d$
    - ***Iterative Step:*** $d_1 = d_0 + v.\Delta t$; $d_2 = = d_1 + v.\Delta t$
  - What if object has a constant acceleration, ***a*** ?
  - ***Initial step:*** $d_0 = d; v_0 = v$
  - ***Next Step:*** $v_1 = v_0 + a.\Delta t$; $d_1 = d_0 + v_1.\Delta t$
  - ***& next:*** $v_2 = v_1 + a.\Delta t$; $d_2 = d_1 + v_2.\Delta t$

- To save repeated writing of equations, we create a simulation step

Exercise 1:
Build Computational Models

- Make a turtle agent walk at constant speed to make a regular shape
- Make a turtle agent walk at an increasing speed defined by a constant acceleration to make the same kind of shape
  - What form will this shape take?
- Make a turtle agent walk at a decreasing speed defined by a constant acceleration to make the same kind of shape
  - What form will this shape take?

Building Object movement models

- Make a vehicle travel on a road with constant speed
- Use $d_{i+1} = d_i + v.\Delta t$
- *Repeat*

- Make vehicle travel on road with constant acceleration
  - *Update speed:* $v_{i+1} = v_i + a.\Delta t$;
  - *Update distance traveled:* $d_{i+1} = d_i + v_{i+1}.\Delta t$
  - *Repeat*

Learning activity progression
1-D Motion

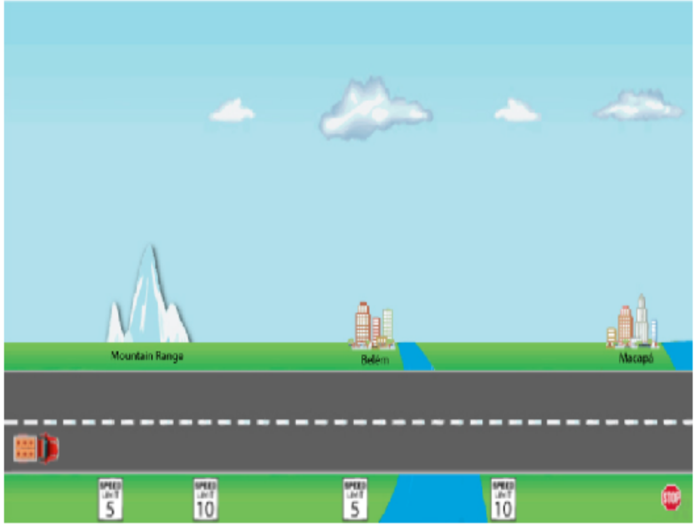
- Instructional Task - Develop Simple Motion Simulation
- Instructional Task - 1D Velocity: Elaborate Your Simulation
- Instructional Task - 1D Velocity: Model Planning
- Check-In #1
- Model Building - 1D Velocity: Simulate the Motion of a Truck
- Check-In #2
- Instructional Task - 1D Acceleration: Changing Velocity
- Check-In #3
- Model Building -1D Acceleration: Make Your Truck Stop
- Challenge Problem: Deliver the Medicine to the River!

The Challenge

Time to complete the first part of our journey (green) in Brazil. The truck should begin at rest on the road at the far left side of the stage. Given the map and the environment speed limits, program the medical truck to start at an initial location and accurately arrive at the final destination along the Amazon river.

Hints:

- - Don't forget your Resources section!
- - Planning is key - refer back to your model planning tools to help organize your code.



Let’s get started

- Work on your own
- But, feel free to discuss with one another
- We are here to guide, help, & answer your questions