System Dynamics in TerraME

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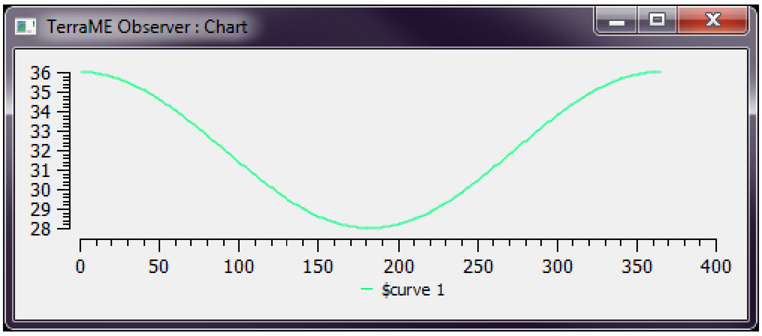
QUESTION 1) Using the TerraME modeling platform, implement a function **simulateSeasonalTemperature(time, amplitude, peridiocity, translationY, translationX)** that returns the temperature for a day of the year considering that the variation of temperature is a seasonal process. Like it occurs Brazil, the function should consider that the first and last trimester of the year are warm and that the second and third trimester are cold. It should also consider that the warm period has its climax on the day 0 (1st January) and that the cold period has its climax on day 182.5 (middle of June). See below the shape of temperature variation curve along one year:



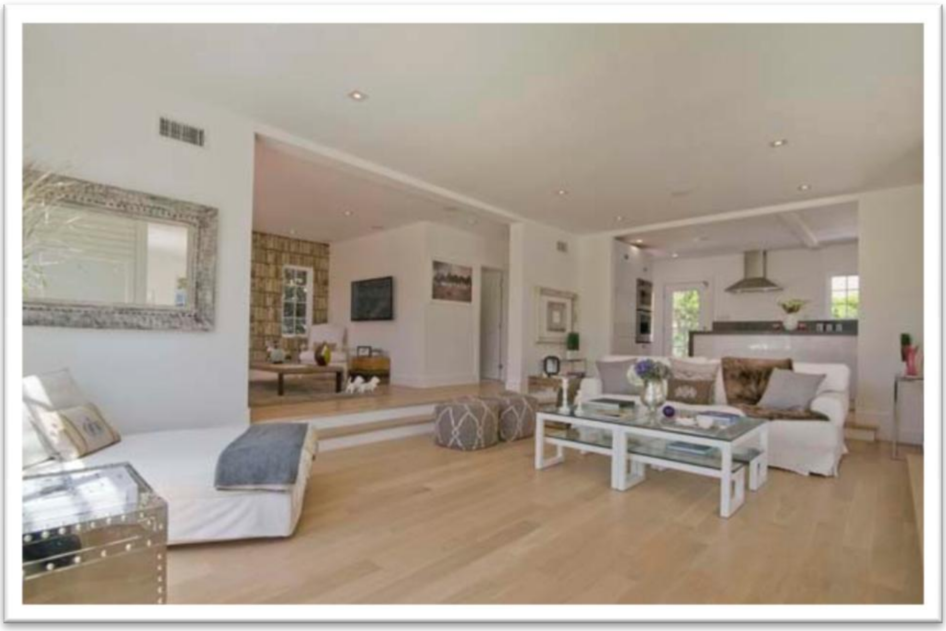
This code has been used the generate the above Figure:

```
for t = 1, 365 do -- try 730
   simulateSeasonalTemperature( t, 8, 365, 32, math.pi/2);
end
```

See below the expected returning value **simulateSeasonalTemperature**( ) for different sets of parameter:

```
print( simulateSeasonalTemperature( 0,          2, 1, 0, 0 ) )            -- 0
print( simulateSeasonalTemperature( 1/4,        2, 1, 0, 0 ) )            -- 1
print( simulateSeasonalTemperature( 1/12,       2, 1, 0, 0 ) )            -- 0.5
print( simulateSeasonalTemperature( 0,          4, 1, 0, 0 ) )            -- 0
print( simulateSeasonalTemperature( 1/4,        4, 1, 0, 0 ) )            -- 2
print( simulateSeasonalTemperature( 1/12,       4, 1, 0, 0 ) )            -- 1
print( simulateSeasonalTemperature( 0,          2, 2, 0, 0 ) )            -- 0
print( simulateSeasonalTemperature( 1/2,        2, 2, 0, 0 ) )            -- 1
print( simulateSeasonalTemperature( 1/6,        2, 2, 0, 0 ) )            -- 0.5
print( simulateSeasonalTemperature( 365/4,      8, 365, 32, 0) )          -- 36
print( simulateSeasonalTemperature( 365*1.75,   8, 365, 32, 0) )          -- 28
print( simulateSeasonalTemperature( 0,          8, 365, 32, math.pi/2) )  -- 36
```

QUESTION 2) Imagine a single-room house with an American-kitchen as illustrated below. The initial room temperature is 20 °C. Is cold outside and the room loses heat at a rate of 10% per minute. What will be the room temperature after 10 minutes? Implement a model to simulate this system. (**Solution**: 6.973568802 °C)



QUESTION 3) Imagine that to prepare the lunch the house holder kept the oven at 300 °C during one hour. Before this the room temperatures was 20 °C. However, the oven loses 5% of its internal heat to the room. Knowing that is cold outside and that the room loses heat at a rate of 10% per minute, determine:

- What are the temperatures of the room and oven at the instant immediately before the lunch? (**Solution**: time = 60 min, room = 149.76638866101°C, oven = 300 °C)
- What are the temperatures of the room and oven 10 minutes later? (**Solution**: time = 70 min, room = 127.23786051925°C, oven = 179.62108177151 °C)
- Implement a model to simulate this system.

QUESTION 4) In a more realistic model, the exchange of heat between the room and the environment should depend on the discrepancy of the temperature values. Let's say that if the environment is at 38°C and the room is at 20°C them the exchange of heat will be proportional to 18°C. Imagine that the initial room temperature is 20°C and that the room's walls exchange heat at a rate of 10% per minute. Implement a model in which you can vary the external temperature and calculate the room temperature after 10 minutes and 1 hour. What would be the room temperature if the external environment is at:

- (1) 20°C? (**Solution**: 10 min = 20°C, 60 min = 20°C)
- (2) 38°C? (**Solution**: 10 min = 31.7237880782°C, 60 min = 37.967652814602°C)
- (3) 5°C? (**Solution**: 10 min = 10.2301766015°C, 60 min = 5.0269551544987°C)

QUESTION 5) Imagine a very simple home heating system, whenever the room temperature falls below the thermostat setting, the thermostat detects a discrepancy and sends a signal that turns on the heat flow from the furnace, warming the room. The thermostat is a continuous system that sends a signal proportional to the perceived discrepancy. When the room temperature rises again, reaching the thermostat setting, the thermostat turns off the heat flow. At this point, the room starts to lose heat to the external environment in a fix rate equal to 10%. Suppose that the initial room temperature is 20°C, that the thermostat is set to 30°C, and that furnace has a fix temperature equal to 100°C. For your convenience, I would like to let you know that the model outcome for the first 5 iterations must be:

Time	**0**	**0.03125**	**0.0625**	**0.09375**	**0.125**
RoomTemp	**20**	**20.97916**	**21.85327**	**22.63360**	**23.33020**

- Using TerraME, model this heating system and answer the questions:

(a) Set the thermostat to different values { 5, 25, 50, 100, 1000} °C, run the model for each value, and show the room temperature dynamics along 1 hour.

(b) Now, suppose you have bought a cheaper furnace with fix temperature equal to 30°C. Set the thermostat to the same values { 5, 25, 50, 100, 1000} °C, run the model for each value, and show the room temperature dynamics along 1 hour.

(c) What can be conclude?

- Using the furnace of 30°C and the thermostat set to 50°C, run the model to different rates of heat loss 0%, 20%, 50% and 100%:

(d) Show the room temperature dynamics for each situation along 1 hour.

(e) What can be concluded?

QUESTION 6) Now, imagine a house heating system a little bit more realistic, in which a new feedback get in context, that is, the exchange of heat with the external environment is proportional to the discrepancy between the room temperature and the outside temperature. Consider the heat transfer coefficient of room walls equal to 10%. Consider the initial room temperature equal to 20°C, the thermostat is set to 30°C, and that furnace has a fix temperature equal to 30°C. The external environment temperature is constant and equal to 17°C. For your convenience, I would like to let you know that the model outcome for the first 5 iterations must be:

Time	**0**	**0.03125**	**0.0625**	**0.09375**	**0.125**
RoomTemp	**20**	**20.30315**	**20.59583**	**20.87847**	**21.15140**

- Using TerraME, model this new heating system and answer the questions:

(a) Set the external temperature to different values { 0, 17, 42} °C, run the model for each value and show the room temperature steady state values.

(b) What can be concluded about the model and the system?

- Using TerraME, model this new heating system and answer the questions:

  (c) Set the external temperature to 17°C and set the heat exchange rate with the external environment (isolation coefficient) to different values {0, 0.5, 1}, run the model for each value, and show the room temperature steady state values.

  (b) What can be concluded about the model and the system?

QUESTION 7) Imagine a house heating system much more realistic, in which the loss of heat additionally depends on the external environment temperature dynamics that is cyclical and performs an warm and a cold period at each 15 minutes, varying from 13°C to 20°C. Use the function developed in Question 1 to simulate this dynamics: **simulateSeasonalTemperature(t, 7, 15, 16.5, 0).** Consider the heat transfer coefficient of room walls equal to 10%. Consider the initial room temperature equal to 20°C, the thermostat is set to 30°C, and that furnace has a fix temperature equal to 30°C. For your convenience, I would like to let you know that the model outcome for the first 5 iterations must be:

Time	**0**	**0.03125**	**0.0625**	**0.09375**	**0.125**
RoomTemp	**20**	**20.30156**	**20.59290**	**20.87436**	**21.14630**

- Implement and run the new model in TerraME.

- Using 3 different chart observers, present 1 hour variation of the variables: (a) instantaneous heat exchange, (b) room temperature and (c) external environment temperature.

- Using 3 different chart observers, present 1 hour variation of the variables: (a) room temperature and (b) external environment temperature.