אוניברסיטת תל-אביב
TEL AVIV UNIVERSITY

# Hybrid Models in Developing System Thinking

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# Outline

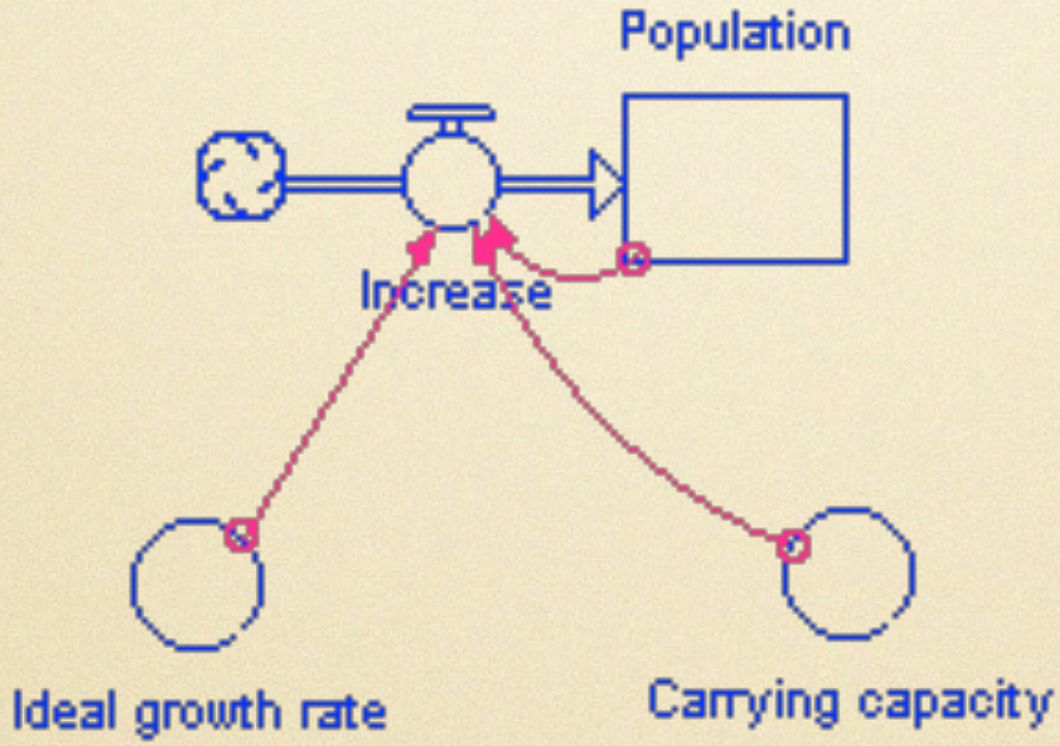
- Hybrid models
- Study
- Results
- Discussion

# Hybrid Models

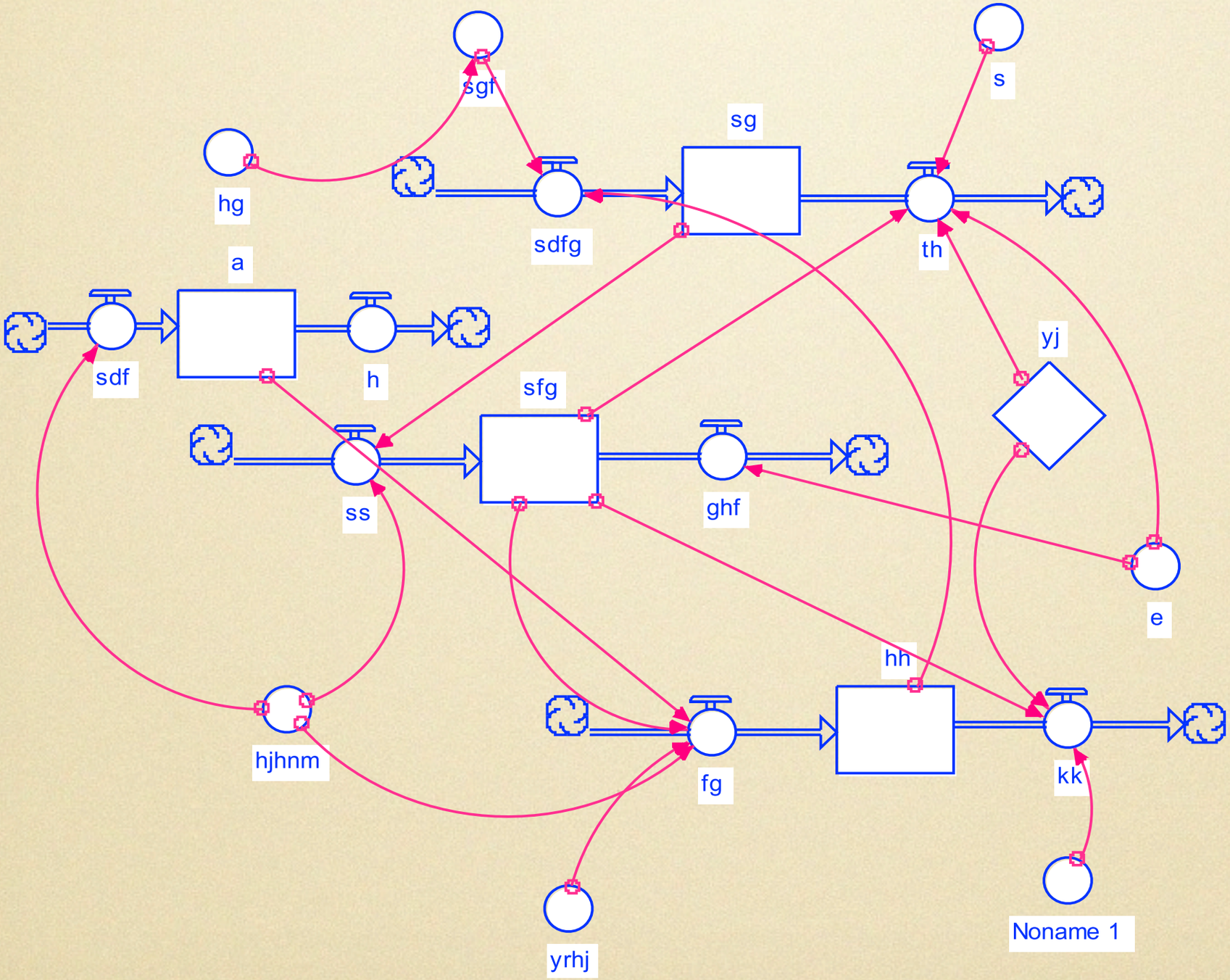
- Stock Flow Models
- The Spaghetti problem
- Control vs. Process
- Digital vs. Continuous
- Examples

# Stock Flow Models

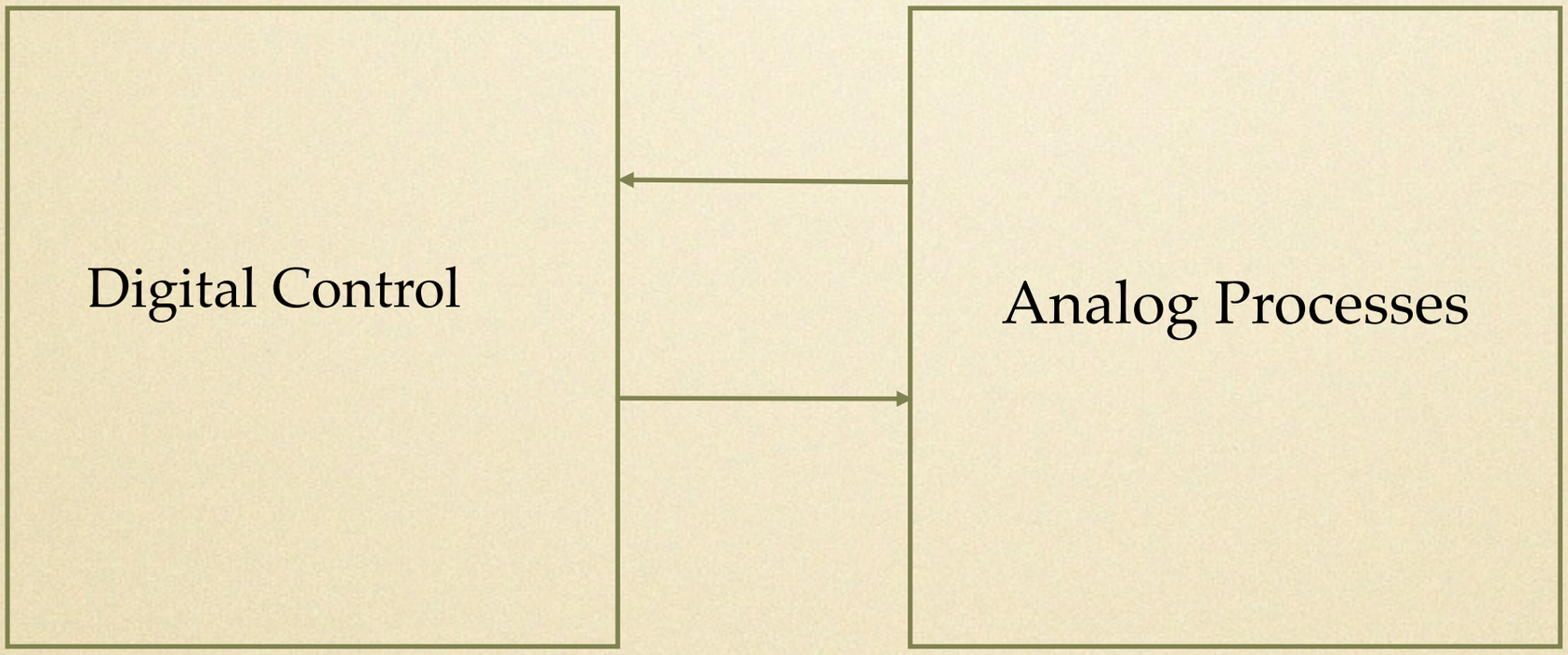
The Continuous Paradigm



# The Spaghetti problem

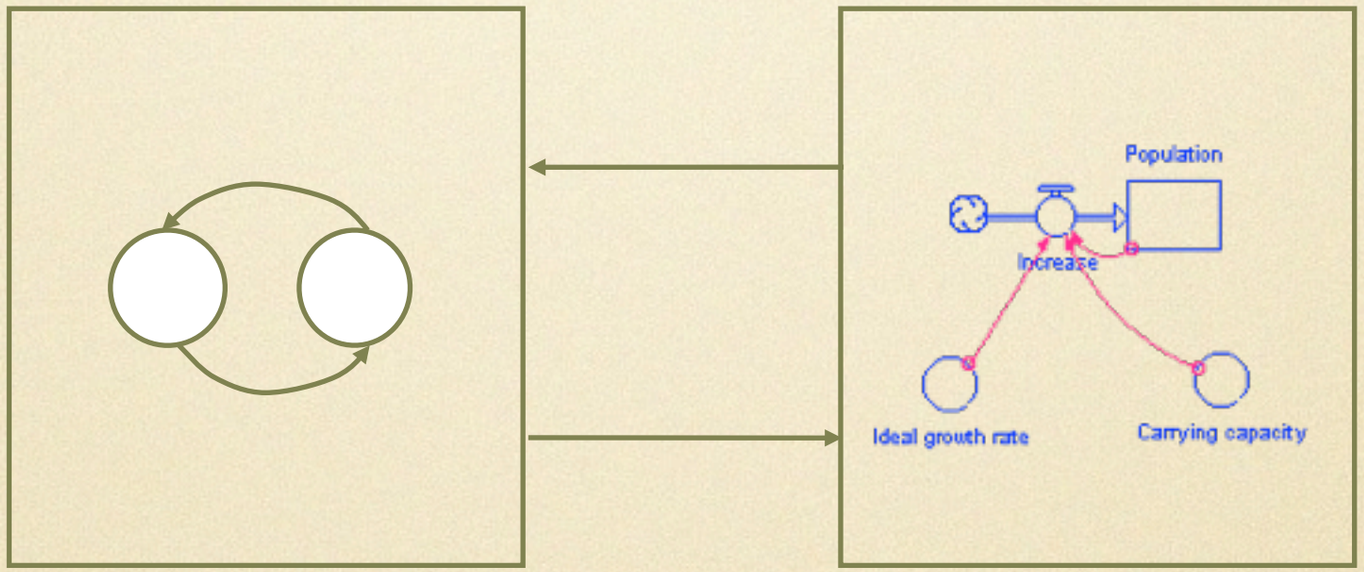


# Control vs. Process



# Digital vs. Analog

Basic hybrid structure




State diagram

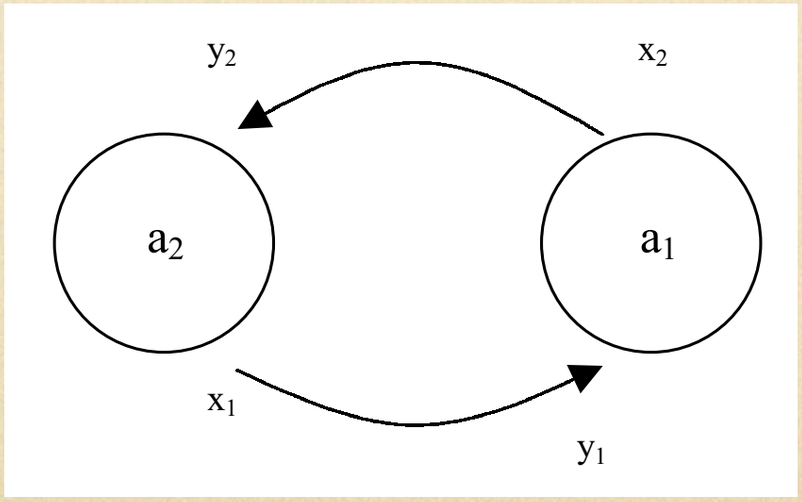
Stock-Flow

# Digital vs. Analog

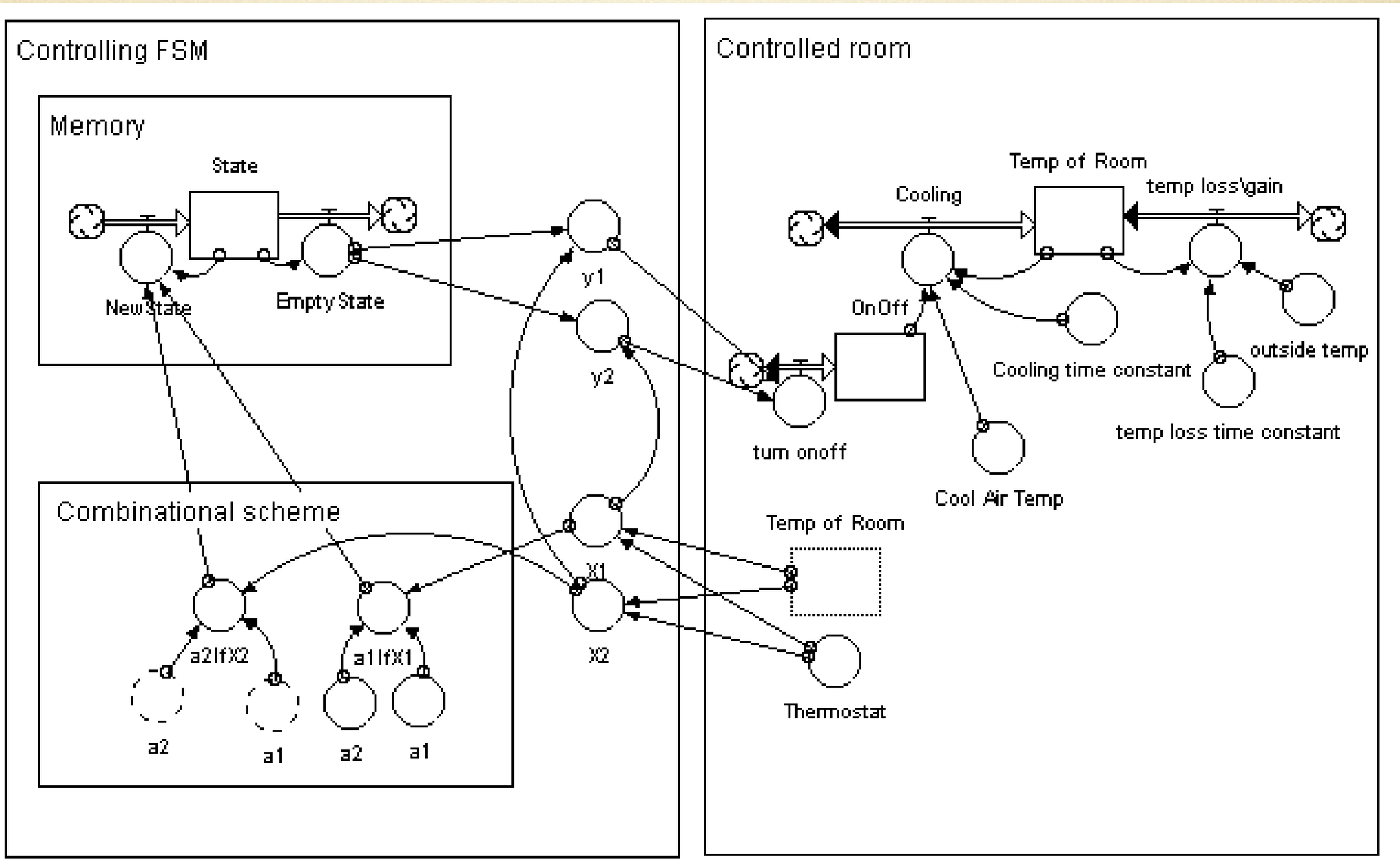
| | *Digital* | *Analog* |
|---|---|---|
| *Mathematical model* | Finite state machine | Differential/difference equations |
| *Behavior* | State transition according to input and transition rules | Change as a derivative/integral function |
| *Graphical Model* | State diagram | Stock-Flow diagram |
| *Type of control* | Event driven control | Local feedback loops |

# Example: Clime control

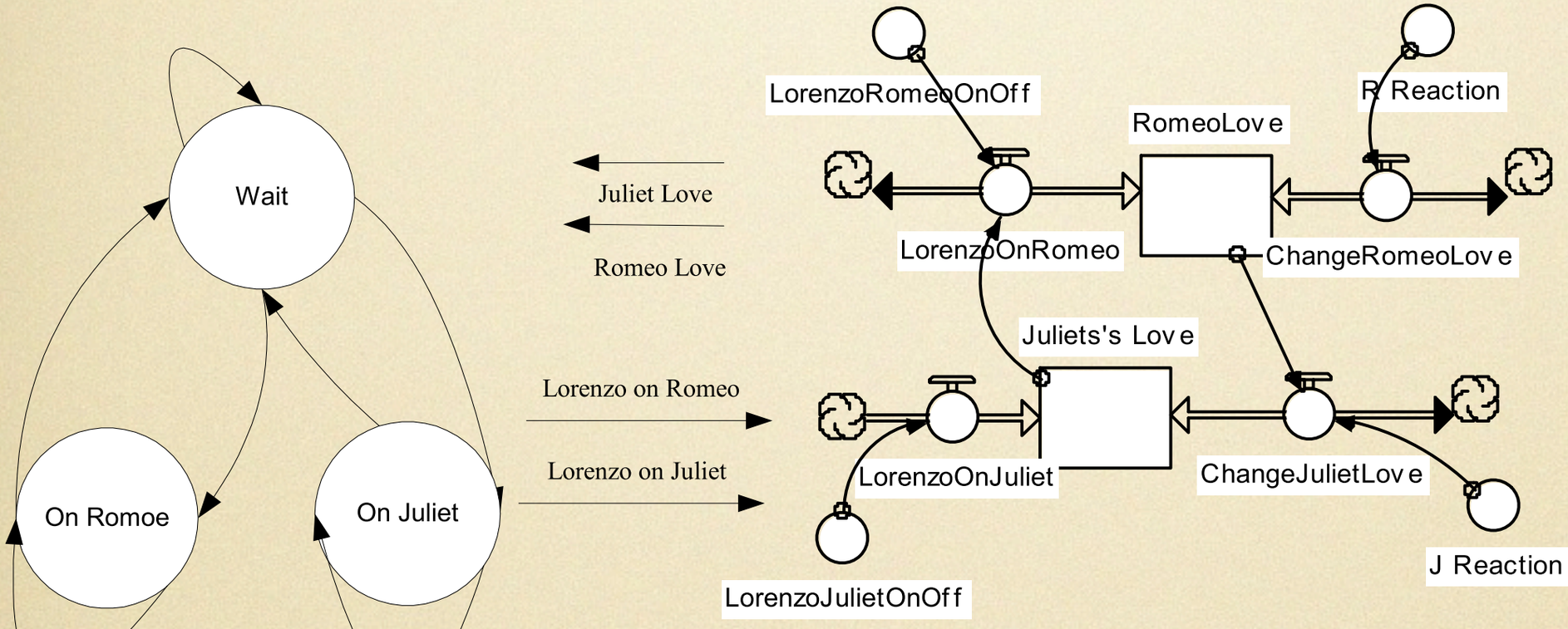
- Traditional way to model the system uses a proportional-integral controller, which turns a radiator on or off.
- An alternative approach uses a digital controller - FSM. The controller monitors the range of the room temperature, turns on and off the radiator according to the FSM.



# Hybrid STELLA implementation of Clime Control



# Poetic Example

# Study

- Q1: Rabbits population dynamics
- Q2: Room temperature dynamics
- Q3: Bank account dynamics

# Control assignments

- A1: Hunting policy
- A3: Heating regulator
- A2: Investment strategy

# Q1: Rabbits population dynamics

- *The birth rate of rabbits living in a natural park is 10% of the population size per month.*
- *The births are distributed equally throughout the days of the month.*
- *The death rate is 5% of the population per month.*
- *The deaths are also distributed equally through the month.*

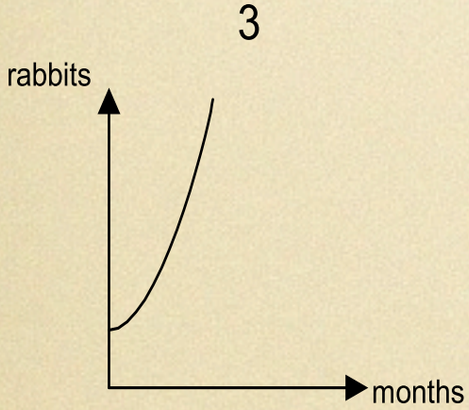
# Q1: Rabbits population dynamics

*1.How does the rabbits population change over time?*

- *Grow in increasing speed*
- *Grow in declining speed*
- *Grow in a constant speed*

*2.Which of the following graphs best describes the growth in the rabbits population over*

3

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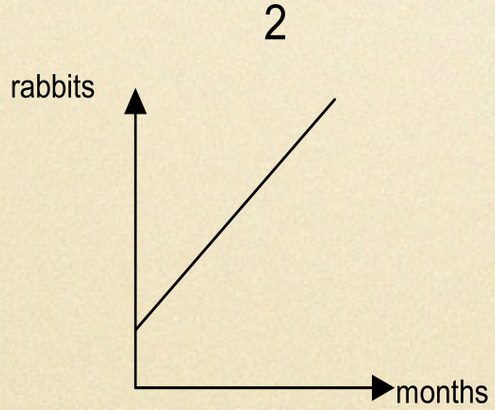


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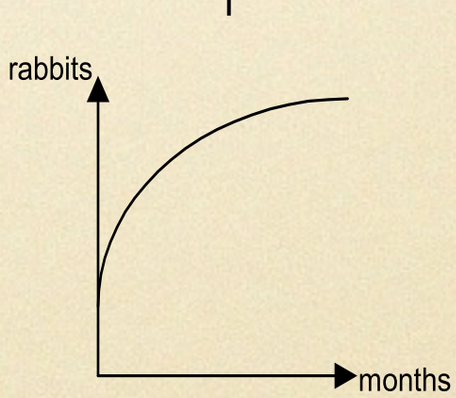


# Q1: Rabbits population dynamics

*On hunting seasons the death rate jumps to 15% per month, while the birth rate stays on 10% as before.*

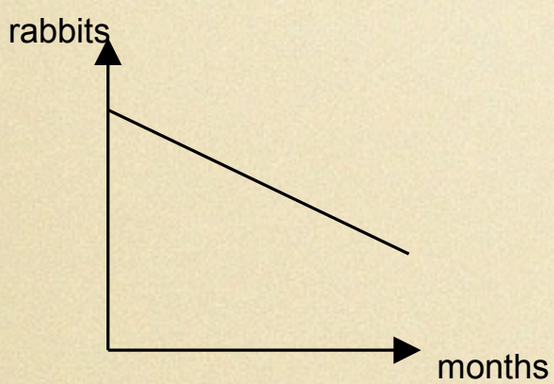
*How does the rabbit's population change over time on hunting seasons?*

- *Decline in constant speed*
- *Decline in declining speed*
- *Decline in increasing speed*

# Hunting policy

*Which of the following graphs best describe the change in the rabbits population on hunting seasons?*

3

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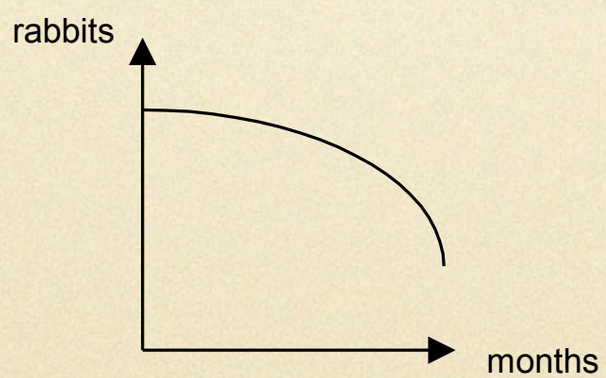


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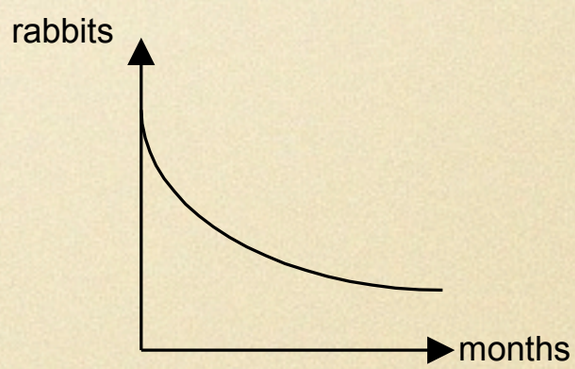
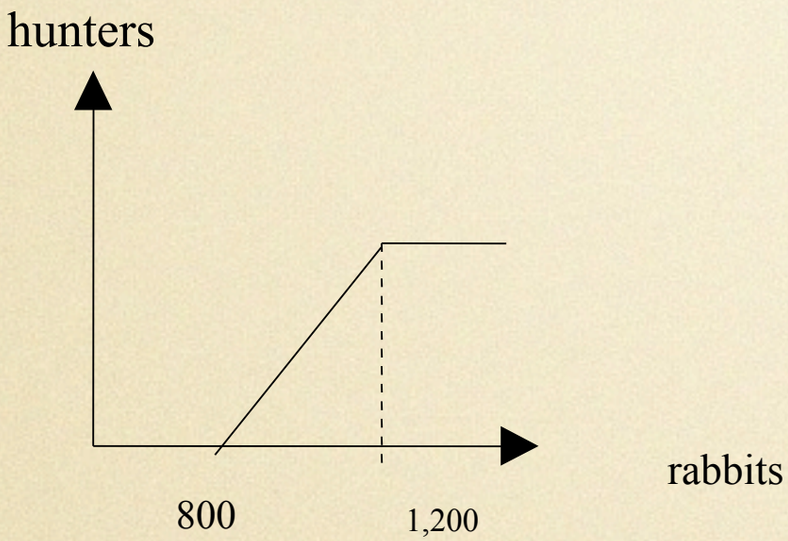
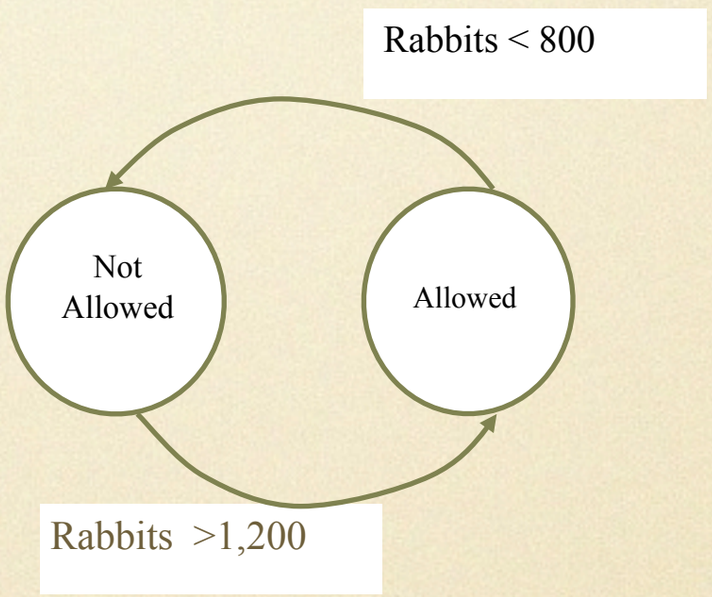


# Control in hunting policy

Continuous ? Hybrid




**Gradual Policy**

When the number of rabbits exceeds 800, allow hunting gradually. The number of hunters will grow in proportion to the number of rabbits. When the number of rabbits exceeds 1.200, hunting is free.

**Two States Policy**

When the number of rabbits exceeds 1.200, allow free hunting.

When the number of rabbits drops below 800, prohibit hunting.

# Hunting policy questionnaire

1. Which of the policies will secure the number of rabbits within the safe limits?

   a) gradual policy  b) two states policy  c) both

2. Which of the policies will keep the number of rabbits closer to the ideal state (1.000)?

   a) gradual policy  b) two states policy  c) both

3. Which of the policies is simpler to implement?

   a) gradual policy  b) two states policy  c) both

4. Which policy would you recommend?

   a) gradual policy  b) two states policy  c) both

5. If you could change the numerical values, which policy will you recommend?

   a) gradual policy  b) two states policy  c) both

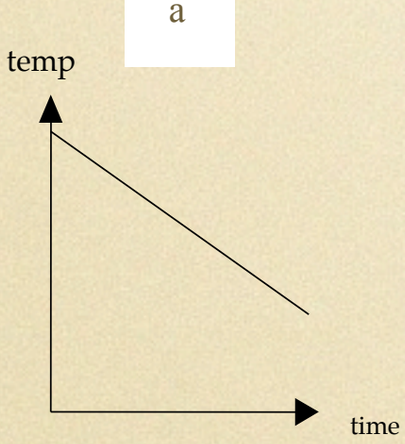
# Q2: Room temperature dynamics

*Assume that the room temperature will eventually get to $10^0$C. How will it change during that process?*

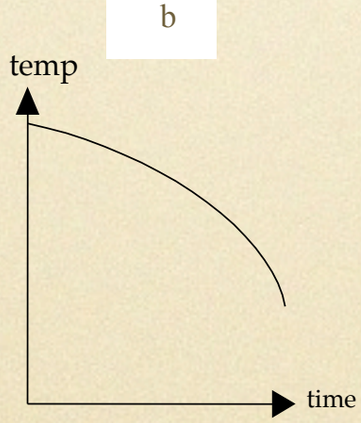
- *Decline in increasing rate*
- *Decline in constant rate*
- *Decline in decreasing rate*

*Which of the graphs best illustrates the change in the room temperature?*

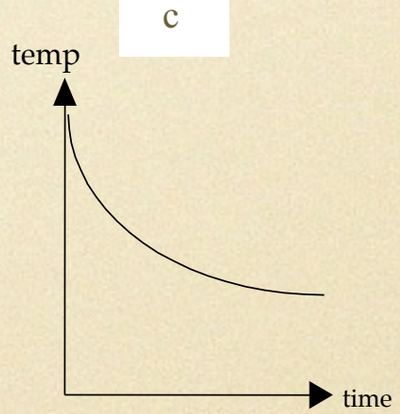
a




b




c

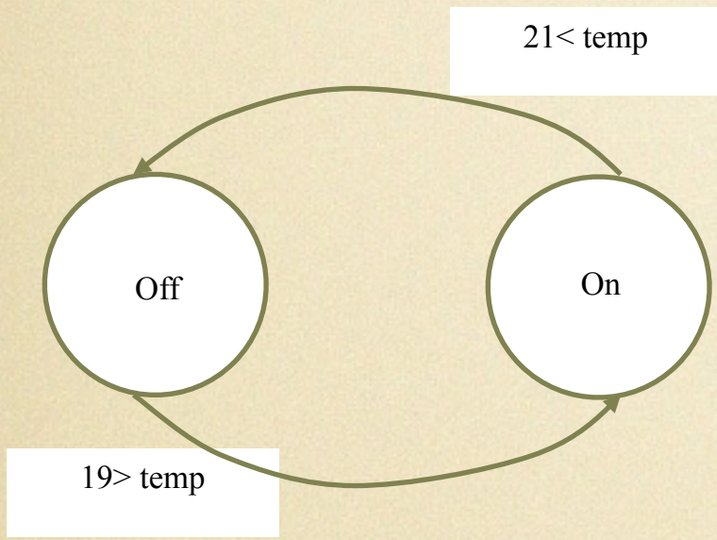


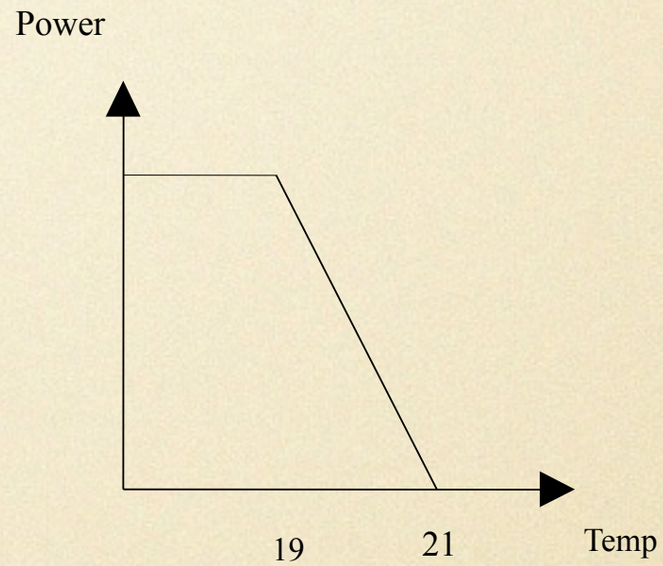
# Heating Regulator

Hybrid

?

Continuous




**Two states model**

When room temperature drops below $19^0$c degrees, it starts working. When the temperature rises above $21^0$c, it stops working.

**Continuous model**

Bellow$19^0$ it works with full power. From $19^0$c towards $21^0$c the power gradually decreases. Above $21^0$c it stops working.

# Q3: Bank account dynamics

Income and expenses in your bank account vary in a periodic cycle.

| *Period* | *1* | *2* | *3* | *4* |
|---|---|---|---|---|
| *Income* | 20,000 | 5,000 | 20,000 | 5,000 |
| *Expenses* | 10,000 | 10,000 | 10,000 | 10,000 |

*1. Which of the following best describes the changes of income?*

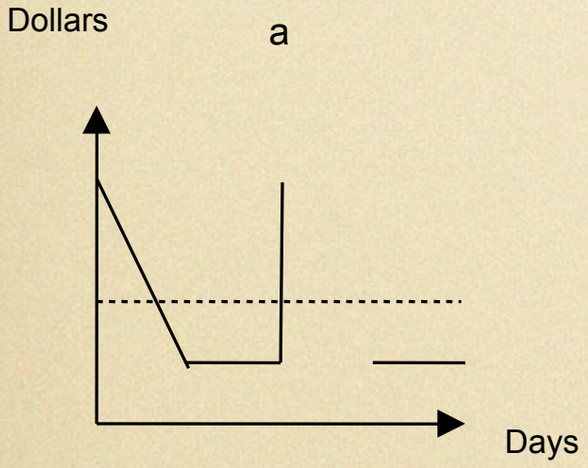
*a. Income rises gradually in one period and declines gradually in the next period*

*b. Income rises or declines gradually in one period and then is constant*

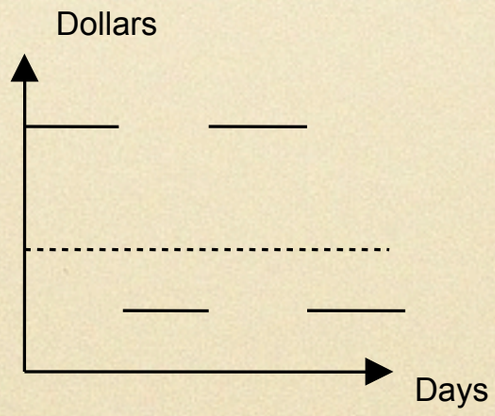
*c. Income is constant during each of the periods, with changing values of the income*

*2. Which of the following graphs best describes the changes in income (line) and expenses (dots) over time?*

a




b

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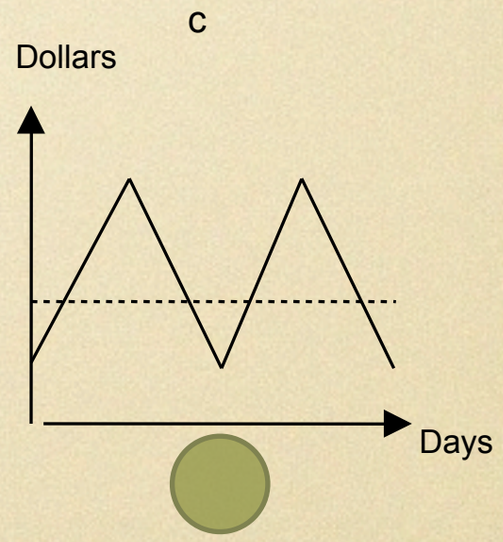
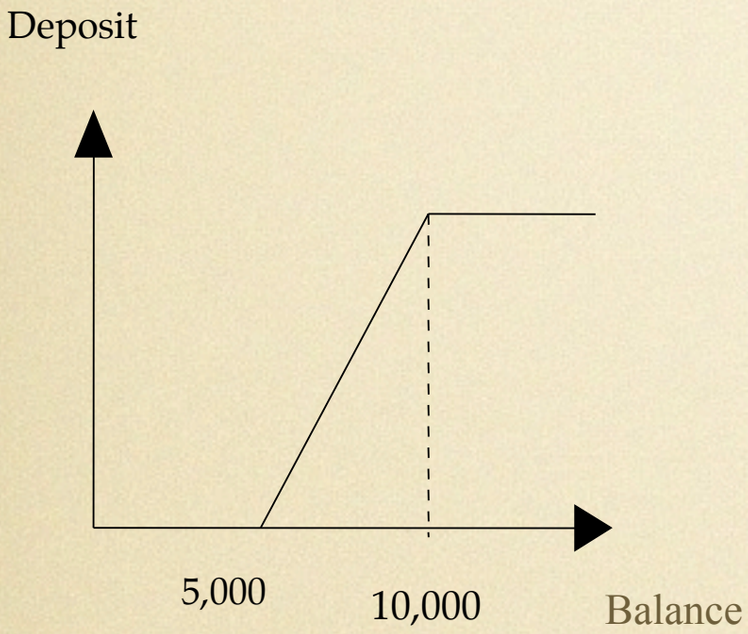
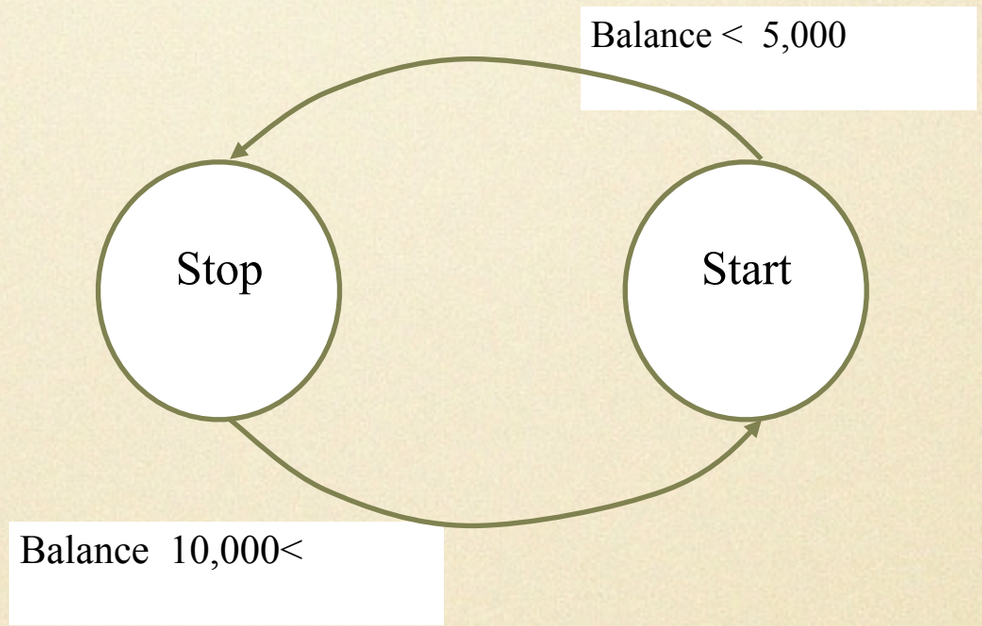


# Investment Strategy

Continuous ? Hybrid




**Gradual investment**

When the balance passes a certain value, deposit daily for saving. The deposit will gradually rise, as the balance rises. Above a certain maximum value, the deposit remains constant.

**Two states investment**

When the balance passes a maximum value (e.g. 10,000 dollars), start depositing a constant amount daily. When the balance is below a minimal value, stop depositing for saving.

# Results

- Students with low dynamic thinking prefer the hybrid solution

- Students with high dynamic thinking prefer continuous solution

- Social sciences students prefer the hybrid solution

- Natural science and engineering prefer continuous solution.

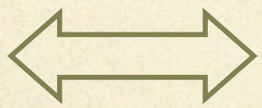
# Discussion

- Further research required
- Hybrid moral reasoning
- Modeling the digital age
- Towards a dualistic worldview

# Hybrid moral reasoning

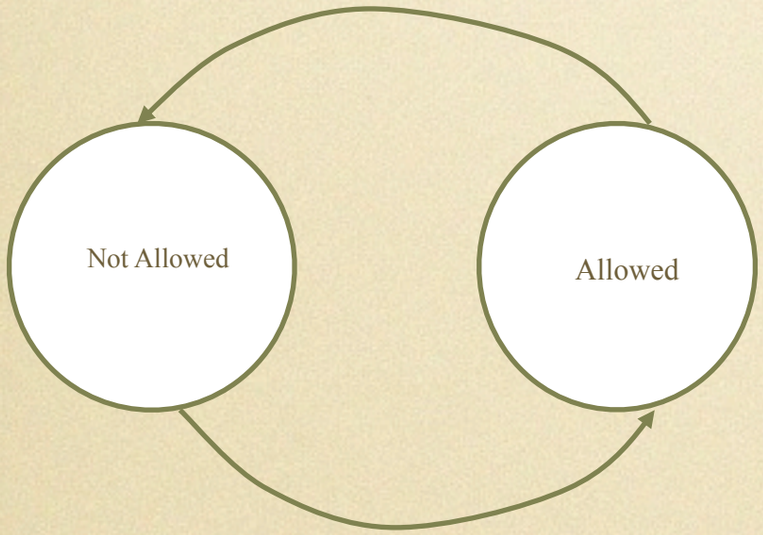
Discrete

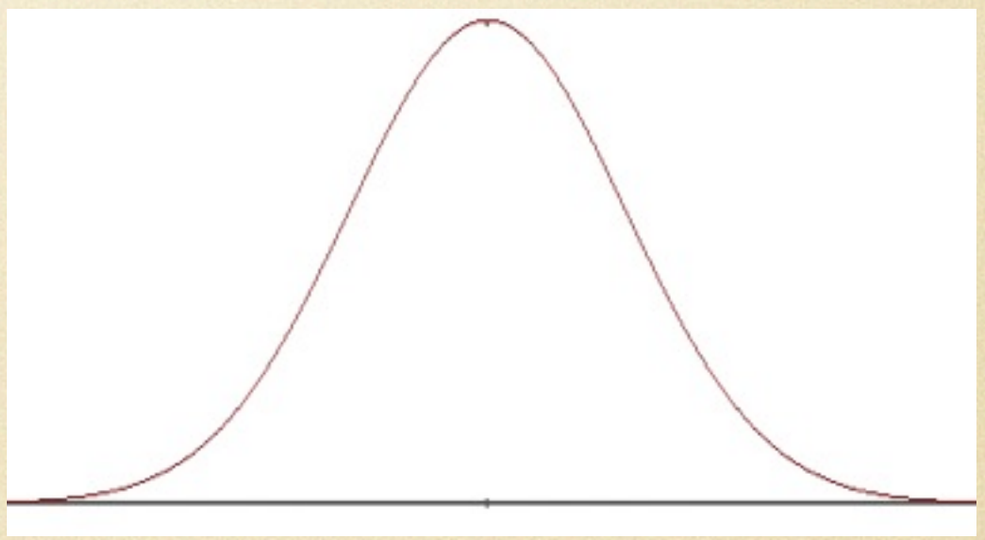
personal values



Continuous

social norms



# Modeling the Digital Age

Virtual

Actual

# Towards a dualistic Worldview

Personal Identity Online

Real Identity