Model Proposal for

"Behavior Change Dynamics on Community Networks"

By Nanjundi Karthick Krishnan

- **Course ID: CMPLXSYS 530,**
- **Course Title: Computer Modeling of Complex Systems**
- **Term: Winter, 2018**

Goal

Provide a short, 1-3 sentence description of the goal of your model

Success and impact of development programs and public policy interventions depends on this phenomenon of "behavior change". Economic growth and development outcomes are not purely a function of individuals and their formal interaction with economic institutions like firms, governments, banks and the likes. Much of sustained economic growth and hence the success of development interventions relies on the interaction of individuals with the society they live in and how the ecosystem as a whole moves from an initial steady state (of non-compliance to desired behavior) to an alternate state (of compliance to the desired behavior).

The goal of this model is to study the network dynamics at play in a behavior change program setup and understand how local interaction interplays with external intervention. Behavior change on network involves the complex combination of information percolation and individual's desire to change. Hence the model aims to simulate the following stage transition amongst individuals:

(a) From being unaware to becoming aware of the benefits of the desired change
(b) From being aware to actually taking action
(c) From taking action to making it a habit

And along the way, the network setting allows us to demonstrate the negative impact of society and a possible process of either unlearning or negative learning. i.e., an individual could go from taking action to stopping action and becoming aware (but not following).

Having designed the process, the objective of the model would be to study emergent community dynamics and the role of internal dynamics vis-a-vis external intervention, as well as understand the phase transitions that emerge in the community.

Justification

Short explanation on why you are using ABM

Heterogeneity in such systems is defined by both differences in the characteristics (attributes) of the individuals interacting, as well as by the difference in outcomes of individual interactions amongst similar individuals. It is this heterogeneity that leads to complex outcomes amongst societies. Hence complex systems would be a relevant way to unearth the mechanisms underpinning shift in societal behavior patterns.

Secondly, most development programs that target behaviour change have noted that individual behaviors are not just a function of the direct mechanism of the program intervention. The interaction of the individual with the environment (people that surround

the individual) plays a key role - especially as we move up the ladder of behavior change from awareness to access to action and finally habit.

Hence the idea of using Agent-Based-Models would be to mimic such an ecosystem and study how individual interactions and possibilities of behavior change, percolates through the system. The environment in this case would also include the development intervention (randomly targeting a set of individuals in the system to change behavior). Hence a pertinent question that can also be answered is: By when can the government be certain that the system will not revert to the non-compliant state, thereby stopping its external funding for the intervention. Hence an Agent-Based-Model will allow for both a micro-founded theory of behavior change driven by incentives and interactions, as well as a macro-founded question of 'how long to fund such programs?'

Main Micro-level Processes and Macro-level Dynamics of Interest

Short overview of the key processes and/or relationships you are interested in using your model to explore. Will likely be something regarding emergent behavior that arises from individual interactions

As has been explained in the motivation sections, the agents are to be placed in a network setting. The network setting is assumed to be static for the duration of the game. The justification for this is that public policy induced behavior change is a short term program during which network equation could be assumed to be static. Also, in terms of tractability, a dynamic network setting would induce higher levels of complexity in the system.

Agent Level Micro Dynamics:

- Each agent is expected to have a network of neighbors. What kind of network would be appropriate is an open question(?)
    - Random Graph or Configuration Model type network
    - Nature of Degree Distribution is important because, the interactions are based on local ties
    - It is also proposed that closed community societies might have possibly networks that have cycles, rather than tree-like characteristics of large social networks
- Each agent is randomly assigned one of four behavioral states (Unaware(U) - Aware(W) - Action(A) - Habit(H))
- At every tick, the agent meets his/her neighbors with a probability (pm; say 50% - This means, that each agent on average is expected to meet 50% of his/her neighbors in every tick)
- The agent is non-strategic, but adaptive. This means that the agent is not thinking through a complex rule to take action. The agent is in-fact with some probability moving through the various stages based on each interaction.

- ***Rules of interaction:***
    - U meets W,A,H - becomes aware with probability P_u
    - W meets U - no reaction
    - W meets A - starts action with probability P_{wa}
    - W meets H - starts action with probability P_{wh}
    - A meets U - no reaction
    - A meets W - goes back to W(non-believer) after meeting X consecutive W with probability P_{aw}
    - A meets H - starts habit with probability P_{ah}
    - H meets U - no reaction
    - H meets W - goes back to A after meeting X consecutive W with probability P_{hw}
    - H meets A - goes back to A after meeting X consecutive W with probability P_{ha}

    Note: We could make this a strategic decision based on a utility that the agent gains by acting a certain way in their local network, rather than probabilistically

- For every M rounds, the government or the social planner, chooses to exogenously change behaviors
    - Strategic and targeted programs
    - Random targeted programs
    - ***Rules:***
        - U is targeted - Converts to A
        - W is targeted - Converts to A
        - A is targeted - Converts to H
        - H is NOT Targeted

Society level Macro Dynamics:

- Society initially starts with a large proportion of U's
- Target: To move the society to a state of A and H largely (say 90% of the population)
- Emergent behavior expected:
    - A slow initial transition in terms of moving up the ladder
    - Initial exogenous shocks to provide impetus to the transition
    - Study the phase transitions and critical points of acceleration / breaking down
    - Identify critical points of alternate equilibrium attainment
    - Could find pockets of non-change. To study starting position characteristics of these nodes (incl. local network)

Results Expected:

- The process of transition and impact of various parameters
- Phase transitions and nature of frequency of external interventions (When to be more frequent and when to stop)

- Insights on how targeted interventions might lead to accelerated transition to new equilibriums
- Insights on how to model strategic decisions of agents (like utility based representation of behavior change based on local network acceptance)

Model Outline

---

1) Environment

Description of the environment in your model. Things to specify if they apply:

- *Boundary conditions (e.g. wrapping, infinite, etc.)*
- *Dimensionality (e.g. 1D, 2D, etc.)*
- *List of environment-owned variables (e.g. resources, states, roughness)*
- *List of environment-owned methods/procedures (e.g. resource production, state change, etc.)*

```
# Include first pass of the code you are thinking of using to construct your environment

# This may be a set of "patches-own" variables and a command in the "setup" procedure, a list, an array, or Class constructor

# Feel free to include any patch methods/procedures you have. Filling in with pseudocode is ok!

# NOTE: If using Netlogo, remove "python" from the markdown at the top of this section to get a generic code block
```

Environment Setup

- Number of Agents (N = 50 say)
- Distribution of the Behavioral Stages (U-W-A-H) amongst the agents
- Network environment (based on a simulated random graph or configuration model with given degree distribution or based on empirical evidence in literature)

Note: Need to check if Netlogo or Python will be the most useful for this network implementation. Need more knowledge based on the next few classes

Environment Owned Variables

- Number of Agents (N)
- Links between Agents (Adjacency List)
- Frequency of Interaction modeled by the probability of interaction with local neighbors at every tick

- Frequency of external intervention (After every 'x' ticks)
- Number of targeted agents in each external intervention (TNA)
- Interaction Mapping Rules
- Target Stopping Rule for the Society (Alternate Equilibrium achieved over x number of ticks)

Environment Owned Procedures

- Local Interaction Rule Book
- External Intervention Rule Book

2) Agents

Description of the "agents" in the system. Things to specify if they apply:

- *List of agent-owned variables (e.g. age, heading, ID, etc.)*
- *List of agent-owned methods/procedures (e.g. move, consume, reproduce, die, etc.)*

```
# Include first pass of the code you are thinking of using to construct your agents

# This may be a set of "turtle-own" variables and a command in the "setup" procedure, a list, an array, or Class constructor

# Feel free to include any agent methods/procedures you have so far. Filling in with pseudocode is ok!

# NOTE: If using Netlogo, remove "python" from the markdown at the top of this section to get a generic code block
```

Agents in the system have following attributes namely:

- Node ID
- Local Network Ties with Other Agents (Static)
- Behavioral Status (U-W-A-H)

3) Action and Interaction

Interaction Topology

Description of the topology of who interacts with whom in the system. Perfectly mixed? Spatial proximity? Along a network? CA neighborhood?

Action Sequence

What does an agent, cell, etc. do on a given turn? Provide a step-by-step description of what happens on a given turn for each part of your model

Step 1

Step 2

Etc…

- Check Stopping Rule
  - If 90% of network in A or H, stop_tick += 1
  - Else stop_tick = 0
  - If stop_tick = target_ticks, STOP
  - Else Continue
- Count Ticks to see if External Intervention to be Triggered
  - If Mod(Ticks, X_ticks) = 0, External Intervention Procedure
  - Else Continue
- External Intervention Procedure
  - Select TNA agents randomly
  - Apply External Intervention Rule book
- Interaction Procedure(Current Configuration)
  - Procedure Configuration = Current Configuration
  - For Each Agent
    - For each connected Agent
      - Random draw to interact (Y/N)
      - If Interact, Check Neighbors Status and Add to Count of Status
    - Interacting Status = Status of Interacting Neighbors with Maximum Count (If there is a tie, choose same status or randomly between competing status)
    - New Status = Interaction Rule book (Agent's current status, Interacting Status)
  - New Configuration = New Status of All Nodes

- Go Procedure

    Tick = Tick + 1

    Current Configuration = New Configuration

    Check Stopping Rule

    Count External Intervention Ticks

    Interaction Procedure

4) Model Parameters and Initialization

Describe and list any global parameters you will be applying in your model.

Describe how your model will be initialized

Provide a high level, step-by-step description of your schedule during each "tick" of the model

Global Parameters

- N = number of agents
- Behavior Distribution
- Network Structure
- Pm - interaction probability in each tick
- Rule Book Probabilities
- Target Ticks and Target Behavior Results
- External Intervention Frequency

Model Initialization

- Network Initialization (N Agents, Random Graph/Configuration Model/Alternate Network)
- Agent Behaviors Initialization

Schedule During Each Tick

- Provided Above in previous section

5) Assessment and Outcome Measures

What quantitative metrics and/or qualitative features will you use to assess your model outcomes?

- Number of Ticks to achieve target equilibrium
- Phase Transition of Behavior Status Counts by Ticks
- Spikes during External Intervention Shocks
- Agent level transitions
- Local Network measures and Time for Status Change to A / H

6) Parameter Sweep

What parameters are you most interested in sweeping through? What value ranges do you expect to look at for your analysis?

- All Probabilities
- Stopping Criteria
- Robustness to Network Structures
- Sensitivity to Starting Distribution of Behaviors
- External Intervention Frequencies