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CMPLXSYS 530

Assignment 2: Brainstorm and Lit Review

Due: Tuesday, 2/06/2018 via Canvas Dropbox

Topic Identification (1 paragraph)

Provide a quick overview of the phenomena or systems that you are interested in modeling. Address the following questions:

- *Why do you think complex systems might be relevant to this topic ?*
- *How do you think an ABM approach might further our understanding of it?*
- *What do you hope to achieve with your model?*

The Indian Government over the last 3-4 years has been working on a Swachh Bharat Abhiyan (Clean India Mission). One of the key pillars of the program is to make Indian villages and cities Open-Defecation-Free (ODF). While the program has intervened by building toilets (community toilets, toilets in schools and in households), a major lever for the success of the program lies in the individuals in these villages using and maintaining these toilets. The infrastructure is just the access - the bait and hook. Whether the program really succeeded depends on the behavior change achieved - coercing the fish to take up the bait. Much of the 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 the change envisioned) to an alternate state (of compliance to a changed society).

There is a growing view amongst economists and other social scientists that individuals are complex physical and emotional beings, but our cognitive computational ability is limited to making decisions based on simple rules. However, what makes the society (an aggregate of these individuals) complex, is the heterogeneity amongst these individuals and furthermore the heterogeneity in the nature of interaction amongst them.

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

To illustrate the heterogeneity with a simple example:

A poor villager in India might be unaware of good hygiene practices. On interacting with the sarpanch (head of the village) of his village, he might become aware of the benefits of being hygienic. Now consider an interaction between the villager's younger brother (for sake of homogeneity) who is also lectured on the same topic by the sarpanch. However the fact that the younger brother had an argument with the sarpanch previously, might mean that he ignores the lecture and hence resorts to not becoming more hygienic.

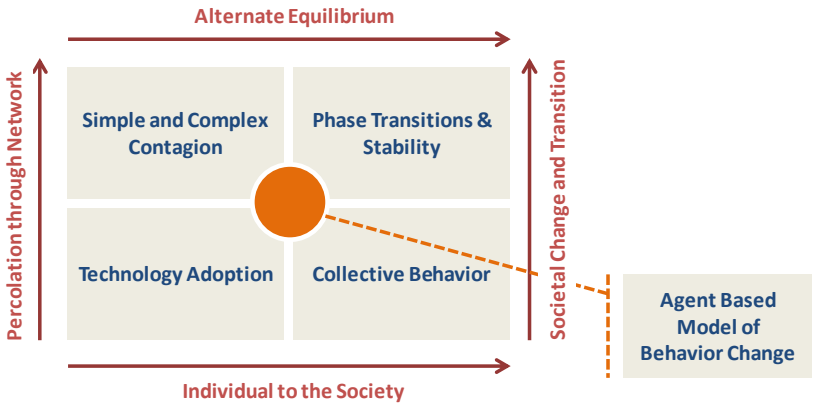
change have noted that individual behaviors are not just a function of the direct mechanism of the program intervention. The interaction of the individual with the environment (people that surround the individual) plays a key role - especially as we move up the ladder of behavior change from awareness 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?'

Literature Review (2-3 paragraphs)

Provide a brief summary of some of the papers or literatures that you think will be most relevant to your model. Of particular importance will be the substantive information you expect to use to design of your agents, interactions, and environments. In your research, you will also want to be especially diligent in seeking out any potentially relevant computational models that others have used to represent the system you are interested in (or systems that might be closely related to it).

Bear in mind the tradeoffs involved in picking subjects which have not been modeled previously. Choosing something that hasn't been modeled before might allow you to be a lot more innovative but will likely prove to be more work than the alternative scenario in which you can modify or extend an existing set of models.

The breadth of literature relevant to the topic is as illustrated in the diagram below:

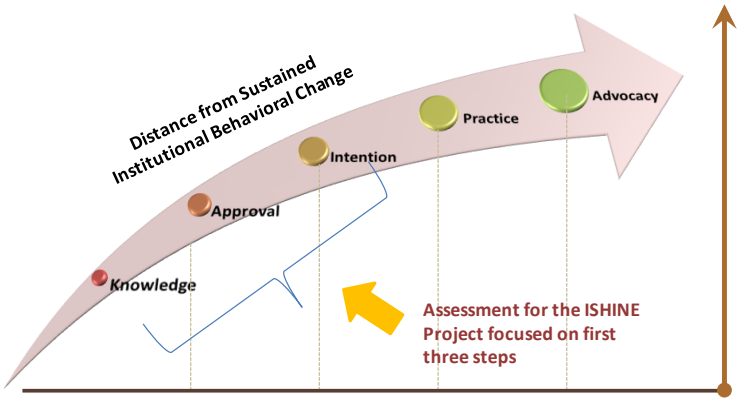


A. Technology Adoption (Individual with Information):

- Much of the behavioral and development economics literature on behaviors has focused on the individual. With behavior change an outcome of an interaction of the individual with the environment (that contains information), the papers have defined theoretical models and conducted field experiments to ascertain how individuals make the decision to 'switch' from a particular habit or practice to another. Most recently and perhaps the most well known examples of research in this direction relate to farmers and their adoption of

new technology or modern methods of farming.[1] Other technology adoption processes have also been studied.

- International development researchers and practitioners have also focused extensively on behavior change. Many models of behavior change grounded in the effect of behavior change communication have been explored, especially in the public health domain. Key survey papers in this literature explain the evolution of behavior change models and theories.[2,3] A model of behavior change adopted from some of the existing models and developed during my stint as an monitoring & evaluation practitioner would be useful for the purposes of the proposed ABM, and is illustrated below:



Adapted from Piotrow et al. 1997 (Social Mobilization)

B. Collective Behavior (Game Theoretic Models related to Cooperation and Common Good):

The survey of literature on consensus and collective action results in models ranging from game theory to evolutionary approaches, from complex systems science to evolution of social systems etc.. These have been studied in the context of money, languages, fairness or rules, social consensus etc. and also from the perspective of how to design mechanisms that yield appropriate behavior aimed at consensus or collaboration and developed through a cooperative or competitive process. [4]

C. Contagion (Percolation through networks):

Percolation through networks and hence contagion is broadly studied from two perspectives. Information spread through networks or disease spread through networks. However the key takeaway for our model is the fact that in a behavior change model, not only are the rules determining the outcome of interaction complex but also the number of jumps required is multiple. Hence these contagion models (both simple and complex) could be used as building blocks but need to be redefined to look at contagion from the perspective of "complex contagion through different states of the individual". For example when an unaware individual meets someone who is aware, they for sure could become aware of the benefits of changing, but as we move from aware to action, the transition is not just a function

1 Hanna, Rema, Sendhil Mullainathan, Joshua Schwartzstein, "Learning Through Noticing", QJE 2014
2 Waisboard, Silvio, "Family Tree of Theories, Methodologies and Strategies in Development Communication", Prepared for The Rockefeller Foundation
3 Elder, John P, Guadalupe X. Ayala, Stewart Harris, "Theories and Intervention Approaches to Health-Behavior Change in Primary Care", American Journal for Preventive Medicine 1999
4 Baronchelli, Andrea, "The Emergence of Consensus", City, University of London

of meeting, but also about who we meet and how the conversation goes. There are many papers on contagion both complex and simple that are relevant to the proposed ABM. (Note: only a few are mentioned here) [5, 6, 7]

D. Phase Transitions and Stability (Contagion leading to Stability of Collective Behavior):

While we are interested in the stability of complex systems and the transition from one equilibrium to another, we are also interested in the ability of a network to stabilize such that most nodes are now compliant to the desired behavior. It is these properties of the system that make it useful to adopt results from statistical physics in studying social systems. [8]

The above literature would be useful in thinking about the ABM for behavior change that envisions a group of agents that move from being unaware to changing habits. The goal of the social planner in this case is to get an emergent transition from the non-compliant state to the compliant state for most of the nodes in the network, by using the contours of the social systems and networks, rather than having to change individual behavior. It is this formulation of the problem that requires the combination of the various streams mentioned above.

Approach (2-3 paragraphs)

In this final part of the assignment, sketch out some ideas on how you might translate the topic of interest into an ABM. Consider the following questions in your discussion:

****** Answers Inline ******

- *What will be the agents in the model?*
  - The individuals in the network would be the agents of the model.
  - They would be a heterogeneous group of individuals. The heterogeneity could be defined in terms of attributes like location, social group, gender, income etc. (or a combination of those). Another level of dynamic heterogeneity would arise from the fact that nodes would be at different stages of behavior change as the process of interactions goes along

- *What sorts of interactions do you think will be most important and what sort of interaction topology do you think will be most appropriate to use?*
  - Primarily interactions between individuals on a random basis (amongst their networks).
  - When an interaction takes place, there could be stochastic way of defining how each individual comes out of the interaction - meaning what each individual takes away from the interaction.
  - Occasionally the social planner would randomly interject and spread information through the network to people who are unaware.
  - The agent-to-agent interaction would be in greater frequency because in real life they happen more frequently than government program officers interacting with individuals. Also, we are interested in the combination of percolation effects and random input effects

5 Karsai, Marton, Gerardo Iniguez, Kimmo Kaski, Janos Kertesz, "Complex Contagion process in spreading online innovation", Journal of The Royal Society 2014
6 Smith, Laramie et. al, "Evaluating network-level predictors of behavior change among injection networks", Journal - Drug and Alcohol Dependence, 2017
7 Snijders, Tom et. al, "Modeling the co-evolution of networks and behavior", Department of Sociology, University of Groningen, 2005
8 Perc, Matjaz, "Phase transitions in models of human cooperation", Perspective Article in Physics Letter A 2016

- In terms of topology, a network topology would be the most appropriate - leading to questions of how to target giant components, how rules differ between giant and small components etc.

- *What will be the role of the environment?*

  ****** Proposed based on current thinking ******

  - The environment for an individual is the local network that he/she belongs to. Geography and other environment factors are defined as agent attributes and determine the network structure.
  - Also the social planner and their random interventions would be part of the environment

- *Will you need to design everything from scratch or do you anticipate being able to modify or extend existing models (either from the literature you have reviewed or by identifying a potentially "analagous" model from a different discipline or area)?*

  - The contagion models on networks would be useful tools, especially from the information percolation or virus percolation literature

- *What will be the modeling outcomes you are most interested in measuring and understanding?*

  - Micro-outcome: Behavior change percolation through the network and achievement of stability. Basically on the 4-box diagram --> going from individual adoption of compliant practices - through network contagion - reaching a stable compliant state
  - Macro-outcome: Collective behavior change and when should any intervention on the system be withdrawn. On the 4-box diagram --> going from intervention to a non-compliant individual - through collective behavior - achieving a phase transition to a new equilibrium where majority are compliant