Overview, Design and Details (ODD) Protocol for: Improving Innovation Adoption Projections by Understanding Outgroup Aversion Effects in Network Environments

Overview

1. Purpose

The model is meant to show how network structure and characteristics, and in-group affinity or outgroup aversion impact adoption (of a new product, policy, practice, behavior, etc.) and polarization. By defining groups and starting with a few initial adopters, the model simulates potential impacts due to prior membership within a group or not, along with a factor that may impact aversion to the group that an agent does not belong to.

2. Entities, state variables, scales

Individuals (turtles) who are members of group 1 or group 2. Patches are also in the models as collections of individuals. An individual can have a "adopted" level of 0 (not adopted) or 1 (adopted).

In the base Smaldino model, the patches are arranged in a 7 x 7 grid with 36 – 49 turtles on each. Adjacent patches are used to define a "local" observation of turtles. For "global" observation, any turtle on the grid can be observed.

Individuals making a decision for adopting or not adopting a product based on two factors: frequency or out-group/in-group aversion/affinity.

Group one or group two (does not change), variable: adopted or not

Group	Adopted	
Group 0: N0	Adopted = 1	Adopted = 0
Group 1: N1	Adopted = 1	Adopted = 0

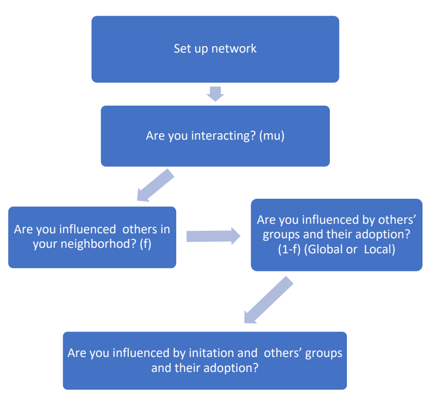
Each agent makes decision at each time interval, based on probabilities (2 probabilities). Spatial resolution is based on mixtures of groups within a lattice or region (patch) with groups having a range of group 0 and group 1. 49 spatial collections of individual are formed with percentages of group 0 and group 1 varying from 10/90 split to a 90/10 split to understand impact when groups are predominated by one or the other group.

3. Process overview, scheduling - methods section of the paper.

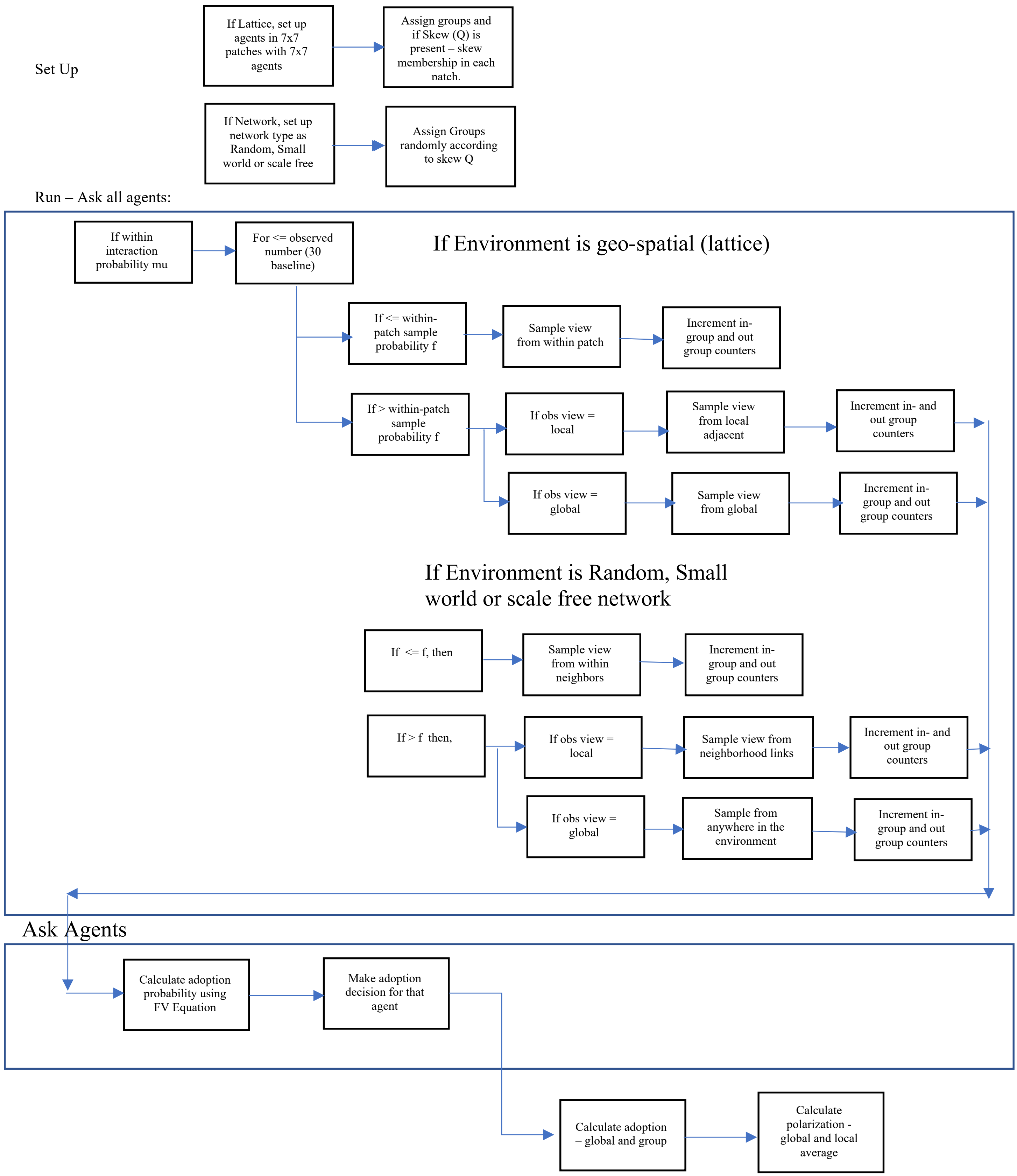
At a certain interaction (mu) and exposure (f) probabilities, turtles take m observations of the turtles immediately around them or randomly from the whole group to aggregate those that are in their group, or not and the share of adopters respectively in each. After aggregating these into shares of adoption or not with-in an in-group or out-group, an adoption probability p is calculated, using the formula from the Smaldino article, which is composed of an exposure component (F)and a out-group aversion (or inGroupBias) component(V). The exposure element is a simplified Bass awareness and the outgroup piece uses the formula in the article.

Adoption is then determined by the adoption probability, and then followed by calculations of adoption and polarization.

For the network version, the sampling of m neighbor turtles (the lesser of m or the number of n-link neighbors) will be done using a level of distance out from the turtle sampled. That is, for ask turtles, the sample will come from the group of turtles that are connected 1, 2 and up to n links out from the turtle sampled (not to exceed the diameter of the network).



- Choose lattice, random network, small world network, scale-free network
- Initialize values
- Apply probability of interacting
- Look in your immediate neighborhood or an extended view (30 iterations)
- View others (locally or globally): geo-spatially or network distance
- Calculate adoption probability, make adoption decision
- Calculate global and group adoption and polarization


Set Up
If Lattice, set up agents in 7x7 patches with 7x7 agents
Assign groups and if Skew (Q) is present – skew membership in each patch.
If Network, set up network type as Random, Small world or scale free
Assign Groups randomly according to skew Q
Run – Ask all agents:
If within interaction probability mu
For <= observed number (30 baseline)
If Environment is geo-spatial (lattice)
If <= within-patch sample probability f
Sample view from within patch
Increment in-group and out group counters
If > within-patch sample probability f
If obs view = local
Sample view from local adjacent
Increment in- and out group counters
If obs view = global
Sample view from global
Increment in-group and out group counters
If Environment is Random, Small world or scale free network
If <= f, then
Sample view from within neighbors
Increment in-group and out group counters
If > f then,
If obs view = local
Sample view from neighborhood links
Increment in- and out group counters
If obs view = global
Sample from anywhere in the environment
Increment in-group and out group counters
Ask Agents
Calculate adoption probability using FV Equation
Make adoption decision for that agent
Calculate adoption – global and group
Calculate polarization - global and local average

High level pseudo-code:

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Setup:
Set up network as a community (Future: two networks)
Assign groups randomly over the network (Future:one with proportion oQ of one group and the other with proportion of 1-Q)
Seed groups with early adopters
Run:
Ask turtles:
If interaction/observation takes place, (mu probability)
        Take 30 observations
                If lattice:
                        If taken from own patch (probability f)
                                Sample from current patch
                        Otherwise
                                If obs=local, sample from adjacent patch
                                If obs=global, sample from any patch
                If network (new):
                        If taken from own neighborhood (probability f)
                                Sample from (input: neighborhood-links)
                        Otherwise
                                If obs = local, sample from >= neighborhood but <= local-links (input:local-links)
                                If obs = global, sample from any node

        Increment number of in-group, number of outgroup, adopted share-in, adopted share-out
         Calculate probability of adoption (using current patch share, lambda, outgroupBias and (share-in – share-out)
        If adoption occurs,
                Set the appropriate color in the appropriate group
Ask turtles: If adopted, change adopted status to 1
Calculate local polarization
Calculate global polarization
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What entity does what, in what order?

- Steps taken by all agents, based on four factors: probability of interaction (prob-m), if increment is less than observed, and probability of frequency effect (prob f), and finally the probability of interacting with an in-group or out group member (V).

Is the order imposed or dynamic?
Random

When are state variables updated?
At the end of a tick (global variables)

How is time modelled: as discrete steps or as a continuum over which both continuous processes and discrete events can occur?
Discrete steps

Design concepts

4. Design concepts

Basic principles

The main concept is that adoption of something new can sometimes be hindered by group membership, if the group (either local or global) is not already adopting. The base model characterized these groups across spatial patches where adjacent patches were similar in composition, but in total spanned a range of group membership.

In this extension, the groups are randomly dispersed within a random network. The random dispersion reflects a realistic characteristic of people living in a place but being randomly associated with a group. A bigger consideration is whether the network should be random or not i.e. what if it was a preferential attachment network or a small-world network, or a network with high modularity or with high clustering?

The goal of this immediate extension was to demonstrate the core principles from Smaldino's paper on a network environment to see if the variables changes have any impact: Lambda (setting that impacts Bass word-of-mouth diffusion), B: ingroupBias – the higher this is the more likely there is an outgroup aversion impact.

Future extension can consider two networks with connectors i.e. a 20-80 network for one group and a 80-20 network for the other group with a portion of the total agents connected to both.

Several factors are used to demonstrate the concept of adoption:
- Frequency dependent bias – defined by x^{λ} – i.e. the more popular a product is in a population, the more likely people are to adopt it
- Aversion bias – where agents are less likely to adopt if it has been adopted by members who are not in their group.

Emergence

The simulation has two main emergent outcomes: Adoption (in total and by group) and Polarization (local and global level). The local level polarization is still spatially based, so less meaningful than the global for the network environment.

Changing Lambda has an interesting impact; due the small number of seed adopters, if this is high, the rate of adoption is actually very slow for these small seeds to spread from such a small based. When the out-group/ingroup component is added in, the rate of adoption does grow faster, but often levels off when only local observation is used for sampling by an agent.

Under a local observation setting, the adoption almost never goes to 100%, where as in a global context it almost always goes to 100%.

Adaptation

Agents individually adapt or react to the number of ingroup or outgroup adopters. Their probability of adoption can go up or down if those in their "view" are opposite their own group. However, there is no specific "fitness" outcome metric for improving or changing behavior or rules.

Objectives

The agent's main outcome is to evaluate the adoption of those around them and make an adoption determination based on a probability calculated by the aggregate result of the observations. The competing factor in the adoption decision is an imitation or frequency factor that may drive higher adoption due to sheer volume of adopters.

Learning

There is no specific learning reference; however, for future reference there is a cumulative factor called "memory" that can be used to weight the current observation set vs. the cumulative total. In this exercise this was set to zero to only use the current result of the observation set.

Prediction

Prediction may be done qualitatively based on these model results matched to empirical data with multiple case studies. For example, in a new innovation that is known to be highly polarized e.g., vaccines, there may be an ability to provide a range of potential outcomes for adoption in total and by group as well as an assessment and range of polarization outcomes.

Sensing

Sensing takes place by each agent observing those in their immediate neighborhood, or in a more adjacent neighborhood or from a global view. The signal is whether those observed people have adopted or not and what group they belong to. The sensing is both using geo-spatial and network based looks. Global sensing is an option that is selected and tested.

The network structure is imposed from the beginning as an initialization function. Agents obtain information based on direct observation without explicit modelling for 'truth', i.e., observations are taken for "known".

Interaction

Interactions are the observations of adopter behavior around an agent in order to make an adoption probability and an adoption decision. The only other influence is if the number of adopters is overwhelming that may override any outgroup aversion tendencies. There is no other direct interactions or competition between agents.

Stochasticity

Randomness is entered into the model via the probability of interaction (mu) and the probability of neighborhood vs. local vs. global views (probability f). In addition, the influence of adopter volume (lambda) and the outgroup factor are channelled into an adoption probability.

In addition, the network generation for each run of the model is subject to the probability and stochastic creation of the network in each case. Additionally, the assignment of groups is also random as are the initial early adopters.

Collectives

Individuals are formed into two groups; in the geo-spatial model these are in turn formed into "patches" with a skew if group membership. In the network models, this intermediary group skew is ignored in this version of the model.

Groups are assigned at the beginning of the initialization.

Observation

Polarization and adoption in total and by each group is collected; additionally network variables are also collected:

Adoption and polarization are calculated as follows:

Polarization = $|n_1 - n_2| / (n_1 + n_2)$
Adoption = $(n_1 + n_2) / N$

Where n_1 and n_2 are adopters in each group, and N is the total number of agents.

Network metrics collected for each replication are:

- average betweenness centrality – to understand the nodes through whom one must connect the most
- average local clustering coefficient (global clustering coefficient) – to understand if "friends are friends" triangles
- eigenvector centrality – a measure of the connectedness of a node and the role it plays in the network with respectd to connections.

Table 1: Model Variables

Variable	Default Value
Probability mu – interaction probability	.05
Probability f – immediate neighbor view probability	.7
Seeds for early adopters	5
Q – skew of groups (used in lattice only within patches)	.9
b - Outgroup aversion factor	1
Lambda – imitation factor	.3
Observations – number of data points to make decision	30

Environment type	Local vs. global view	Q	f	lambda	b	seeds	Obs
Lattice	Local	.9	.7	.3	1	5	30
Lattice	Global	.9	.7	.3	1	5	30
Random network	Local	n/a	.7	.3	1	5	30
Random network	Global	n/a	.7	.3	1	5	30
Small world network	Local	n/a	.7	.3	1	5	30
Small world network	Global	n/a	.7	.3	1	5	30
Scale free network	Local	n/a	.7	.3	1	5	30
Scale free network	Global	n/a	.7	.3	1	5	30

Details

The basic pseudo code is:

1. Initialization/ Setup
    a. Set up turtles in a grid/lattice (default) or in a network or a series of networks.
        i. For default configuration (lattice), distribute group membership in the grid with a progressive ratio of group 0 to group 1 from upper left to lower right corner patch
            1. 7 x 7 patches with 7x7 turtles on each, skewed from Q members of group 1 to 1-Q proportion of members in group 2.
        ii. For network configuration, the group membership is distributed randomly across nodes (turtles). The network itself may have communities based on node degrees and/or communities, but that will be an additional extension.
    b. Seed a small group of turtles as "adopted" as a starting point.
2. At each increment, ask turtles:
    a. If random-float 1 < mu – mu or (prob-m) is the interaction rate (default = .05)
        i. Take m (default = 30) observations of other turtles (default program allows random or local sampling)
            1. If random-float 1 < f , with f being the probability of Bass adoption due to social pressure (with no outgroup aversion effects)
                a. Ask one of the other turtles if they are adopted
                    i. If in the same group as the observing turtle:
                        1. If other turtle is adopted, then increment share-in and number in-group
                        2. If no, then increment number in-group only
                    ii. Else if not in same group
                        1. If other turtle is adopted, then increment share-out and number out-group
                        2. If not adopted, then just increment number out-group
            2. Else (with probability 1 – f):
                a. If local sampling
                    i. Sample turtles from adjacent squares and calculate share-in-group, number-in-group, share-out-group, number-out-group.
                b. If global sample
                    i. Sample turtles from all patches and calculate share-in-group, number-in-group, share-out-group, number-out-group
            3. If the current turtle is adopted,
                a. Increment Share-in-group and number-in-group
            4. Else
                a. Increment number-in only
            5. Increment i in while loop
        ii. At the turtle level, add accumulators for number-group-in, number-group-out, share-in-group, share-out-group (results after m observations)
            1. Calculate share-ingroup (cumshare-in – cumshare-out)
            2. Calculate share-in = cumshare-in / cumulative-number-in
            3. Calculate share-out. = cumshare-out/cumulative-number-out
            4. If patch policy >0, then calculate the probability of adopting:
                a. Prob = share^Lambda x (1-ingroupBias)x ingroupBias/(1 + exp(-beta(share-ingroup)
            5. If random-float 1 < prob
                a. Set newly-adopted = 1 and set color to adopted (depending on group)
            6. Else
                a. Set newly-adopted = -1 and set color to and set color to not-adopted
3. For all turtles(ask turtles): if newly-adopted = 1, set adopted = 1, else set adopted = 0
4. Calculate polarization and adoption
    i. Calculate local polarization
    ii. Calculate global polarization
    iii. Calculate global adoption