Overview

Purpose:

Institutional Bundle theory in Netlogo is designed to explore the dynamics of interdependency of economic institutions and contagion of collapses. Specifically, the model is designed to explore some of the factors affecting collapses. The model demonstrates the spread of collapse through a network. The model is abstract but has many applications in various fields. One such application is based on the interpretation that each node represents a firm, and we are modeling the progress of collapse of a firm and its partners represented by link (partnership or interdependency) in this network. Each node may be in one of three states: stable, unstable, or collapsed. Each time step (tick), each unstable node (colored orange) attempts to affect all of its neighbors. If its neighbors have not failed or collapsed, their thresholds are compared with the stress concentration with a certain probability. Stable neighbors (colored green) will be infected with a probability given by the SPREAD-CHANCE slider. This corresponds to the probability that a stable firm actually expresses the impact of unstable firm. And collapsed nodes (colored red) cannot be collapsed with a PERMENAT-COLLAPSE-CHANCE slider. Once this happen, the links between it and its neighbors are colored red, corresponding to their removal from the system. Another way of doing this could be reattachment of the stable links and nodes. But this will complicate the modeling.

State variables and scales:

The most important variable for this simulation is the firm (nodes) agent. All nodes are initialized with the random node-failed-threshold varying around node-failed-threshold-means.

Number-of-nodes: number of nodes created

average-node-degree: average number of links coming out of each node

initial-unstable-node: starting number of unstable nodes and determines how many of the nodes will start the simulation unstable.

spread-chance: the probability that instabilities will spread to other nodes.

Tick-frequency: number of time to check whether the node is unstable or not

collapse-chance: the probability that unstable node is check for whether it can fail or become stable in the next time step

perminant-collapse-chance: the probability that unstable node will collapse.

Node-failed-threshold-mean: the average mean of the threshold of collapse.

*Beta: W*eibull parameters (it was assumed to be one in order for the distribution to be exponentially distributed).

Unstable?: ask if the node is stable or unstable. If the node is unstable, the variable is set to true.

Collapsed?: As in unstable?, the node is asked whether it has collapsed or not.

Process Overview and scheduling

Design concept

Emergence: The most interesting phenomena that emerges as a result of the model is the node-threshold distribution. The regularity of the distribution (emergence of log-normal distribution) is the result of multiple parameters. The other emergent behavior is the occurrence of collapsed nodes when it is not expended, this is a result of the agent actions within some of the parameters. Tipping point phenomena also emerge, where between the Rule space (projection of spread-chance, average-node-degree and collapse-chance) 4 and 6 the dynamics seem to change drastically.

Adaptation: the agents adapt to their experiences based on the instability occurrence and their node-failed-threshold. They attempt to increase their thresholds if they experience instabilities and then later become stable. This ability to mutate makes them adaptive.

Fitness/Objectives: the goal and objective of agents are to increase their node-failed-threshold in order to avoid collapses and prevent the contagion effect of their neighbors.

Prediction: The agents do not predict the consequences of their actions

Sensing: Agents (nodes) are able to detect whether their neighbors are stable, unstable or have collapsed. If they are unstable and sense their linked neighbors are stable, they will attempt to impact them assuming the threshold conditions are met.

Interactions: The interaction of agents is modeled as SIS-type dynamics. Agents only interact with other agents if they are linked to them.

Stochasticity: Stochasticity is accomplished through node-failed-threshold, collapsed-chance, and perminant-collapsed-chance, node instability and collapse procedures.

Collectives: The agents are not grouped.

Observations: the number of nodes is set fix, and percent of stable, unstable and collapsed nodes are recorded. In addition, average node-failed-threshold, and average K-measure are also recorded at each time step (tick). All of these are also measured on log-scale so see if there are any other emergent properties at different scale.

Details

Initialization: The model is initialized with values specified by the user. First the number of node is set. The node-failed-threshold-mean is chosen. The user can set all the slider values: number-of-nodes, average-node-degree, initial-unstable-node, spread-chance, tick-frequency, collapsed-chance, perminant-collapsed-chance, node-failed-threshold-mean and beta. Once these are set and the set-up buttom is pressed, each node is randomly assigned node-failed-threshold that is exponentially distributed around the chosen mean; and all nodes are given the same K-measure value of 1. Each node corresponds to firm or industries. Using the sliders NUMBER-OF-NODES and the AVERAGE-NODE-DEGREE, the network is created is based on proximity (Euclidean distance (equation 2.5)) between nodes. A node is randomly chosen and connected to the nearest node and the process is repeated until the network has the correct number of links to give the specified average node degree. The SETUP is pressed to create the network, and the GO button runs the model.

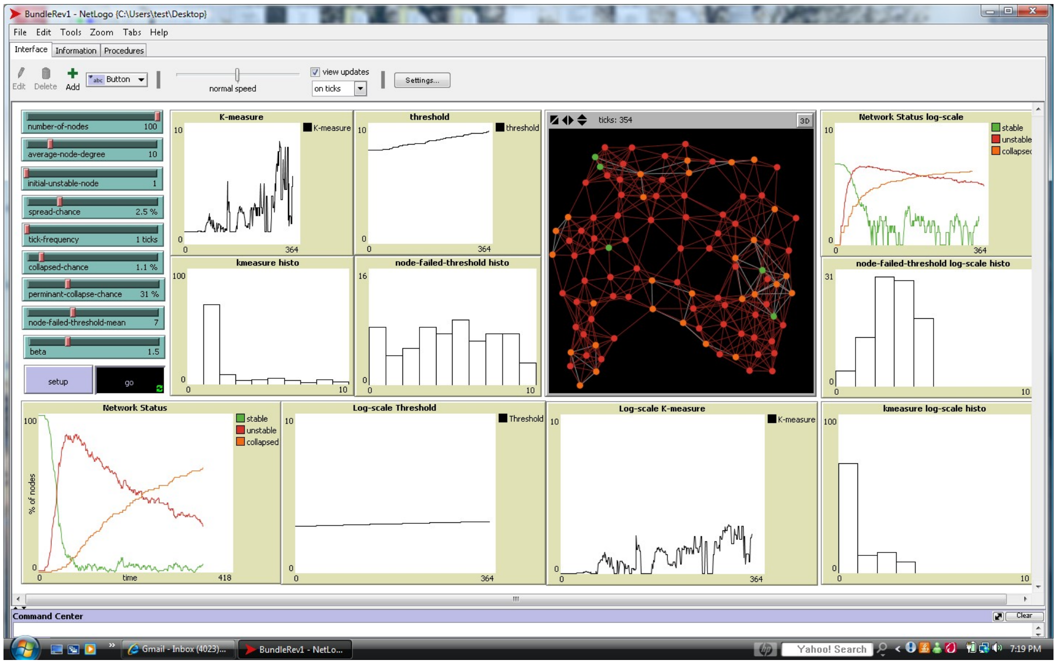

Figure 1: Schematic of Netlogo output of the model

Input: No input data required for the model.

Submodels:

Stable:

We use binary operation in this procedure. The unstable? And collapsed? are set to false.

Unstable:

If the node satisfies this condition:
(1 - exp (node-failed-threshold / (random-float node-failed-threshold-mean + 1)) ^beta) < random-float 100
we set the unstable? and collapsed? variables to true and false, the color of the node to orange.

Collapse: Similarly to unstable procedure, assume binary statement where the collapsed? is set to true. If true, the link is changed to red indicating that the node has be removed from the system and no longer interact with other nodes.

Spread:

It provides most of the spread of instability and collapsed contagion. Each unstable node is asked when their neighbors are stable, if they are it attempts to spread its instability to them with probability of spread-chance.

Ticking:

Ticking procedure provides the mean in which the collapse occurs and/or stability is secured. Each unstable node is asked whether they satisfy the probability of collapsed-chance using the following statement (***random-float 100 < collapsed-chance***). If the satisfy this condition, they again ask for the possibility of collapsing permanently. The model is: random-float 100 < permanent-collapse-chance (we could also use this condition K-measure? * node-failed-threshold < permanent-collapse-chance) but notice that it provides similar dynamics. So for simplicity, the former sub-model was used. If the statement is true, then the node collapses, otherwise, it becomes stable and increases its node-failed-threshold by:

node-failed-threshold = node-failed-threshold + random-float (random node-failed-threshold-mean).

Note that this method is normalizing. The other method implemented is the K-measure. In this case, K-measure is calculated for stable nodes assuming that there are linked neighbors. The expression is as:

K-measure? = 1 + ((count link-neighbors with [collapsed?]) / (count link-neighbors with [not unstable? and not collapsed?]))