Introduction to Agent-Based Modeling
Summer 2022
Model Design Assignment Questionnaire

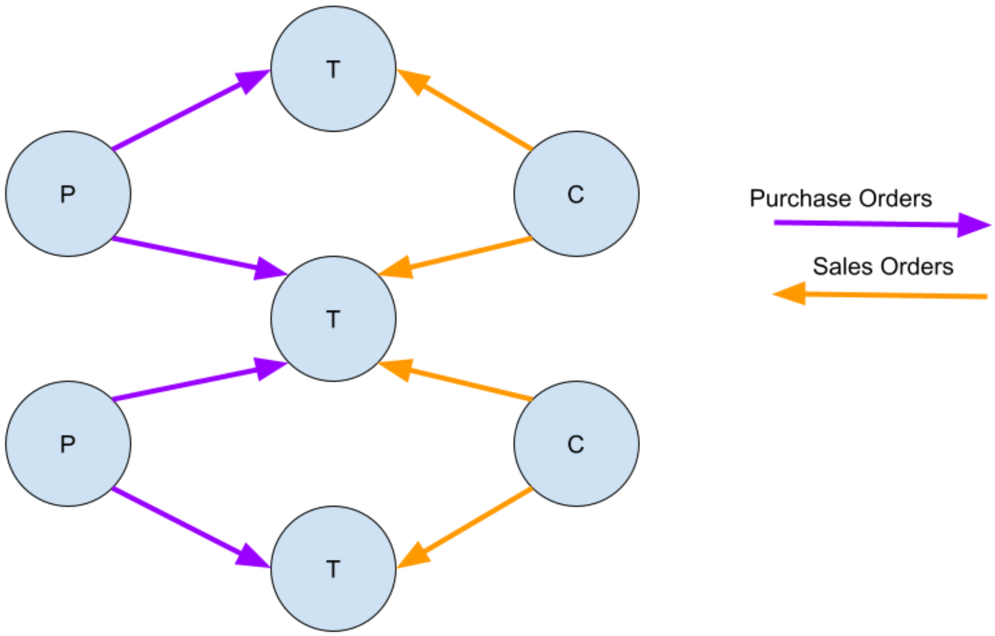
(1) What part of your phenomenon would you like to build a model of? Make sure that the phenomenon is appropriate for an agent-based model that could be completed in the next month.

This project will model the phenomenon of agents trading a commodity for money through a supply chain network. In particular, how competing over price can affect the performance of the network. Initial focus would be on hard-coded network topologies and agent strategies, but if there is time then alternative topologies and strategies could be investigated. Inspiration comes from the game “Middleman” from *Games with Pencil and Paper* by Eric Solomon (1993) and from “The Beer Game” by John Sterman (1989). Unlike both games, Consumers here will have infinite demand limited only by the amount of money that they have. Also– in the initial implementation at least– this project will not model operating costs, or communication and transportation delays between the agents. Those may be areas of further research.

(2) What are the principal types of agents involved in this phenomenon? Illustrate all of the agent types necessary for the model.

The agents involved would be *Producers*, *Traders*, and *Consumers*. Producers supply the commodity and sell to Traders. Consumers demand the commodity and buy it from Traders. Traders can buy from Producers or other Traders, and sell to Consumers or other Traders. Traders will be the main driver of the action in the model.

An example network might look like:



(3) What properties do these agents have (describe by agent type)? Describe for all agent types.

All of the Producers, Traders, and Consumers would have:

- *inventory*, the amount of commodity they currently possess.
- *money*, the amount of money they currently possess

Traders would have:

- *suppliers*, the set of agents in the supply that chain from which this agent can buy
- *buyers*, the set of agents in the supply chain to which this agent can sell
- *buy-price*, the price at which the Trader is willing to buy the commodity
- *buy-strategy*, the strategy that the Trader uses to set its buy-price
- *sell-price*, the price at which the Trader is willing to sell the commodity
- *sell-strategy*, the strategy that the Trader uses to set its sell-price

(4) What actions (or behaviors) can these agents take (describe by agent type)? Describe all appropriate behaviors for all agent types.

Producers

- Produce some amount of commodities.

Consumers

- Earn some amount of money.

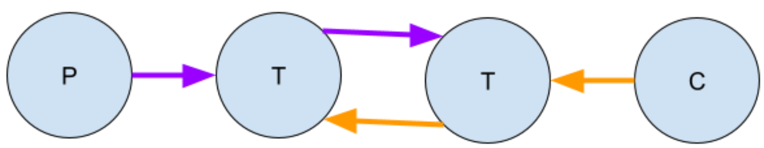
Traders

- Choose their buy price and sell price
- Buy some amount of commodities from connected suppliers.
- Sell some amount of commodities to connected buyers.

(5) In what kind of environment do these agents operate? Describe the basic environment type
(e.g., spatial, network, featurespace, etc.) and fully describe the environment.

Agents operate in a network environment. The network represents a supply chain going from Producers, through Traders, and to Consumers. Agents will be linked to both who they buy from, and who they sell to. Producers and Consumers can each only connect to Traders. Traders may connect to any type of agent.

An example network where a Trader is linked to another Trader:



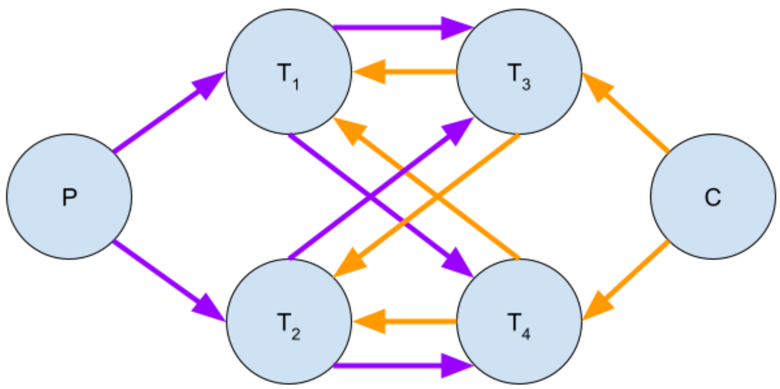
(6) If you had to "discretize" the phenomenon into time steps, what events and in what order would occur during any one time step? Fully describe everything that happens during a time step.

At each time step, the agents will perform these actions in the following order:

1. Each Producer will produce its amount of commodities. Any commodities and money exchanged in the final action of the previous time step are now available to trade.
2. Each Trader will choose a buy price using some strategy.
3. From highest buy price to lowest, Traders will buy commodities from their connected suppliers. If they are connected to more than one supplier, a supplier is chosen arbitrarily. They buy commodities until either the Trader runs out of money or their suppliers run out of inventory. Commodities purchased this way will not be available to be purchased again during this action, and money earned this way will not be available to purchase other commodities during this action.
4. Each Consumer earns its income in money. Commodities and money exchanged in the previous action will now be available to trade.
5. Each Trader now chooses a sell price using some strategy.
6. From lowest sell price to highest, Traders will sell commodities to their connected buyers. If they are connected to more than one buyer, a buyer is chosen arbitrarily. They sell commodities until either the Trader runs out of inventory or the buyers run out of

money. Commodities sold this way will not be available to be sold again during this action, and money earned this way will not be available to buy other commodities during this action.

For example, given the network:



Let the Producers and Consumers have 0# in inventory and $0 in money. Let all Traders have $100 in money. Let T_1 and T_2 have 0# in their inventory and T_3 and T_4 have 10# in their inventory.

A timestep would look like:

1. Let producer *P* produce 10# commodities.
2. Let T_1 choose a buy-price of \$11 and T_2 choose a buy-price of \$9. Because T_1 and T_2 have no inventory, T_3 and T_4 have nobody with inventory that they can purchase from and so will not participate in this action.
3. Going from highest buy-price to lowest, T_1 makes a purchase-order of 9# commodities for \$99. *P* only has 1# left in their inventory, so T_2 can only make a purchase order of 1# commodity for \$9.
4. All purchase orders clear, so T_1 now has an inventory of 9# and \$1 in money, and T_2 now has an inventory of 1# and \$91 in money.
5. Let Consumer *C* earn \$100
6. Let the Traders choose their sell prices as follows: T_1 = \$12, T_2 = \$10, T_3 = \$14, T_4 = \$15
7. Going from lowest to highest, T_2 has the lowest sell price at \$10. T_2 has only 1# in their inventory, and both T_3 and T_4 can buy from T_2, so the sales order is chosen arbitrarily. Let T_2 make the sales order to T_4 at 1# for \$10.
8. Next, T_1 can sell its 9# commodities at \$12. Both T_3 and T_4 can buy from T_1, so the sales orders are chosen arbitrarily. There is already a \$10 sales order to T_4 , so T_4 only has \$90 to promise while T_3 has \$100. Say that T_1 makes a sale order of 6# for \$72 with T_3 and 3# for \$27 with T_4.
9. Now T_3 can sell the 10# of commodities it started with during this action for \$14. *C* has \$100 so the sales-order is for 7# of commodities at \$98.
10. Consumer *C* does not have enough money left to fulfill a sales order for T_4, so the action finishes.

11. All sales orders are cleared. The final properties are:
    a. P has 0# and $108
    b. T_1 has 0# and $100
    c. T_2 has 0# and $101
    d. T_3 has 9# and $126
    e. T_4 has 4# and $63
    f. C has 7# and $2

(7) What are the inputs to the model? Identify all relevant inputs.

The topology of the supply chain network– defining the supplier and buyer connections between the Producers, Traders, and Consumers– will be set before the model begins.

All agents will start with some configurable amount of money and some amount of commodities in their inventory. Traders will also have the strategies that they will use to buy and sell.

In addition, Producers will have a *production-rate* parameter to control how quickly they produce commodities. Similarly, Consumers will have an *income* parameter to control how much money they earn.

(8) What do you hope to observe from this model? Identify all relevant outputs.

This project will monitor the money and inventory of each agent, and by agent type. It will also monitor the prices at which each Producer can sell its commodities and each Consumer can buy its commodities, and the profit that each Trader can make. Comparing and contrasting these values over different network topologies and agent buying/selling strategies will be the main focus of this model.

References

Solomon, E., 1993. *Games with pencil and paper*. New York: Dover Publications.
Sterman, J.D., 1989. Modeling managerial behavior: Misperceptions of feedback in a dynamic decision making experiment. *Management science, 35(3)*, pp.321-339.