Supply Chain Management League 2021: An Overview

SCML Organizing Committee:

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The purpose of this document is to provide an overview of the Automated Negotiation Agent Competition (ANAC) Supply Chain Management League (SCML).[1] We summarize the rules of the game, and then we explain how to play: i.e., the mechanics of the tournament.

1 Overview

The SCM world simulates a supply chain consisting of multiple factories that buy and sell products from one another. The factories are represented by autonomous agents that act as factory managers. Each agent decides which other agents to buy and sell from, and then negotiates with them. Their goal is to turn a profit, and the agent with the highest profit (averaged over multiple simulations) wins.

The simulation proceeds in discrete time steps, which we refer to as days. During each day, multiple simultaneous negotiations transpire, and outputs are manufactured from inputs. The game is intended to further research on agent negotiation; as such the design emphasizes negotiation and de-emphasizes operations (e.g., scheduling).

Factories　**Factories** in the SCM world convert **products** into other products by running **manufacturing processes** on their **production lines**. All processes take one day to complete. Factories store the inputs and outputs of manufacturing processes in their **inventories**, and their funds in their **accounts**.

Each factory has multiple production lines, each of which is assigned a profile specifying the cost at which it can execute the various manufacturing processes. In general, these costs can vary from factory to factory, may vary from line to line. In SCML2021, however, each factory will have a set of identical production lines, each of which can run only a single manufacturing process (i.e., all other processes will have infinite cost).

Factory costs are private information: i.e., no factory knows any other factory's costs.

Production Graph　The **production graph** is assumed to be directed and acyclic, with products and manufacturing processes as its nodes. An edge from a product to a process node indicates that this product is an <u>input</u> to this process. An edge from a process to a product node indicates that this product is an <u>output</u> of this process. (Note that there are no edges between product or between process nodes.)

Figure 1 depicts a sample production graph for SCML2021. Observe that it is a **chain**. Because each factory can run only one manufacturing process in SCML2021, each can likewise be assigned to only one production level, corresponding to their particular process assignment.

Agents and Negotiation　The agents in the SCM world function as **factory managers**. In addition to managing production, they negotiate with other agents to reach agreements to buy and sell products, which they can then sign as contracts. Such agreements are generated via bilateral negotiations using a variant of the **alternating offers protocol** typically used in ANAC competitions [**?**, **?**]. Each offer specifies a buyer,

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[1] We use SCM to refer to our simulation of a supply chain management world, SCML to refer to the league running at ANAC, and SCML20XX to refer to the league running during year 20XX.
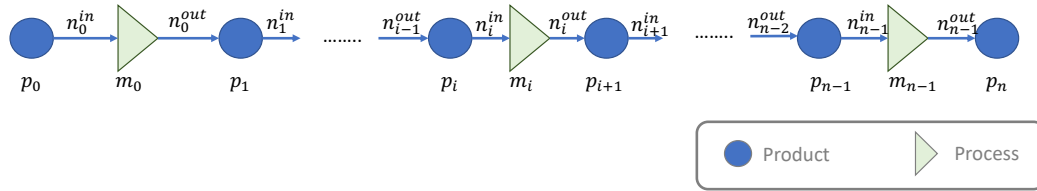
Figure 1: A sample production graph, with manufacturing processes m and products p. Numbers (denoted by n) on edges indicate the quantity consumed or produced by the corresponding manufacturing process.

a seller, a product, a quantity, a delivery time, and a unit price. The sequences of offers and counteroffers in a negotiation are private to the negotiating parties.

In SCML2021, agents negotiations are restricted such that they can only negotiate to buy inputs required for their own production, and to sell outputs produced by their own factory. No other negotiations are allowed; in particular, there are no "middle men" in the SCML2021 world.

The SCM world does not endow agents with utility functions. On the contrary, all utility functions are endogenous, meaning they are engendered by the simulation dynamics and agents' interactions with other agents. Endogenous utility functions are a distinguishing feature of SCML. It is an agent's job to assign utilities to potential contracts, given its unique production capabilities, and then to negotiate with other agents to secure those which are most favorable to them.

In SCML2021, agents consuming the raw material will be endowed with exogenous buy contracts but no exogenous sell contracts, while agents producing the finished product will be endowed with exogenous sell contracts but no exogenous buy contracts. No other agents will be endowed with any exogenous contracts. By design, no agent can turn a profit without negotiating successfully, since no agent is endowed with both exogenous buy and exogenous sell contracts.

Breach Processing When a contract comes due, the simulator tries to execute it (i.e., move products from the seller's inventory to the buyer's, and move money from the buyer's account to the seller's). If this execution fails, either because of insufficient funds on the part of the buyer, insufficient products on the part of the seller, a breach of contract occurs. Figure 2(a) depicts these two possible breach conditions. In both cases, the contract is executed to the extent possible, and the agent in breach of contract is penalized and reported to the breach list.

Bankruptcy Processing If an agent is unable to meet its financial obligations, it is declared bankrupt. The assets of bankrupt agents are liquidated, and their factories are closed (no further production can transpire). They can no longer participate in negotiations. The simulator takes over their outstanding contracts, and fulfills them to the extent possible.

Spot Market The SCM world also simulates a spot market. Generally speaking, the spot market exists so that agents who would otherwise be in breach of contract for insufficient products (funds) can instead buy (sell) as necessary on the spot market at buy (sell) prices, which are always above (below) **trading prices**— an average over the historic prices at which products are traded. In SCML2021 specifically, sellers with insufficient products are forced to buy on the spot market, while buyers with insufficient funds are declared bankrupt immediately, in which case the simulator uses the spot market for liquidating the inventory of bankrupt agents.

Bulletin Board The SCM world contains a world-readable **bulletin board** (see Figure 2(b)) that conveys both static and dynamic information about the game and all factories over the course of the simulation. The static information includes the simulator settings (e.g., number of simulated days), and product information,
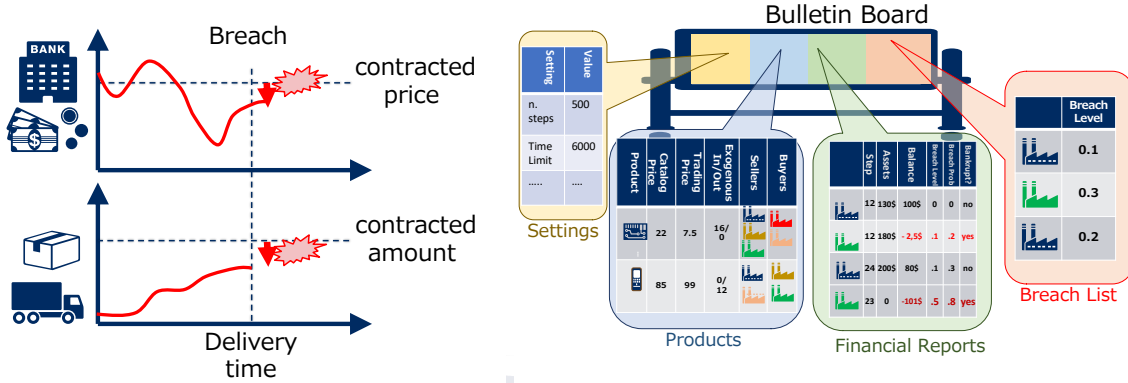
(a) The two potential breach conditions: insufficient funds and insufficient products.

(b) The bulletin board includes Simulator Settings, Product Information, Financial Reports, and the Breach List.

Figure 2: Breach conditions and the bulletin board.

namely a list of the consumers and producers of all products (i.e., all factory's positions in the production graph), and **catalog prices**, one per product, which is a nominal price that represents the starting point of trading prices, and can also be used by agents to guide negotiations. The dynamic information includes a breach list, where breaches of contract are reported; and a financial news section, which is updated only periodically (except in the case of bankruptcy), that reports the financial standing of all factories.

Note that trading prices are not known to the agents. They are maintained by the simulator for use in breach and bankruptcy processing, and for valuing inventory at the end of a game.

The Simulation Each simulation of the SCM world runs for multiple (say, 1000) days. Before the first day, each agent is assigned a private manufacturing profile. In addition, the bulletin board is populated with the production graph information and catalog prices, an initial balance is deposited into each agent's account, and agents are endowed with exogenous contracts. Then, during each day:

1. Agents can engage in multiple (say, 100) rounds of negotiations with their negotiating partners. They can also read the bulletin board, and request negotiations with other agents (for the next day).

2. All contracts that have come due are executed: i.e., products are moved from the seller's inventory to the buyer's, and money is moved from the buyer's account to the seller's.

3. The manufacturing processes on all lines in all factories are run: i.e., inputs are removed from inventory, outputs are stored in inventory, and production costs are subtracted from the factories' accounts.

2 Tournament Mechanics

How to Participate To participate in the Supply Chain Management League (SCML), all you need to do is write and submit code for an autonomous agent that acts as a factory manager. While the production graph will be a chain in SCML2021, with agents managing but one factory with identical lines, your agent should be robust enough to manage any such factory with any manufacturing profile (i.e., any factory assignment and production cost), because its particular profile will vary from simulation to simulation.

How to Compete There will be three separate tracks in SCML2021. All agents will be run in both tracks. In the standard track, at most one instantiation of each team's agent will run in each simulation, together

with an unknown mix of agents prepared by other participants and agents prepared by the organizing committee.

In the collusion track, multiple instantiations of the same team's agent will run during a single simulation. The exact number of instantiations of each will vary across simulations, and will not be announced in advance. In this track, it is perfectly legal for instances of the same agent to collude with one another to try to corner the market, or exhibit other collusive behaviors.

The final track is the OneShot track which is a simplified version explained in details here. This document is only concerned with the standard and collusion tracks.

How to Win An agent's[2]n this section, whenever we speak about an agent we mean its type not its instantiations. performance will be measured by its score. An agent's score will be the turncated mean[3] [4] of its profits in all simulations. The profit of an agent type is the sum of the valuation of all the factories it controls in this simulation[5].

The profit accrued by an agent during one simulation is calculated as follows:

$$\text{Profit} = \frac{\sum_{a \in F} B_N(f) + \epsilon\, I_N(f) - B_0(f)}{\sum_{a \in F} B_0}, \tag{1}$$

where, ϵ is the fraction of trading price at which to value the inventory at the end of the game[6]. F is the set of all factories controlled by instantiations of the agent, $B_0(f)$ and $B_N(f)$ are the factory's balances at the beginning and end of the simulation, respectively, and $I_N(f)$ is the value of the products in the factory's inventory at the end of the game. This value is based on the trading price (see Equation **??**), but to incentive trade, inventory is valued at only half the trading price; that way, it is more profitable on average to sell products rather than hoard them.

The two tracks will be conducted in two rounds, a qualifying round and a final round. All entrants that are not judged to break any of the SCML and ANAC submission rules will be entered into the qualifying rounds. Top-scoring agents in the qualifying round will then be entered in the final round.

The final results will be announced at IJCAI 2021. It is expected that finalists will send a representative to the ANAC workshop at IJCAI 2021, where they will be given the opportunity to give a brief presentation describing their agent.

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[3]The truncated mean will be found by sorting all scores *per agent* and then removing the top and bottom x_t, x_b scores where x_t and x_b are values selected by the organizing committee to balance test efficiency (taking into account as many individual scores as possible in the final agent score) and robustness (insensitivity to outliers or few simulations in which the agent gets extremely high or low scores.)

[4]In SCML2019, the agent's score was the mean.

[5]This is different from the SCML2020 evaluation in which each factory's score was counted separately. In 2021, we are using a consolidated financial statement like evaluation.

[6]In SCML2020, this was fixed at 0.5. In 2021, it is fixed, again, at 0.5.