Industrial symbiosis coordination under asymmetric information via contracts: A game theory-based approach

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1 Introduction

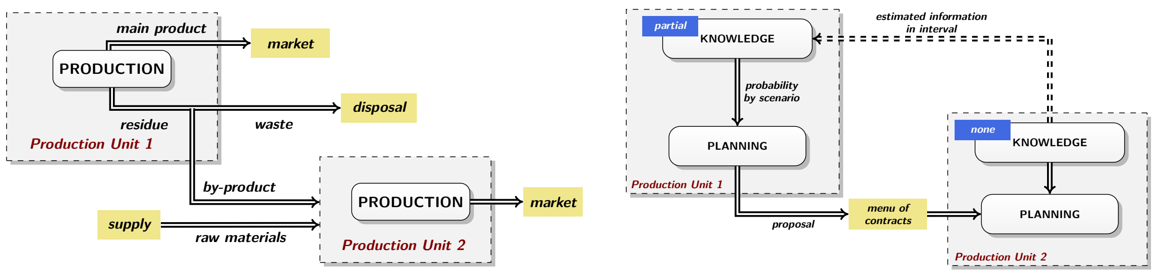
Industrial symbiosis aims to convert production residues into high value-added products. The by-product synergy is a particular configuration of an industrial symbiosis system, where the by-product generated by a production unit are used as raw materials by another production unit. The by-product exchange takes place between two or several (related or autonomous) companies, which requires to align lot-sizing decisions of each involved actor. As long as several production units are involved, issues related to their collaboration and information sharing can occur. The collaboration policies can differ from one industrial symbiosis to another depending on the information each actor is ready to share with its partners. Let us classify the collaboration mechanisms according to the level of information sharing [1]: **(i)** *full information sharing*: centralized collaboration policies, **(ii)** *no information sharing*: no collaboration and, **(iii)** *partial information sharing* (symmetric, one-sided/multilateral asymmetric). One-sided asymmetric information sharing means that one actor, called *leader*, has more information than another one, called *follower*. In the framework of partial information sharing, sensitive information are kept private. It leads to collaboration policies based on the negotiation process, contracts (provided mainly by game theory approaches) or auctions [5].

To the best of our knowledge, no paper deals with collaboration policies in an industrial symbiosis framework, despite the abundant number of industrial joint production systems studied in the literature. In this paper, we investigate a game-theoretic collaboration policy under one-sided asymmetric information sharing between two actors in an industrial symbiosis network, namely one supplier and one receiver of a by-product.

2 Problem statement

Consider an industrial symbiosis single-item lot-sizing problem (ULS-IS) that involve two production units PU1 and PU2, as introduced in [4] and illustrated in Figure 1a. The ULS-IS problem can be assimilated to a classical two-level lot-sizing problem, where the levels (the supplier of by-product and its receiver) are linked by a by-product flow.

Under asymmetric information sharing, let us distinguish three categories of problem parameters depending on their sensitivity degree: known (non-sensitive), determinable (weakly sensitive), and unknown (highly sensitive). In our case, we assume that demands and the by-product inventory capacity are known. Estimated parameters are: the inventory holding costs of both the main product and by-product, the setup cost-holding cost ratios, and the gain of reusing the by-product instead of disposing it of and purchasing raw materials. Note that,



(a) Material flows

(b) Information flows (PU1 leader)

FIG. 1: Diagrams of the considered industrial symbiosis network

all costs being time-independent, the knowledge related to unitary production, disposal and purchasing costs has no impact on designing contracts. In game theoretic-based collaboration policies under one-sided asymmetric information sharing proposed in this paper, we assume that only one parameter is estimated at a time.

3 Collaboration policy under one-sided asymmetric information sharing: A game theory-based approach

In an industrial symbiosis network, the leader and the follower aim to collaborate, i.e. to synchronize their production plans in order to reuse the by-product generated by the supplier, although a collaboration between them is not essential. For this purpose, based on the available knowledge and the estimation of the unknown parameter, the leader proposes a menu of contracts. The unknown parameter follows a known probability distribution defined on a finite and discrete support. For each scenario of the estimated parameter, a contract is provided by the leader, as illustrated in Figure 1b and based on [2, 3]. A contract is composed of a production plan, and a potential side payment, i.e. an amount of money given by the leader to the follower to encourage him/her to accept the contract. The problem is thus represented under the form of a mixed integer linear program solved using a commercial solver.

Numerical experiments are conducted on a large number of heterogeneous instances, generated in accordance with the definition of the by-product synergy. A careful analysis is performed to evaluate the impact of the estimation quality of the unknown parameter (range and probability distribution). Based on the obtained results, the relevance of the game theoretic-based collaborations policies is discussed with respect to the baseline collaboration policies under full and no information sharing.

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