Cooperative capacity planning and resource allocation by mutual Outsourcing using ant algorithm in a decentralized supply chain

Expert Systems with Applications (2009)
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INTRODUCTION

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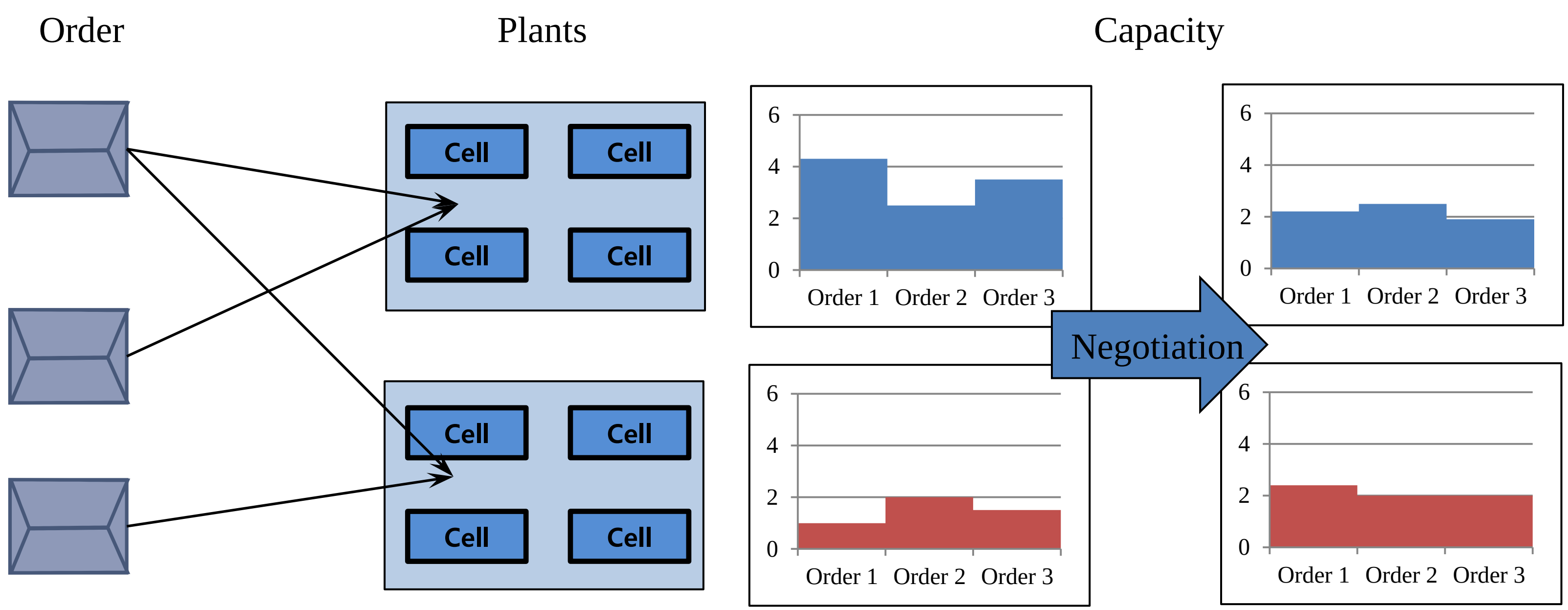
1 Introduction

Introduction

➢ **Capacity planning and resource allocation with negotiation**



The study focuses on

- Capacity planning with negotiation framework
- Allocating resources to fulfill all orders of products in each production period

Literature review

- Bard JF, Srinivasan K, Tirupati D.(1999)
  - Resource allocation + SA approach

- Tiwari MK, Vidyarth NK(2000)
  - Resource allocation + GA approach

- Wang K-J, Lin SH(2002)
  - Resource allocation + Capacity expansion + GA approach

- Wang K-J, Hou TC(2003)
  - Resource allocation + Capacity expansion + Multiple resource + Budget + GA approach

- S.M.Wang, J.C. Chena, K.-J.Wang(2007)
  - Resource allocation + Capacity expansion + Multiple resource + Budget + Inventory + GA approach

2 Problem description

Problem description

- **Problem**
  - The cooperative capacity planning and resource allocation

- **Objective**
  - Maximize the total profit

- **Decision variables**
  - Capacity Planning Decision
  - Resource Allocation Decision

- **Assumptions**
  - the quality of product is not considered
  - no backlogging

Problem description

Parameters

$a_{t,j}$ Configuration relationship between orders and manufacturing cells, a_{tj} {0,1}

$d_{k,j}$ Demand quantity (in pieces) of order j in planning period k, k = {1,2, . . .,p}

$\mu_{t,j}$ Throughput of manufacturing cell t when used to produce order j (in pieces per planning period)

W Working hours of each period of time

$u_{k,t}$ Target utilization of manufacturing cell t in period k

$c_{k,t}$ Costs of purchasing manufacturing cell t in period k

I Capital interest rate

$C`_t$ Unit price of selling capacity of remaining manufacturing cells t of a capacity seller

$C_{t,j}$ Capacity seller's unit price of manufacturing cell t to produce capacity buyer's order j (or, equivalently, the unit cost of resource usage of the capacity buyer)

CC upper bound of initial budget.

R adjustable parameter of price of resource capacity.

P_j unit profit of order j.

Decision variables

$N_{k,t}$ number of manufacturing cell t in period k

$x_{k,t,j}$ quantity produced by manufacturing cell t to meet order j in period k.

$\delta_{k,t}$ increment (or decrement) number of manufacturing cell t from period k 1 to period k.

$N`_{k,t}$ number of remaining manufacturing cell t in period k.

$d`_{k,j}$ number of remaining quantities of order j in period k after task allocation of an individual factory is done.

Problem description

- Formulation – Individual factory capacity planning model
  (a factory with capacity over demand) – demand need to be fulfill – Model 1

Object Function

$$Max \qquad z = \sum_{k=1}^{p} \frac{1}{(1+I)^k} \sum_{t=1}^{v} N`_{k,t} C`_t$$

(1) Obj. : Maximize Total profit

Subject to

$$\sum_{t=1}^{v} a_{tj} x_{ktj} = d_{kj}$$

(2) Capacity balancing equation

$$0 \le \sum_{k=1}^{p} \sum_{t=1}^{v} \frac{c_{kt}\delta_{kt}}{(1+I)^k} \le CC$$

(3) Upper bound of budget

$$N_{kt} - \sum_{j=1}^{n} \frac{a_{tj} x_{ktj}}{W u_{kt} \mu_{tj}} \ge 0$$

(4) Capacity limit of manufacturing cells

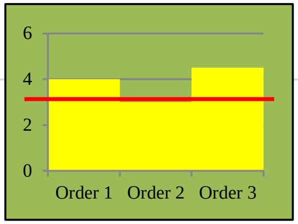
$$N`_{kt} = N_{kt} - \sum_{j=1}^{n} \frac{a_{tj} x_{ktj}}{W u_{kt} \mu_{tj}}$$

(5) Remanding capacity of manufacturing cells

$$\delta_{kt} = N_{kt} - N_{(k-1),t}$$

(6) The change in the number of machines

Problem description



- Formulation – Individual factory capacity planning model
  (a factory with capacity over demand) – demand need not to be fulfill – Model 2

Object Function

$$Max \qquad z = \sum_{k=1}^{p} \sum_{t=1}^{v} \frac{\sum_{j=1}^{n} P_j x_{ktj} - c_{kt}\delta_{kt}}{(1+I)^k}$$

(1) Obj. : Maximize Total profit

Subject to

$$\sum_{t=1}^{v} a_{tj} x_{ktj} \le d_{kj}$$

(2) Capacity balancing equation

$$0 \le \sum_{k=1}^{p} \sum_{t=1}^{v} \frac{c_{kt}\delta_{kt}}{(1+I)^k} \le CC$$

(3) Upper bound of budget

$$N_{kt} - \sum_{j=1}^{n} \frac{a_{tj} x_{ktj}}{W u_{kt} \mu_{tj}} \ge 0$$

(4) Capacity limit of manufacturing cells

$$\delta_{kt} = N_{kt} - N_{(k-1),t}$$

(5) The change in the number of machines

$$N_{kt}, x_{ktj} \in Z^+, \qquad \delta_{kt} \in Z$$

Problem description

- Formulation – Inter-factories capacity planning model
  (a factory with capacity over demand) – Model 3

Object Function

$$Max \qquad z = \sum_{k=1}^{p}\sum_{t=1}^{v}\sum_{j=1}^{n}\frac{(P_j - C_{tj})x_{ktj}}{(1+I)^k}$$

(1) Obj. : Maximize Total profit

Subject to

$$\sum_{t=1}^{v} a_{tj}x_{ktj} \le d`_{kj}$$

(2) Capacity balancing equation

$$N`_{kt} - \sum_{j=1}^{n}\frac{a_{tj}x_{ktj}}{Wu_{kt}\mu_{tj}} \ge 0$$

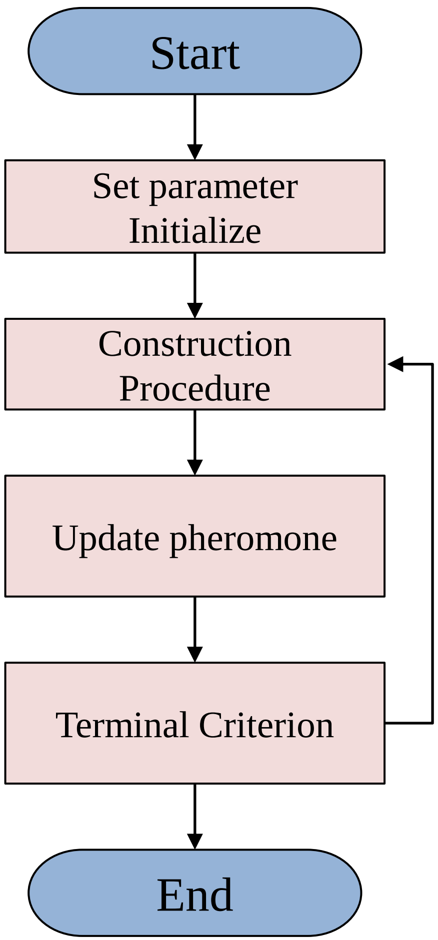
(3) Capacity limit of manufacturing cells

$$N`_{kt}, x_{ktj} \in Z^{+}$$

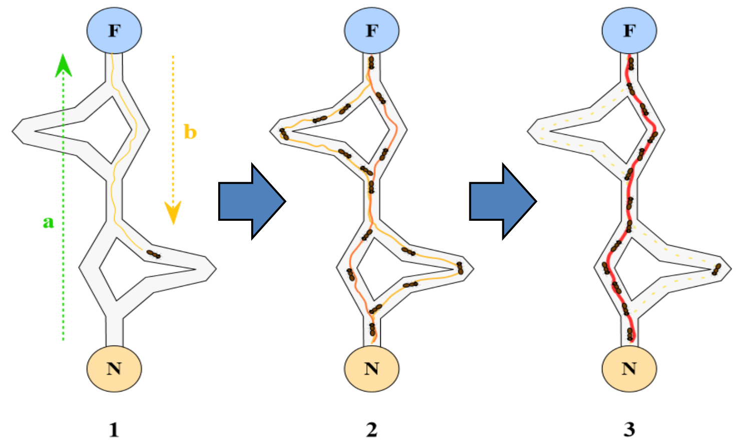
3 Solution algorithms

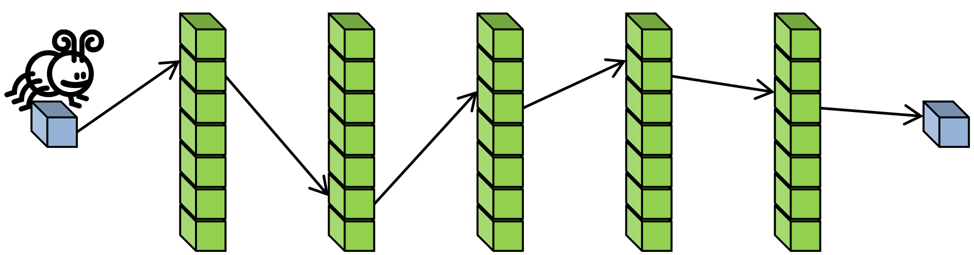
Solution algorithms

- Overall solution approach



- Concept of ant colony optimization algorithms

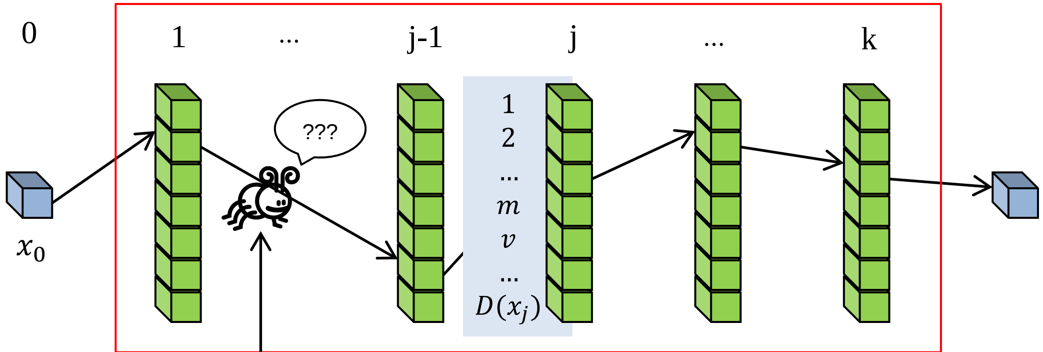




Solution algorithms

- Ant colony algorithm

$SET\ A = \{\langle x_1, v_1\rangle, \dots, \langle x_k, v_k\rangle\}$



$$N_{kt} \geq \sum_{j=1}^{n} \frac{a_{tj} x_{ktj}}{W u_{kt} \mu_{tj}} \geq 0$$

N_{kt} is ceiling integer

Graph G=(V,E)

Amount of pheromone = $\tau_A(\langle x_j, v\rangle) = \tau_{\langle x_{j-1}, m\rangle \in A}(\langle x_{j-1}, m\rangle, \langle x_j, v\rangle)$

Probability of transition = $p_A(\langle X_j, v\rangle) = \dfrac{[\tau_A(\langle X_j, v\rangle)]^{\alpha} [\eta_A(\langle X_j, v\rangle)]^{\beta}}{\sum_{w \in D(x_j)} [\tau_A(\langle X_j, w\rangle)]^{\alpha} [\eta_A(\langle X_j, w\rangle)]^{\beta}}$

단, $[\eta_A(\langle X_j, v\rangle)]^{\beta} = (\frac{1}{D(x_j)})^{\beta}$

Initial solution	β=0	
Model 1	β=0	$\rightarrow \sum_{t=1}^{v} a_{tj} x_{ktj} = d_{kj}$
Model 2,3	β=1	$\rightarrow \sum_{t=1}^{v} a_{tj} x_{ktj} \leq d_{kj}$

Local

$\tau(i,j) \leftarrow (1-\rho) \cdot \tau(i,j) + \Delta\tau(A_k, i, j)$

Global

$\tau(i,j) \leftarrow (1-\gamma) \cdot \tau(i,j) + \Delta\tau(A_l, i, j)$

단, $\Delta\tau(A_k, i, j) \begin{cases} = \frac{1}{TC(A_k)} & if\ \{i,j\} \in A_k \\ = 0 & otherwise \end{cases}$

4 Experiments

Example and results

- Experiments environment
  - Computing power

    P4 CPU / 256MB –Coding : JAVA

Parameters	Value
α (weighting the pheromone)	1
ρ (evaporation rate-local) γ (evaporation rate-global)	0.01
N_{ants} (number of artificial ant)	75
C (number of cycles in a trial)	1000
RF (number of reinforcement cycles)	25

Example and results

➢ **Results**

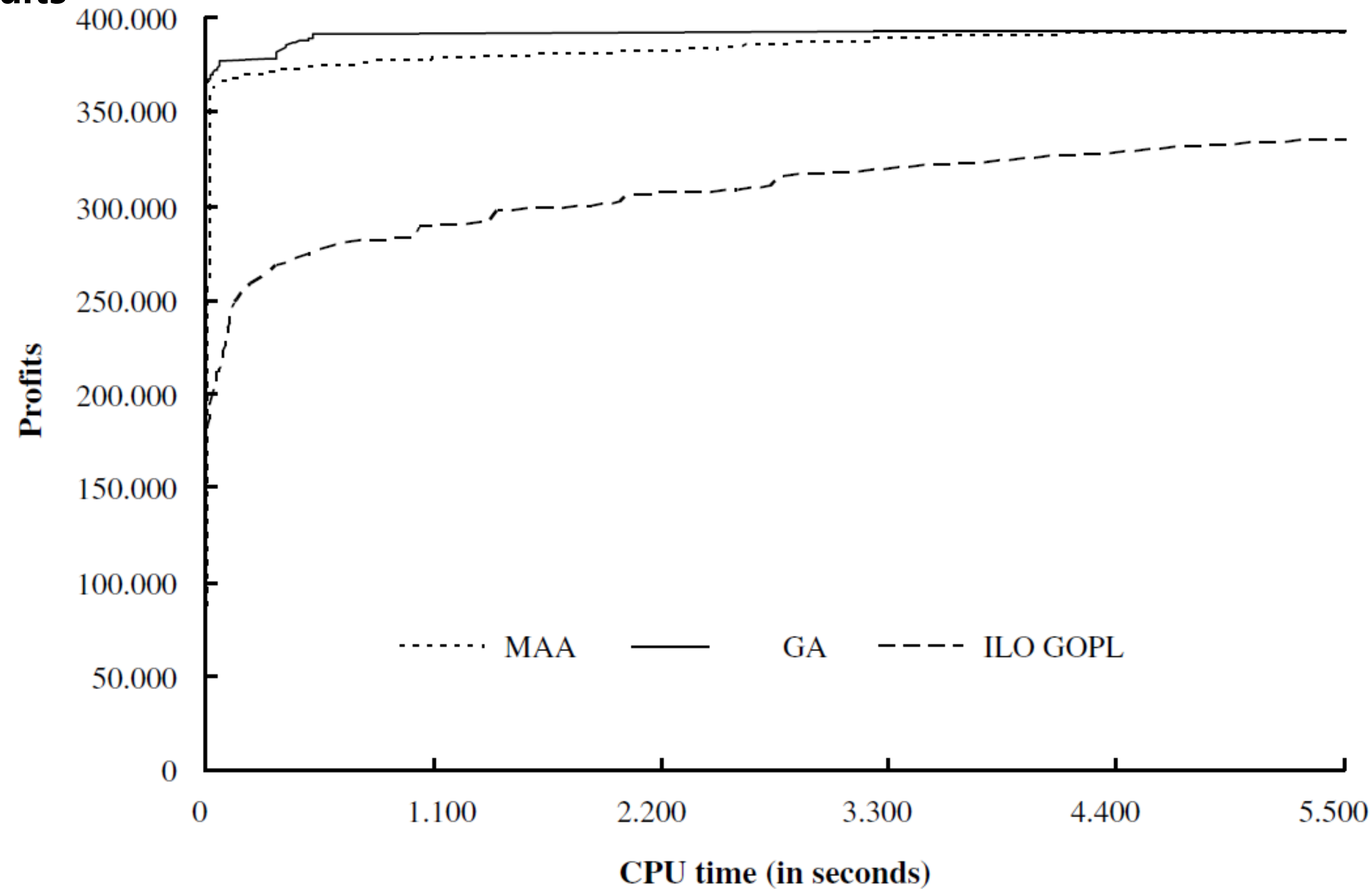


Fig. 6. Objective function evolutions of CPGA, MAA and ILOG OPL.

Example and results

➤ **Results**

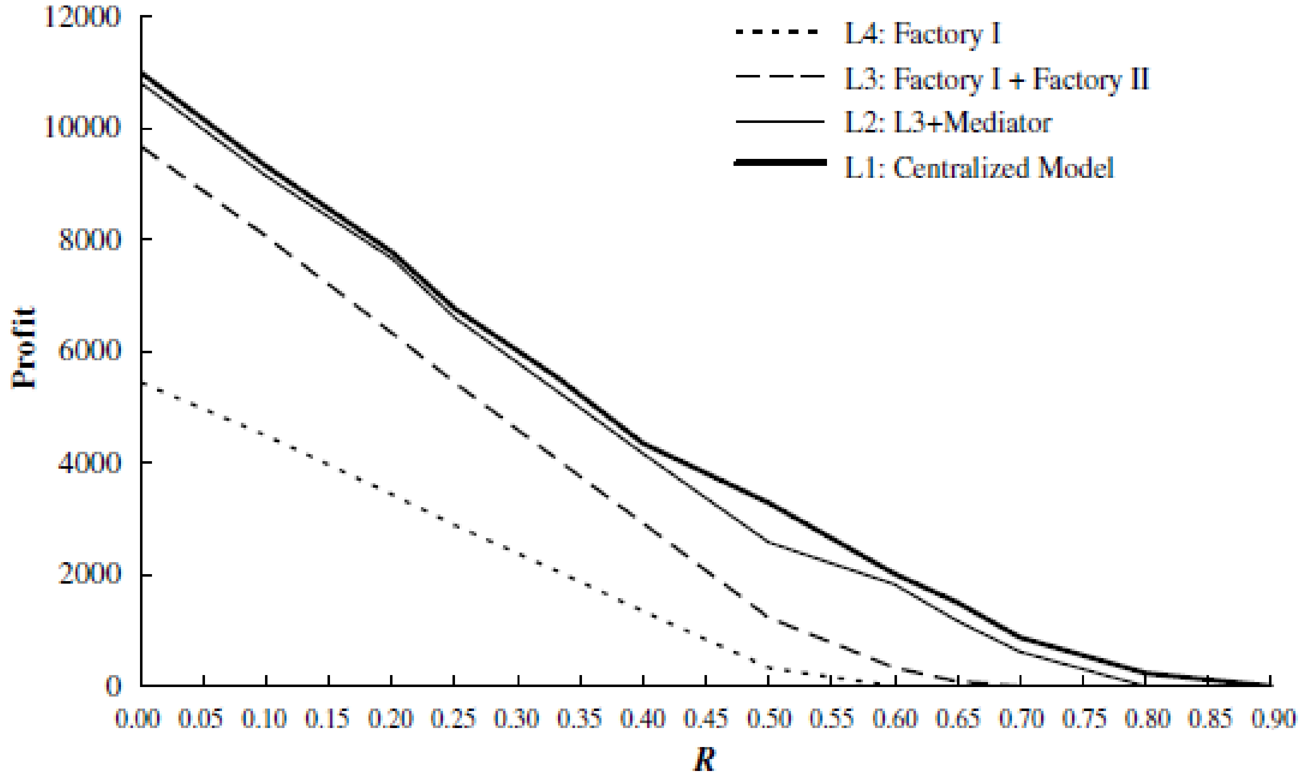


Fig. 7. Profit share structure for different R.

5 Conclusion

Conclusion

- **Conclusion**
  - Presented a MILP Model
  - Suggested ACO approach