INRIA

INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET EN AUTOMATIQUE

Project-Team sagep

Simulation, analysis and management of production systems

Lorraine

THEME 4B

Activity Report

2003

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1. Team

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2. Overall Objectives

The SAGEP team focuses on design, control and evaluation of complex dynamic systems. The main activities developed this year concern two main topics:

- Supply chain. A new paradigm for the design and the management of production systems and projects. The most important problems, specific to supply chains, that have been solved this year concern:
  - the real time scheduling of assembly systems [11],
  - a new approach for the so-called sharing process [31],
  - the selection of partners of supply chains [11].
- Urban traffic. An ongoing thesis is dedicated to a computer aided system to select, in real-time, the fastest path to join two locations in a city, taking into account the traffic. A second objective is the management of cybercar fleet.
  In urban traffic, we proposed a new approach to evaluate the fastest paths between given locations in a city. This approach is a hierarchical approach based on the analysis of data provided by simulation, the simulation software being itself based on the analysis of the urban network (see [20], [21] and [22]).
  Several other scheduling problems (for instance [23] to [27]) have been published in 2003, but concern the work developed in 2002.

3. Scientific Foundations

3.1. The supply chain problems

Key words: *Real time scheduling*, *System modeling*, *System evaluation*, *Assignment*.

Participants: Satyaveer Singh Chauhan, Valery Gordon, Jean-Marie Proth.

At the strategic level, supply chains require a high flexibility in the design of systems. Several models have been developed for the choice of partners when a new supply chain is designed. Depending on the type of system, various constraints apply, and thus numerous models should be studied. Three models have been proposed this year:

1. Selection of providers for productions units, under non convex constraints (see [11] and [13]). This work is the extension of the work carried out in 2001. In this work, we explored the complexity of the problem and proposed some new results.

2. Selection of partners in a three-stage supply chain, knowing that:

   – more than one partner can be selected at each level,
   – investments to increase the production or/and transportation capacities are allowed (see [11]).

3. Selection of partner in a multistage supply chain under the following constraints:

   – only one partner should be selected at each level,
   – investment is not allowed, which means that each partner is allowed to use only his available capacities (see [11]).

   Indeed, such a problem may have no solution.

At the tactical level, two main problems have been solved:

- Real-time scheduling of assembly systems. A simple and efficient algorithm has been proposed. It minimizes the makespan, that is the completion time of the product. It also control the level of Work-In-Process (WIP) as well as the production cycle (see [11]).
- Sharing process in supply chains. In this work we present a supplier-retailer partnership model based on profit sharing. We introduce the fact that customer demand depends upon the retail price and tends to zero as the price of commodity increases. We propose an approach to maximize the combined profit and introduce a risk sharing mechanism.

3.2. Urban traffic

Key words: *Data analysis*, *Real-time decision making system*, *Urban traffic*, *Simulation*.

Participants: Anjali Awasthi, Michel Parent, Jean-Marie Proth.

3.2.1. Urban network traffic simulation

Prediction of accurate travel time plays an important role in dynamic route guidance on urban networks. The dynamic traffic flows entering the network affect the behavior of the system and the free flow movement of vehicles. To study the complex system dynamics of an urban network under varying input flows, we begin with the basic unit of the network called a lane. The first step consists in analyzing of the behavior of a single lane and computing the travel time using the characteristics of the lane, the input flow and the constraints on the output flow. The system analysis of the single lane is then applied to the whole network for studying the transfer of flows inside the network. A dynamic network model has been proposed for the network analysis. A simulation software has been developed using the dynamic network model which generates travel times in the network using the input data as the flows coming at the entrances of the system, the initial system states of the lanes and the characteristics of the network.

The second step consists of estimating fastest paths in urban networks using data analysis. The network data for statistical analysis is generated using a macroscopic traffic flow based simulation software. The input to the software are the input flows and the arc loads (the number of cars in each arc), and the outputs of the software are the various paths joining the origins and the destinations of the network.

The network data obtained from the simulation software is subjected to hybrid clustering followed by canonical correlation analysis. The hybrid clustering comprises of two methods namely K-means analysis and Ward's hierarchical agglomerative clustering. The results of the data analysis are decision rules containing arc loads and input flows that govern the fastest paths on the network. These rules are used for predicting the paths to follow while arriving at the entrances of the network. Before entering the network, the arc loads and input flows provided by the rules are checked inside the network. If agreement is found, then the path obtained from the data analysis is the fastest path otherwise the shortest path is chosen as the fastest path.

Real networks are considerably huge in size and the above approach can be applied to networks of relatively small dimension. The next step of our study is to develop an algorithm for approximating fastest paths on real networks. This would be done by decomposing the real network into small sub-networks and computing the fastest path for the sub-networks using the statistical approach discussed in the paper. The fastest path between any origin destination pair of the real network will be obtained by joining the average fastest paths of the sub-networks and by selecting the fastest path in real-time at the entrance of each sub-network.

See [20], [21] and [22].

3.2.2. Cybercars Fleet Management

The fleet management problem consists of providing vehicles(cybercars) to customers on demand for going from an origin to a destination. These vehicles are fully automated and are driven under the supervision of a Centralized Fleet Management System (CFMS). The objective of the CFMS is to achieve maximal customer satisfaction by providing efficient service and at the same time keeping an eye on system costs. The customer satisfaction is measured in terms of minimum waiting and travel time of the customers which is ensured by optimal scheduling and routing of vehicles. The system cost is kept low by ensuring usage of minimal number of vehicles, avoiding empty movement of vehicles, and close accessibility of stops to pickup and recharging stations.

A simulation model was developed for CFMS to ensure demand responsive routing and scheduling of cybercars. Efficient customer service by CFMS is ensured by optimal performance of the following functionalities:

- division of network into clusters,
- request pooling and scheduling,
- vehicle allotment to requests,
- dynamic vehicle routing,
- allocation of empty vehicles after service.

See [19], [18] and [20].

4. Application Domains

4.1. Supply chain design

Key words: *System modeling*, *System evaluation*.

The results obtained at this level are tools for fast selection of partners in a set of candidates in order to build a consortium that will design and run a supply chain to face new market opportunity.

4.2. Real-time scheduling of assembly systems

Key words: *Real-time scheduling*, *Reactivity*, *Assembly systems*.

The algorithm derived from the research conducted by the SAGEP team allowed to schedule, in real-time, all the activities from customers' requirements to delivery. The application of this algorithm requires strict monitoring of the whole system.

4.3. Urban traffic

Key words: *Traffic optimization*, *Vehicle guidance*.

This work aims at providing a computer aided guidance system in a urban environment. The objective is to find the fastest path, taking into account the state of the traffic.

5. Software

5.1. Software CAD-SC-SL

This software is dedicated to the design of supply chains. It helps managers in their strategic decisions. Currently, it is tested by a russian team from Omsk and will be introduced in the University of Laval (Canada).

5.2. Urban traffic simulation software

This software is used to evaluate the fastest path between each input and each output of a urban network according to the state of the system (number of vehicles in the lanes and input flows in the system).

6. New Results

6.1. Real-time scheduling in assembly systems

A new algorithm has been developed this year. Simple and efficient, it minimizes the completion time of customers' requirements while controlling the Work-In-Process (WIP) in assembly systems.

6.2. Sharing process

An important approach has been proposed to introduce a sharing process when designing a supply chain. It aims at maximizing the global benefit and sharing this benefit among partners according to their investment level.

6.3. Guidance in urban traffic

A process to derive guidance rules from simulation results has been proposed. This process is based on statistics and data analyses.

8. Other Grants and Activities

8.1. IMARA

Participants: Anjali Awasthi, Michel Parent, Jean-Marie Proth.

SAGEP is working on urban traffic with the project IMARA from INRIA. The current activity of SAGEP consists in developing a computer aided guidance system in urban environment.

8.2. INTAS project no217

Participants: Anjali Awasthi, Satyaveer Singh Chauhan, Jean-Marie Proth.

SAGEP is the leader of this project. Participants are :

- the University of Osnabrueck (Germany),
- the University of Technology of Troyes (France) replaced by the Ecole des Mines of Saint-Etienne (France) since October 2003,
- the Institute of Engineering Cybernetics of Minsk (Belarus),
- the Institute of Mathematics of Minsk (Belarus),
- the Institute of Informational Technologies and Applied Mathematics of Omsk (Russia),
- the Scientific Center for Machine Mechanics Problems of Minsk (Belarus),
- the Sobolev Institute of Mathematics of Novosibirsk (Russia).

This group aims at developing scheduling and assignment models in random environments. This research is application oriented, and the application domains are communication, production, logistics and computer aided design.

9. Dissemination

9.1. Organization of a NATO Advanced Study Institute (NATO-ASI)

Participants: Armelle Demange, Jean-Marie Proth, Christel Wiemert.

The goal of this Institute, codirected by Professor Eugene Levner (Holon, Israel) and Jean-Marie Proth, was to introduce modern management systems in marine ecosystems management. This NATO-ASI attracted 72 scientists specialized in management and marine ecosystems from France, USA, Canada, Russia, Ukraine, Egypt, Israel, Greece, etc. The NATO-ASI took place at INRIA Sophia Antipolis, on October 1-10, 2003.

9.2. Journal editorial committee

J-M. Proth belongs to the editorial committee of the "International Journal of Production Economics" and the "Journal of Intelligent manufacturing".

9.3. INTAS Workshop

SAGEP organized the second INTAS Workshop in Osnabruek (Germany) on September 8-9, 2003.

9.4. Book in preparation

A book on the design of production systems is in preparation and will be published in 2004. It focuses on system layout and line balancing.

9.5. Invited talks

- "Supply chain design" at the Department of Industrial and Management Engineering, Indian Institute of Technology (IIT), Kanpur (India), January 2003 (S.S. Chauhan).
- "Strategic supply chain design" at the Department of Economics and Management, University of Carlos III, Madrid (Spain), April 2003 (S.S. Chauhan).
- Conference on "New directions of research in industrial engineering", Troyes (France), December 5, 2003 (J-M. Proth).

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