SIMULATION AND FORECASTING IN INTERMODAL CONTAINER TERMINAL

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ABSTRACT

The goal of this paper is to present the first results in the development of a methodology to integrate simulation, forecasting and planning to support day by day and long term decisions for operators working in intermodal container terminals.

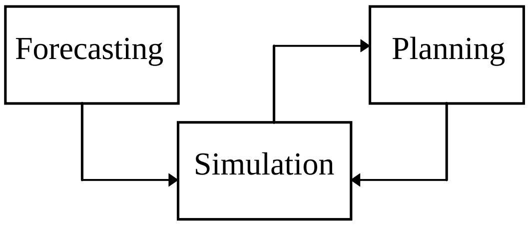
INTRODUCTION

The amount of work a container terminal deals with depends on the quantity of containers in transit (I/O flow). Every day containers arrive at the terminal by train, ship or truck and are stored in the terminal area. Then, the same containers leave the terminal by train, ship or truck to reach their final destination.

One of the main problems in an intermodal container terminal seems to be resources allocation and scheduling (in term of people, machines and other terminal resources) for ship loading and unloading tasks. However, this issue is strongly connected with how effective is the policy for storing containers, especially in relation to expected import/export events. About this matter the staff coordinating the terminal activity reports that, despite of the availability of various communications media (telephone, fax, radio, etc...) which provide information about vessel arrival time and container load, "the daily I/O flow appears to be unpredictable".

Our proposal to solve these problems is the definition of a system composed by three different but strictly connected modules:

- A simulation module to model the terminal in terms of entities and processes.
- A forecasting module able to analyze historical data and to predict future events.
- A planning system able to optimize loading/unloading operations and the container locations.



The main variables to be kept in consideration in this architecture are the current terminal configuration (in terms of container locations), the scheduled operation (in terms of vessels to be loaded/unloaded), the storage policy and the forecast events (in terms of expected flow of ships and containers).

The goals of the system are:

- Evaluation of alternative ships loading and unloading sequences in term of time and costs.
- Evaluation of alternative resource allocations procedures.
- Evaluation of different storage policies both in terms of space and cost of operations.

THE SIMULATION MODULE

The simulation module is charged with a realistic reproduction of the activities and flows that occur inside the terminal. It allows managers and engineers to experiment and compare different policies and techniques before their implementation.

It provides also a graphical interface in order to have easy access to the current state of the simulated terminal and to simulate particular events (fig. 1).

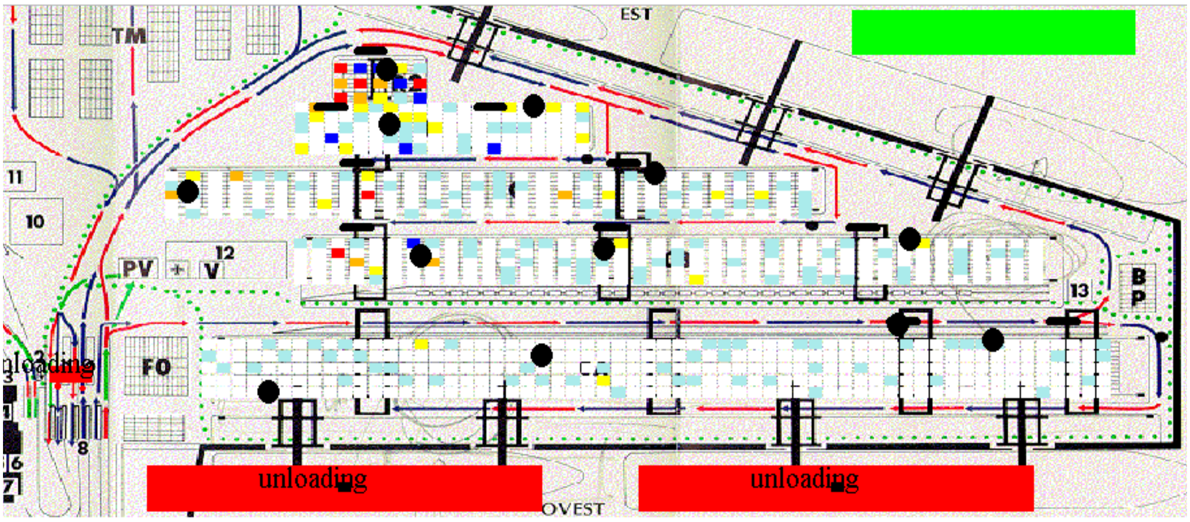


Fig. 1 Simulator graphical interface

An important application of the simulator is related to the problem of estimating cost functions and measures of performance not easily computable. For example inside the terminal, containers are displaced by using different vehicles: a set of small trucks and some big cranes. Both of them, due to their physical constraints, have not complete access to all the positions in the terminal (e.g. quay-cranes move on rail tracks). Moreover, containers are stacked up to the fifth level, with consequent problems of restoring them when container at lower levels have to be displaced.

These peculiar characteristics of the terminals imply that the real cost of each container displacement is a complex function of several factors, whose influence has to be accurately investigated. Therefore, a simulation tool, able to represent different scenarios is indispensable for a correct modeling of the problem.

In our system we are mainly interested to model two different scenarios, at different degrees of abstraction:

- A *long-term* scenario useful to analyze the occupancy level of the yard and to evaluate alternative storage policies.
- A *short-term* scenario useful to describe and evaluate day by day loading and unloading operations.

For the long term simulation we are interested to compute and evaluate the future state of the terminal. The input data for this kind of simulation are:

- current terminal configuration in term of occupancy level
- the expected plan of ship arrivals.
- predictions from the forecasting system in term of expected import/export flows.
- a storage policy based on some reservation/allocation criteria for all the different areas inside the terminal.

Starting from these initial conditions we run the simulation in order to produce some possible final terminal state. At this step we can make an evaluation of the storage policy adopted in the experiment. Our cost function is based on different factors such as the ratio between import and export areas, the violation of the storage criteria, some index of performance of the terminal equipment.

The *short-term* simulation takes into account additional entities at a lower detail such as ships, and terminal resources in terms of cranes and manpower. External events like trains and trucks arrivals are expected to happen with a distribution suggested by the forecasting system. The main goal of this module is to evaluate the cost of a given loading/unloading policy. The evaluated cost function is a combination of total time elapsed, the level of resources allocation and use and the number of conflicts generated for the cranes inside the terminal. A conflict, in our system, is a configuration where different loading/unloading operations must be executed at the same time in the same area of the terminal.

In our architecture the simulation module is then a key factor for an effective design and evaluation of terminal control policy: it results indispensable to provide information to the planning system charged with defining and optimizing control techniques and at the same time to evaluate the impact of these policies on the terminal activity.

THE FORECASTING MODULE

It is envisaged that a system able to estimate the daily I/O flow some days in advance could help the work of the staff involved in terminal resource planning and would drastically reduce the company running costs.

The basic idea is to use *existing data sets* which were collected over the last years for accounting purposes: these data give a daily snapshot of the terminal activity.

In all, the data set describes naval companies I/O flow at different degrees of detail (total number of containers, number of export containers (partitioned by size/destination), number of import containers (partitioned by size/destination), number of full and empty containers, etc.).

The forecasting module intends to integrate two different estimators based on different kinds of information:

1. a dynamic estimator which models the time evolution of the global traffic for the different companies and ships
2. an estimator of the container flow occurring in the terminal since some weeks before the ship's arrival. For the export containers, for example, the containers flow starts some weeks before the ship arrival date and depends on the number of missing days. In principle, the closest the ship arrival date the highest the number of containers that come into the terminal for that ship.

The forecasting system is based on methods of statistical multivariate analysis, time series analysis (Box, Jenkins, Reinsel, 1994) and neural networks (Vemuri, Rogers, 1993). In particular it deals with the problem of model updating by employing techniques of recursive identification in order to cope with the time varying phenomena that concern the economical activity of the terminal.

At the current state of the work we have analyzed data concerning a single navigation enterprise. We employ a linear ARIMA (auto regressive integrated moving average) model for the first estimator: it returns the number of expected container to be loaded at next ship's arrival as a function of past loadings (fig. 2). The second estimator is implemented by a local regression model (Cleveland et al. 1993). It returns the percentage of total number of container expected to enter the terminal by truck as a function of time missing to ship's ETA (expected time of arrival) (fig.3).

The final forecast is made by combining both the estimations (Jacobs, 1995). In fig. 4 we represent how the estimation on the number of containers to be finally loaded on the next ship (continuos line) changes as new containers arrive by truck into the terminal. Let us note how the information due to time distribution of truck arrivals may influence and sometimes strongly improve the prediction of the first estimator.

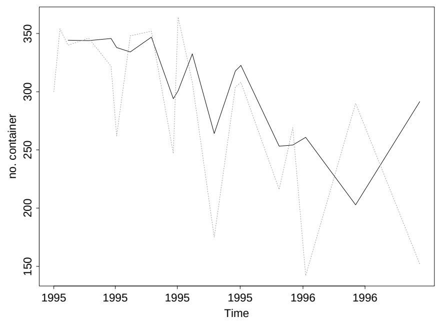


fig. 2 Time series estimation

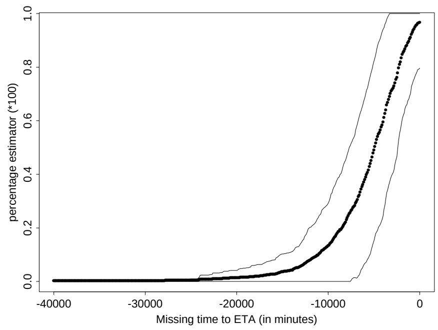


fig. 3 Truck flow model estimator (percentage vs. time)

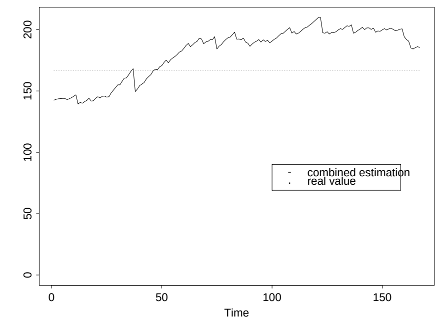


fig. 4 Forecast by combination of estimators (real value in dotted line, forecast in continuos line)

The amount of information provided by the forecasting module will be one of the inputs of the simulation modules in order to better estimate the number of external events (in term of requests for container displacement) that the system have to manage during the loading and the unloading phase of a given set of ships.

THE PLANNING SYSTEM

The main policies to be planned and scheduled in the terminal are:

- how to stock containers in the terminal in an optimal manner (yard planning)
- how to load and unload containers in an optimal manner.

It results evident how a good performance of the second activity is strictly related to a good result in the first one. In addition, time is not the only parameter to evaluate a ship loading/unloading operation because an other possible way to evaluate the result of this operation is the new state of the terminal. A good planning system must be able to evaluate the costs of a terminal operation sequence both in term of effective costs and in term of final state of the terminal because the quality of the final terminal state could increase or decrease the costs of the following operations.

The decision where a container is to be located in the stocking area depends on many parameters: the present occupancy level of the container parking area, the final destination of the containers, the next carrier and the best position to load the containers, the containers' size, the container content and so on.

The problem becomes still more significant because the parking area is overcrowded.

This problem is usually solved by allocating some terminal sub-areas to the containers with a given destination.

The objective is to reduce operative time and costs introducing some methodologies to decide and evaluate containers parking strategy.

Automatic stocking policy (automatic parking) are usually based on a set of rules and constraints. The basic idea is to book some terminal sub-area for containers with the same features and to fill these area with a fixed methodology (e.g. form left to right, first on the floor and after on top etc.) An important point to notice is that a booked area is not already occupied by the "real" containers and that it is always possible to change its destination. Our simulation and planning system is also able to analyze and evaluate stocking policy and we are investigating the possibility of automating a part of the sub-area allocation process. In particular, some search techniques typical of artificial intelligence state of the art have been applied to this problem.

The problem of optimal loading and unloading will be seen at the high level of resource allocation and management. This problem is hard to solve. Taking the example of ship loading, it can be shown that, fixing the order in which the containers have to be loaded and which resources are used for handling the containers, the problem is the NP-hard job-shop scheduling. The resolution of the real loading problems is even more complex since the final place of each container, the used resources and the containers loading order have to be decided. For solving this problem, we intend to develop methods based on advanced optimization techniques (Taillard, 1994), (Morton, Pentico, 1993) Expecially, we will take into consideration that some information is known only up to a certain degree.

CONCLUSION

One major goal for the management of an intermodal terminal is to increase productivity and decrease costs at the greater extent. All over the world an always increasing amount of terminals and port invest in technology to improve their efficiency (Hayuth, Pollatscheck, Roll, 1994) (Sheikh, 1987). This paper shows how this goal may be pursued by integrating methodologies of artificial intelligence, simulation and production management.

ACKNOWLEDGEMENTS

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BIOGRAPHY

Luca Maria Gambardella is research director at IDSIA, Istituto Dalle Molle di Studi sull’intelligenza Artificiale, a private institute located in Lugano supported also by Canton Ticino and Swiss Confederation. His major research and practical experiences are in the area of machine learning and adaptive systems applied to robotics and optimization problems. He is the leader of several research and applied projects.