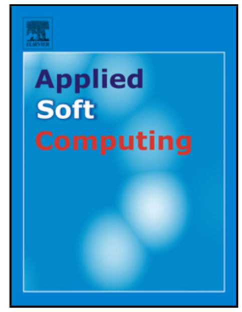
Accepted Manuscript



Title: A Hybrid Approach based on Genetic Algorithms and (Max, +) Algebra for Network Applications

Author: id="aut0005" author-id="S1568494617300108-1f2385bcd64bd80beb243287b4d25d92" biographyid="vt0005"> Karla Quintero id="aut0010" author-id="S1568494617300108-e3fcd7717f0440a0f28f7363484c4a70" biographyid="vt0010"> José Aguilar id="aut0015" author-id="S1568494617300108-8952f9c84f957d08c9f430c8f78edfd1" biographyid="vt0015"> Eric Niel

PII:	S1568-4946(17)30010-8
DOI:	http://dx.doi.org/doi:10.1016/j.asoc.2017.01.006
Reference:	ASOC 4000
To appear in:	*Applied Soft Computing*
Received date:	14-9-2015
Revised date:	9-9-2016
Accepted date:	3-1-2017

Please cite this article as: Karla Quintero, José Aguilar, Eric Niel, A Hybrid Approach based on Genetic Algorithms and (Max, plus) Algebra for Network Applications, *<![CDATA[Applied Soft Computing Journal]]>* (2017), http://dx.doi.org/10.1016/j.asoc.2017.01.006

A Hybrid Approach based on Genetic Algorithms and (Max, +) Algebra for Network Applications

Karla Quintero, José Aguilar, *Member, IEEE,* and Eric Niel.

***Abstract*—The following work addresses the problem of scheduling operations on a flow network, as well as alignment (path) allocation. This is a multi-objective problem, and this paper proposes a solution method through a hybrid approach based on a genetic algorithm in conjunction with (max,+) algebra. A concise system abstraction is proposed through a non-linear (max,+) model. This model describes the main optimization constraints which dictate the behavior of the mutation and crossover operations in the genetic algorithm. Additionally, each individual in the population represents the value assignment of the decision variables, which linearizes the (max,+) model. A hierarchic genetic structure is proposed for individuals such that variable dependence is modeled. For each individual, the (max,+)-linear model is solved through a matrix product which determines the daters for alignment enabling for transfer operations. The study is extendable to complex net-structured systems of different nature.**

***Index Terms*—(max,+) algebra, genetic algorithms, artificial intelligence, flow networks, system modeling.**

I. Introduction

THE problem addressed herein is of a flow network with numerous operations to be carried out in an infrastructure with limited resources. The case study is represented by an oil pipeline network and the results are extendable to systems of different nature such as manufacturing systems, transportation networks, and telecommunications applications. The main difficulties with such complex systems sharing resources is that they are characterized by conflict and/or synchronization phenomena.

A. Case study

The case study is an oil seaport for export, however the work generically covers flow network operations, and can be transposed to systems of different nature such as production manufacturing and transportation, for example. The oil must be transferred from source points (i.e. tanks) to destination points (i.e. docks). A set of clients (i.e. tankers) must be processed in a time horizon and, for each one, if the deadline is exceeded, the seaport incurs into a penalty per hour of delay. Late service is costly, representing thousands of dollars in financial penalties per client per hour of delay.

Karla Quintero is with INSA Lyon, 69621, France and with the ULA, Mérida, Venezuela (corresponding author, phone: +33 (0)7 87 64 58 85; e-mail: karla-rossa.quintero-garcia@insa-lyon.fr).

José Aguilar is with the ULA, Mérida, 5101, Venezuela (e-mail: aguilar@ula.ve). Additionally, he is currently Prometeo Researcher at the Universidad Técnica Particular de Loja, Ecuador.

Eric Niel is with the INSA, Lyon, 69621, France (e-mail: eric.niel@insa-lyon.fr).

In order to serve a client, a pipeline alignment must be chosen by a human supervision operator. To enable it, all valves in it must be opened and all adjacent valves must be closed[1]. In the following, resources are represented by the valves in the network, which provide the means to control oil flow.

System supervision is often carried out based on the operators' expertise. Decision making involves selecting an alignment for each client and scheduling oil transfer operations, also called *requests*, as well as maintenance operations on valves. It is considered that a maintenance schedule has been previously determined, and that such dates should be respected as much as possible. Delay on maintenance operations, may, however lead to minimize penalties when scheduling requests. This compromise among objectives is rarely trivial for operators, who deciding on real time basis with an intricate network composed of hundreds of valves.

For the purposes herein, it is supposed that possible alignments for transfer operations are known. These alignment candidates for a specific client can be easily deduced based on the tanks containing the required product, and the docks with the physical capacity for serving the tanker given its size.

B. Previous work

Previous work on penalty minimization for the case study include [1], [2], [3], and [4]. In [1], a non-linear (max,+) model was proposed to minimize penalties related to transfer operations, while considering previously fixed alignments and non-flexible maintenance activities. [2], and [3] explored some linearizations of such model based on potential penalties and operations' criticality, respectively. Finally, in [4], alignment selection was incorporated into the mono-objective optimization problem.

On the network, resources are limited and the number of operations to be carried out (for transfer and maintenance) is considerably high. Therefore, resource exploitation in order to satisfy requests has an impact on the overall performance of the network penalty-wise. The underlying resource allocation problem has been addressed in various fields, including: transportation [5], manufacturing production systems [6], power management [7], and hospital personnel management [8].

Resource allocation conflicts belong to classic operations research problems that can be specially addressed by discrete event systems approaches such as Petri nets. In these representations, conflicts can be solved through a routing policy, i.e. a criterion allowing the choice of a transition

[1]since no product mixture is allowed.