Process Plan Optimization using a Genetic Algorithm

Fabian Märki[1 2], Manfred Vogel[1] and Martin Fischer[2]

[1] Institute 4D Technologies and DataSpaces, Fachhochschule Nordwestschweiz
Klosterzelgstrasse 2, 5210 Windisch, Switzerland
manfred.vogel@fhnw.ch
[2] Department of Civil and Environmental Engineering
Center for Integrated Facility Engineering, Stanford University
Building 550 Room 553H, Stanford CA 94305-4020, USA
{fischer, markif}@stanford.edu

In this paper we present our ongoing research project GAPO (Genetic Algorithm Process Optimization) that focuses on the development of an optimization module for process plans.

GAPO is part of a 4D-Toolbox that conflates different modules for the 4D planning of construction projects. Among other modules, the 4D-Toolbox consists of a DES (Discrete Event Simulator) that automatically sequences activities into a network plan [3] taking structural and process constraints into account. Thereafter, GAPO is used to optimize the generated network plan in terms of time, cost and resource management forming a multiple criteria optimized process plan [4] This process plan can then be joined with the 3D-Model of the construction project - forming a 4D Model - and visualized through the 4D-Player, another module of our 4D-Toolbox.

GAPO is based on a Genetic Algorithm (GA) approach to perform its optimization. GA's are a class of heuristic search methods based on the Darwinian principle of evolution. They mimic and exploit the genetic dynamics underlying natural evolution to search for optimal solutions of general combinatorial optimization problems [1].

Our Evolution Model starts with an initial population of randomly generated process plans. A subsequent population will then be assembled using five strategies which can be weighted by the user. A fraction q of the best individuals will be directly passed to the next population. This guarantees that the quality of the most suited candidates will monotonically increase from generation to generation. A second fraction r of individuals will be passed to the next population after a mutation. On one side, this process opposes early convergence in a local optimum and thereby helps to open new search regions. On the other side, it also allows a fine tuning of suitable solutions by applying small chances on them. A third fraction s of the new population is created by recombining individuals from the old generation. This process forces convergence into an optimum. A fourth fraction t is created by recombining individuals but instead of passing them di-

[3] Sequenced activities with predecessor relationships.
[4] Network plan with time and resource allocations.

E. K. Burke, H. Rudová (Eds.): PATAT 2006, pp. 528–531. ISBN 80-210-3726-1.

rectly into the new population the new individual is mutated beforehand. Last, a fraction u of the new population is created randomly. This process also helps to open new search regions and prevents early convergence in a local optimum [2].

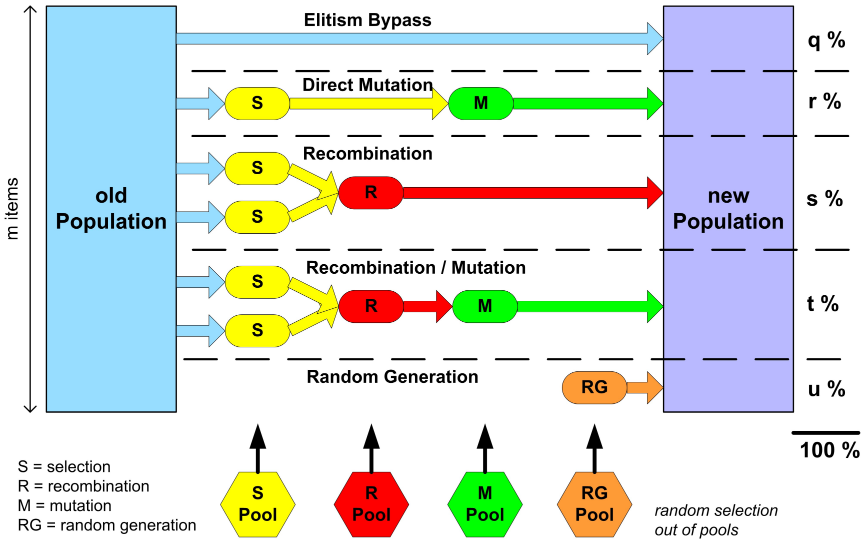

Fig. 1. GAPO Evolution Model

The data structure of a process plan genotype is kept very simple. At the moment, it consists of three arrays. The first array represents the sequence of how the scheduling algorithm should schedule the activities. The second array defines the position where the scheduling algorithm starts to search for a location where the activity can be performed without violating a resource constraint. By definition, this position is between the end of the latest predecessor of the handled activity and the end of the latest scheduled activity. If it is not possible to schedule the activity within this range, it will be added at the end of the schedule as the latest activity. The third array defines the amount of the resources that are assigned to the activity. This representation allows us to use standard mutation and recombination operators [3]. Furthermore, a recombination can also be done by recombining arrays of different individuals.

In the presentation we will show how GAPO is used to optimize construction process plans. This will be done by using our first feasibility study which is based on a real construction project.

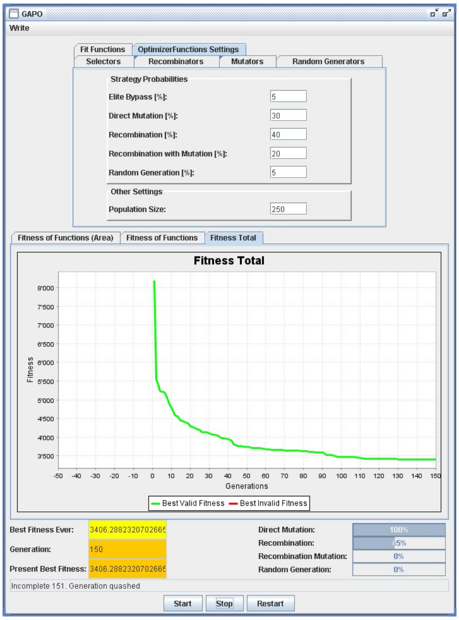

Fig. 2. Screenshot of GAPO's user interface

To further push research on process plan optimization, collaboration between the CIFE[5] and the *i*4D*s*[6] has been established. One of the goals addressed is the development of a GAPO module allowing the optimization of arbitrary process plans. Furthermore, we will also introduce more mechanisms that enable the user to give the optimization a desired direction and consequently have more control over the outcome of the optimization.

Beside the optimization itself, we also work on the integration of a variation study that will take place during the optimization process. The idea of this variation study is to enable GAPO to take decision possibilities into account and give the user a feedback about which decisions would be favourable in terms of process planning [4]. In the current development cycle, we consider the following variations:

– A change in the quantities of the resources used within a resource group
– A change in the resource group assigned to an activity

Candidates for further variations are:

– A change in the process method used to perform a task

[5] Center for Integrated Facility Engineering, Stanford University
[6] Institute 4D-Technologies and Data Spaces, University of Applied Sciences Northwestern Switzerland

– A change in the design of the construction project

Our long term goal is to provide a GAPO module that can be handled by the user as a black box, not requiring any knowledge about optimization, Genetic Algorithms and the like. This would simplify its usage and would also allow using it in other project planning applications.

References

1. Coley, D. A. An Introduction to Genetic Algorithms for Scientists and Engineers. World Scientific Publishing, 1999.
2. Gonçalves, J. F., Mendes, J.J.M., Resende, M. G. C. A hybrid genetic algorithm for the job shop scheduling problem. AT&T Labs Research Technical Report TD-5EAL6J, AT&T Labs Research, 2002.
3. Chevreux, B. Genetische Algorithmen zur Moleklstrukturoptimierung. Universitt Heidelberg, 1997. http://www.chevreux.org/diplom/node5.html Last retrieved 05/08/2006.
4. Kam, C. Dynamic Decision Breakdown Structure Ontology, Methodology, and Frame-work for Information Management in Support of Decision-Enabling Tasks in the Building Industry. Civil and Environmental Engineering of Stanford University, 2005.