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Improving Wedelin’s Heuristic with Sensitivity Analysis

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Abstract

Heuristic is one of the important techniques designed to find quickly good feasible solutions for hard integer programs. Most heuristics depend on a solution of the relaxed linear program. Another approach, Lagrangian relaxation offers a number of important advantages over linear programming [4], namely it is extremely fast for solving large problems. One of the Lagrangian based heuristics is Wedelin’s heuristic [10], which works for the limited class of 0-1 integer programs. It is designed for problems with a specific form ($\min_{x \in \{0,1\}^n} \{c^T x | Ax = b\}$ with coefficients of A in $\{0, 1\}$ and b integral) which prevents its applicability on many problems. Thus to tackle problems with more general structures, [1] presents a generalized Wedelin’s heuristic for integer programming. The performance of this method depends crucially on the choice of its numerous parameters (number of iterations, degree of approximation, history of the *preference matrix*, and others). To adjust these parameters and learn which ones have important influence on whether a solution is found and its quality, we conduct sensitivity analysis combined with a metaheuristic. We choose the Morris method [8] to select parameters providing a feasible/good solutions on a family of instances, and the *genetic optimization using derivatives* (**genoud**) method [7] to find the best solution in limited time for a specific instance. The Morris method consists in discretizing the input space for each parameter, then performing a given number of *One At a Time* random designs (each input parameter is varied while fixing the others). The repetition of these steps allows the estimation of elementary effects for each parameter, and consequently the sensitivity indices [5]. **genoud** combines an evolutionary algorithm method with a derivative based (quasi-Newton) method to solve difficult optimization problems. These difficulties often arise when the objective function is a nonlinear function of the continuous parameters and not globally concave having multiple local optima [7].

We have implemented a C++ parallel version of Wedelin’s heuristic based on [1]. The solver called **baryonyx**¹ has two execution modes: solver mode and optimizer mode. In the solver mode, **baryonyx** runs once trying to satisfy all the constraints. In the optimizer mode, it runs in parallel according to the number of processors, and tries to satisfy all the constraints and to optimize the solution at each run, reporting the best solution found for all runs when it reaches its time limit. Concerning parameters, Morris and **genoud** methods are implemented in R packages. We use Morris package to find useful parameters. Once found, we fix other parameters and we let **genoud** adjusts the useful ones in order to get the best solution within a given time limit. We compare **baryonyx** with exact solver IBM ILOG **cplex** and with two local search methods: a 4-flip neighborhood local search algorithm [9] and an hybrid mathematical programming solver **LocalSolver** [2] which is a simulated annealing based on ejection chain moves specialized for maintaining the feasibility of Boolean constraints and an efficient incremental evaluation using a directed acyclic graph. The following Tables show that **baryonyx** is competitive with the existing solvers on a Set Partitioning Problem (SPP) benchmark [3], but has difficulties on a Mixed Fruit-Vegetable Crop Allocation Problem (MFVCAP) [6].

¹<https://github.com/quesnel/baryonyx>

(600/3600 sec CPU time limit on 2.5GHz Intel XEON using 1 core, except 7200s Borndörfer)

SPP Instance	Cplex12.6	LocalSolver3.1	Borndörfer	Umetani	baryonyx
v0415 (600s)	2,429,415	2,429,415	2,429,415	2,429,568	2,432,717
v0416 (600s)	2,725,602	2,728,391	2,725,602	2,726,156	2,730,390
v0417 (600s)	2,611,518	2,617,387	2,611,518	2,611,518	2,614,359
v0418 (600s)	2,845,425	2,846,265	2,845,425	2,845,425	2,848,692
v0419 (600s)	2,590,326	2,590,511	2,590,326	2,590,326	2,592,139
v0420 (600s)	1,696,889	1,696,889	1,696,889	1,696,889	1,697,954
v0421 (600s)	1,853,951	1,853,951	1,853,951	1,853,951	1,855,344
v1616 (600s)	1,006,460	1,051,749	1,006,460	1,007,402	1,019,799
v1617 (600s)	1,102,586	1,181,503	1,102,586	1,103,651	1,120,193
v1618 (600s)	1,153,871	1,221,162	1,154,458	1,155,986	1,172,519
v1619 (600s)	1,156,338	1,221,960	1,156,338	1,157,537	∞
v1620 (600s)	1,140,604	1,230,809	1,140,604	1,141,976	1,155,197
v1621 (600s)	825,563	838,192	825,563	825,605	832,545
v1622 (600s)	793,445	805,346	793,445	793,708	801,029
t0415 (600s)	5,339,422	∞	5,590,096	5,572,626	5,404,140
t0416 (600s)	6,093,843	∞	6,130,271	6,088,264	6,093,843
t0417 (600s)	5,951,357	∞	6,043,157	6,024,760	5,953,029
t0418 (600s)	6,550,898	∞	6,550,898	6,446,019	6,447,571
t0419 (600s)	5,907,874	∞	5,916,956	5,910,913	5,910,913
t0420 (600s)	4,276,444	∞	4,276,444	∞	4,155,076
t0421 (600s)	4,290,809	∞	4,354,411	4,290,809	4,313,091
t1716 (3600s)	184,160	∞	161,636	165,972	157,442
t1717 (3600s)	200,300	∞	184,692	180,757	167,063
t1718 (3600s)	183,349	∞	162,992	174338	172,652
t1719 (3600s)	203,839	∞	187,677	184,354	179,400
t1720 (3600s)	179,283	∞	172,752	181,868	163,432
t1721 (3600s)	136,092	202,520	127,424	130,047	123,626
t1722 (3600s)	120,303	∞	122,472	114,508	118,242

(3600 sec CPU time limit on 2.5GHz Intel XEON using 10 cores)

MFVCAP Instance	Cplex12.7 MIP/Benders		Cplex12.7 BQP		LocalSolver7.5	baryonyx
	first solution	best sol.	first sol.	best sol.		
Equilibrate 50 × 50	316,500	112,490	587,710	349,050	118,850	329,290

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