Cairo University

3D OVERLAPPED GROUPING GA FOR OPTIMUM 2D GUILLOTINE CUTTING STOCK PROBLEM

By

Maged Rasmy Abd El Malk Rostom

A thesis Submitted to the

Faculty of Engineering at Cairo University

In Partial Fulfillment of the

Requirements for the Degree of

Doctor of Philosophy
in
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Title of Thesis: 3D OVERLAPPED GROUPING GA FOR OPTIMUM 2D GUILLOTINE CUTTING STOCK PROBLEM

Key Words: Cutting stock problem (CSP); Heuristic; Two-dimensional; Genetic algorithm (GA); Grouping genetic algorithms (GGA); Overlapped chromosome (OLC)

Summary:
The cutting stock problem (CSP) is one of the significant optimization problems in operations research and has gained a lot of attention for increasing efficiency in industrial engineering, logistics and manufacturing. In this thesis, new methodologies for optimally solving the cutting stock problem are presented. A modification is proposed to the existing heuristic methods with a hybrid new 3-D overlapped grouping Genetic Algorithm (GA) for nesting of two-dimensional rectangular shapes. The objective is the minimization of the wastage of the sheet material which leads to maximizing material utilization and the minimization of the setup time. The model and its results are compared with real life case study from a steel workshop in a bus manufacturing factory. The effectiveness of the proposed approach is shown by comparing and shop testing of the optimized cutting schedules. The results reveal their superiority in terms of waste minimization comparing to the current cutting schedules. The whole procedure can be completed in a reasonable amount of time by the developed optimization program.

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NOMENCLATURE

B_v : Bill of material of Product, where "v" is the product index

$b_{v,f,e}$: Blanks in product where "v" is the product index, "f" is the blank index and "e" is the number of different thickness

$b_{v,f,e}(r)$: Quantity of blank index "f" in the product.

$b_{v,f}(St)$: Quantity of demand blank index "f " in the product will be stored.

$b_{v,f}(St-1)$: Quantity of blank index "f " in the product which was stored from last production plan.

$b_{v,f,e}(g)$: Width of Blank index "f"

$b_{v,f,e}(h)$: Length of Blank index "f"

$b_{v,f,e}(w)$: Weight of Blank index "f"

C : Cost of weight unit for sheet

d_x: Sheet width

$d_{1\ to\ 6}$: Sheet segments width.

D_v: Product Lot size.

e : The number of different material thickness.

$F_j(a)$: Fitness value

f: Blank index.

i: Pattern index.

j : Considered as a variable that refers to solution or gene or final Genetic solution.

l_y: Sheet length

$L_{1\ to\ 6}$: Sheet segments length

M: Number of solutions in population.

$N_{x,y}$: For calculate the No. of sheets required from index x,y

$n_{x,y}^{v,f}$: No. of blank index "f "from one sheet index "x, y" from one product index "v".

$n_{SA}^{v,1}$: No. of blank index "1" in Segment index "SA" from one product index "v"

$n_{SB1}^{v,2}$: No. of blank index "2" in Segment index "SB1" from one product index "v"

$n_{SA,SB1,SB2,...}^{v,f}$: No. of blank index "f" in Segment index "$SA, SB1, SB2, ...$" from one product index "v"

P : Products Set.

PSV_j: Proportional selection value

Q: It is a cost function represented a penalty if there is increase in patterns.

QB_f : Quantity of each blank index "f " in each pattern.

QP_i : Quantity of pattern index" i" in each solution.

Qb_{biece} : Quantity of blank in piece

Qb_{SL} : Quantity of blank in slice

$R_{v,f}$: Required Blanks

SLQ: Quantity of slice.

$S_i^{x,y}$: No. of sheets in each pattern, where "i" is the pattern index.

SP: Total Number of patterns given in the population.

T_e: Material thickness.

v : Product index.

x, y : Sheet index ,where " x" is width index and " y " is length index

$Z_{x,y}^{v,f}$ Binary variable (=1 if optimum solution & = 0 if otherwise).

$\delta_{x,y}^{v,f}$: The cost function

ρ: Material density.

∅ : The weight factor.

β: The expected number of Gene to be allocated to the best individual during each generation.

α : 2-β

Arrays:

[arr1 (i,j)]: "Genes and patterns" array.

[arr2 (f,i)]: “Blanks and patterns” array.

[arr3 (f,i)]: The Quantity of blanks in each Pattern.

[arr4 (f,j)]: Variable array refers to the Quantity of blanks in each of :solutions, genes and final Genetic solutions.

[arr5 (f)]: Target array.

[arr6 (f,j)] : Used as a constraint to check the blanks in the target, with the blanks in new gene.

[arr7 (i)]: Considered the new pattern index “i” which is added to the gene to find final Genetic solution.

[arr8 (i,j)]: Final genetic solution, where “i” pattern index and “j” final Genetic solution.

[arr9 (i,j)]: Population Solutions and patterns array.

ABBREVIATIONS

2-D.CSP: Two Dimension Cutting Stock Problem
3-D.OLC: Three Dimension Overlapped Chromosome
A-GA: Adaptive Genetic Algorithm
AWF: Almost Worst Fit
BF: Best Fit
BLLT: Improved Bottom Left
BLR: Bottom Left with Rotation
BOM: Bill of Material
CSP: Cutting Stock Problem
DCM: Developed Combination Method
EA: Evolutionary Approaches
EAs: Evolutionary Algorithms
ECP: Extended Cutting Plane
EP: Evolutionary Programming
ERP: Enterprise Resource Planning
ESs: Evolution Strategies
FF: First Fit
FFD: First Fit Descending
GA: Genetic Algorithm
GGA: Grouping Genetic Algorithms
GRASP: Greedy Randomized Adaptive Search Procedure
LP: Linear Programming
MILP: Mixed Integer linear Programming
MINLP: Mixed Integer Nonlinear Programming
MRP: Material Requirement Planning
NF: Next Fit
NFD: Next Fit Descending
OF: Objective Function
OLC: Overlapped Chromosome
TL: Tabu List
TS: Tabu Search
WF: Worst Fit

ABSTRACT

The cutting stock problem (CSP) is one of the significant optimization problems in operations research and has gained a lot of attention for increasing efficiency in industrial engineering, logistics and manufacturing. In this thesis, new methodologies for optimally solving the cutting stock problem are presented. A modification is proposed to the existing heuristic methods with a hybrid new 3-D overlapped grouping Genetic Algorithm (GA) for nesting of two-dimensional rectangular shapes. The objective is the minimization of the wastage of the sheet material which leads to maximizing material utilization and the minimization of the setup time. The model and its results are compared with real life case study from a steel workshop in a bus manufacturing factory. The effectiveness of the proposed approach is shown by comparing and shop testing of the optimized cutting schedules. The results reveal their superiority in terms of waste minimization comparing to the current cutting schedules. The whole procedure can be completed in a reasonable amount of time by the developed optimization program.

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