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Dipl.-Ing. (FH) Jeanette Hamiga,
München

Increasing Output in Transfer Lines through Adaptive Buffer Operation

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Von der Fakultät Maschinenbau der Technischen Universität Dresden

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Prof. Dr. T.H.W. (Thomas) Bäck

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This thesis is intended for engineers and scientists in the field of production. It deals with the goal of increasing output in (serial) transfer lines and simultaneously decreasing labor costs without need of change to the structure of the production system. For this the method adaptive buffer operation is developed, implemented and validated. Adaptive buffer operation proposes a different way of operating buffers, improving the decoupling effect of buffers. The buffers are filled to certain target fill levels at fixed moments (times of the day). Apart from the target fill levels further parameters, e.g. moments of intervention or the intervention frequency, are identified. To find out how to operate the buffers and which parameter combinations work best, a simulation-based optimization method is proposed. This method is split into the evaluative methodology, here simulation, and the generative technique of evolution strategies, solving the multi-objective optimization problem. Proof of performance is demonstrated while applying the method to a simulation model of an assembly of a German automotive plant.

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Index

Nomenclature and acronyms

ADDX	Accelerated DDX
AG	Aktiengesellschaft
BMW	Bayerische Motoren Werke
CVA	ClearVu Analytics, software used for optimization
DDX	Dallery-David-Xie
DLL	Dynamic Link Library
DoE	Design of Experiments
DR	Derandomized
EHPP	environmental HPP
FIFO	First In First Out
HPP	hedging point policy
min	minimum
min	minute
NSGA	Non-dominated Sorting Genetic Algorithm
PHPP	prioritized HPP
R	Range (of the target buffer level)
RSM	Response Surface Methodology
s	second
SDHPP	state depended HPP
T	Target buffer level

tol	tolerated
VW	Volkswagen
V&V	Verification and Validation
WIP	work-in-progress
xml	Extensible Markup Language

Notations

$\boldsymbol{x}$	vector $\boldsymbol{x}$
$\boldsymbol{u} \otimes \boldsymbol{v}$	element-wise multiplication of vectors $\boldsymbol{u}, \boldsymbol{v}, \in \mathbb{R}^n$ $\boldsymbol{u} \otimes \boldsymbol{v} = \boldsymbol{w}$ where $\boldsymbol{w} \in \mathbb{R}^n$ and $w_i = u_i \cdot v_i$ for $i \in \{1, \dots, n\}$
$\boldsymbol{x}^T$	transposition of vector $\boldsymbol{x}$
x_i	indexed component of a vector $\boldsymbol{x} = (x_1, \dots, x_n)^T \in \mathbb{R}^n$

Symbols

η	availability of system in %
α	significance level
Optimization	
k	index for constraints $k = 1, 2, \dots, r$
l	index for constraints $l = 1, 2, \dots, m$
K	total number of inequality constraint functions
L	total number of equality constraint functions
V	feasible set of the original problem
M	total number of objective functions
m	index for objective functions
n	number of parents to be optimized
x	offspring vector
i	index number of individual / solution
j	index number of individual / solution
Evolutionary Algorithms	
t	continuous generation index $t = 0, 1, 2, \dots$
P_t	population at generation t
Q_t	offspring population at generation t
p	individual of population P_t
q	individual of population Q_t

Ψ	finite set of strategy parameters
λ	number of offspring
μ	number of parents
γ	number of generations
ρ	number of parents participating in creating offspring
κ	maximum age of an individual

DR2

$\boldsymbol{\phi}_i$	fitness of individual i
$\boldsymbol{z}_i$	random vector of the multivariate normal distribution
$\boldsymbol{\delta}_{scal}$	local step size
δ	global step size
sel	index of selected offspring
β	exponent for global step size
β_{scal}	exponent for local step size
$\boldsymbol{\zeta}$	vector accumulating selected variation information over generations
c	factor controlling weight of last generation in contrast to current generation

Evolutionary Multi-objective Optimization

r_i	non-domination rank of individual / solution i
d_i	local crowding distance of individual / solution i
$<_c$	crowded comparison operator

NSGA-II

N	size of population P
R_t	population formed by joining P_t and Q_t

$\mathcal{F}_i$	different Pareto fronts, with $i = 1, 2, \dots$ etc.

Developed method

$level_{target}(B_i)$	target level of buffer B_i
$level_{current}(B_i)$	current level of buffer B_i
δ_i	Difference between current and target buffer level of buffer B_i
$units(M_i)$	number of units machine M_i has to produce
$units_{tmp}(M_i)$	number of temporary units machine M_i has to produce
$units(max)$	Number of units the machine, with the maximum number of $units(M_i)$ has to produce
$M_i(cycles)$	Number of cycles machine M_i has to stop before machine with $units(max)$
$cycles(M_i)$	Number of cycle times machine M_i has to stop before the last machine stops or production is ceased in general
$range(B_i)$	Indicates the range within which the buffer fill level can lie for the case of the tolerated buffer fill level as target
$level_{min}(B_i)$	Minimum target fill level (tolerated buffer fill level as target)
$level_{max}(B_i)$	Maximum target fill level (tolerated buffer fill level as target)
δ_{i_min}	Difference between current and minimum target buffer level of buffer B_i (tolerated buffer fill level as target)
δ_{i_max}	Difference between current and maximum target buffer level of buffer B_i (tolerated buffer fill level as target)
$count(\delta_{i\_min} < 0)$	Indicates how many buffers are below minimum fill level
$count(\delta_{i\_max} > 0)$	Indicates how many buffers exceed maximum fill level