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Application of optimal planning methodologies for investigation of echnological processes, devices and systems

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Summary: The optimal planning of experiments methodology by cost and time-consuming expenses has been developed. Hardware and software have been proposed for its implementation. The developed methodology has been tested in the investigation of a number of processes, devices and systems.
Key words: methodology, cost, time, optimal experiment plan, software and hardware.

INTRODUCTION

The problem of obtaining mathematical models appears in solving problems of optimization and control of various objects. At that, naturally, researchers aspire to develop these experimental models at minimal cost and time expenses. For this purpose, the optimal planning of experiments methodology by cost and time-consuming expenses has been worked out [2, 3, 9, 10, 15, 20].

MATERIALS AND RESEARCH RESULTS

The developed methodology includes a complex of methods for experimental plans, software and hardware optimization and their implementation (fig. 1).

The complex of methods allows to synthesize experiment plans that are optimal by cost and time-consuming expenses. Moreover, at that the method of iterative optimal by cost and time-consuming expenses experiment planning [1, 11-14, 17] is appropriate for objects with a number of significant factors $k \leq 4$, the method of sequential optimal by cost and time-consuming expenses experiment planning [4, 5, 8, 16] - for objects with the number of factors $k > 4$ and branch and bound method [6, 21, 22] and the method of successive approximations [7] should be used for $k > 3$. Optimal by cost and time-consuming expenses experiment planning method [18] is used to study dynamic objects. Which is a modification of the iterative experiment planning for static objects.

To implement the proposed methods, a complex of software systems have been developed, which are granted certificates of registration of product copyright at the State Department of Intellectual Property of Ukraine.

To implement the optimal plans on the research object which have been obtained by software, hardware has been worked out, which is protected by patents of Ukraine.

Fig.2 shows the list of the developed software and hardware for the synthesis and implementation of optimal by cost and time-consuming expenses experiment plans. The following methods are used: analysis of the permutations rows of the matrix of experiment planning, random search [23], branches and bounds [24], successive approximation [19, 25] to optimize the experiment plans by the specified criteria.

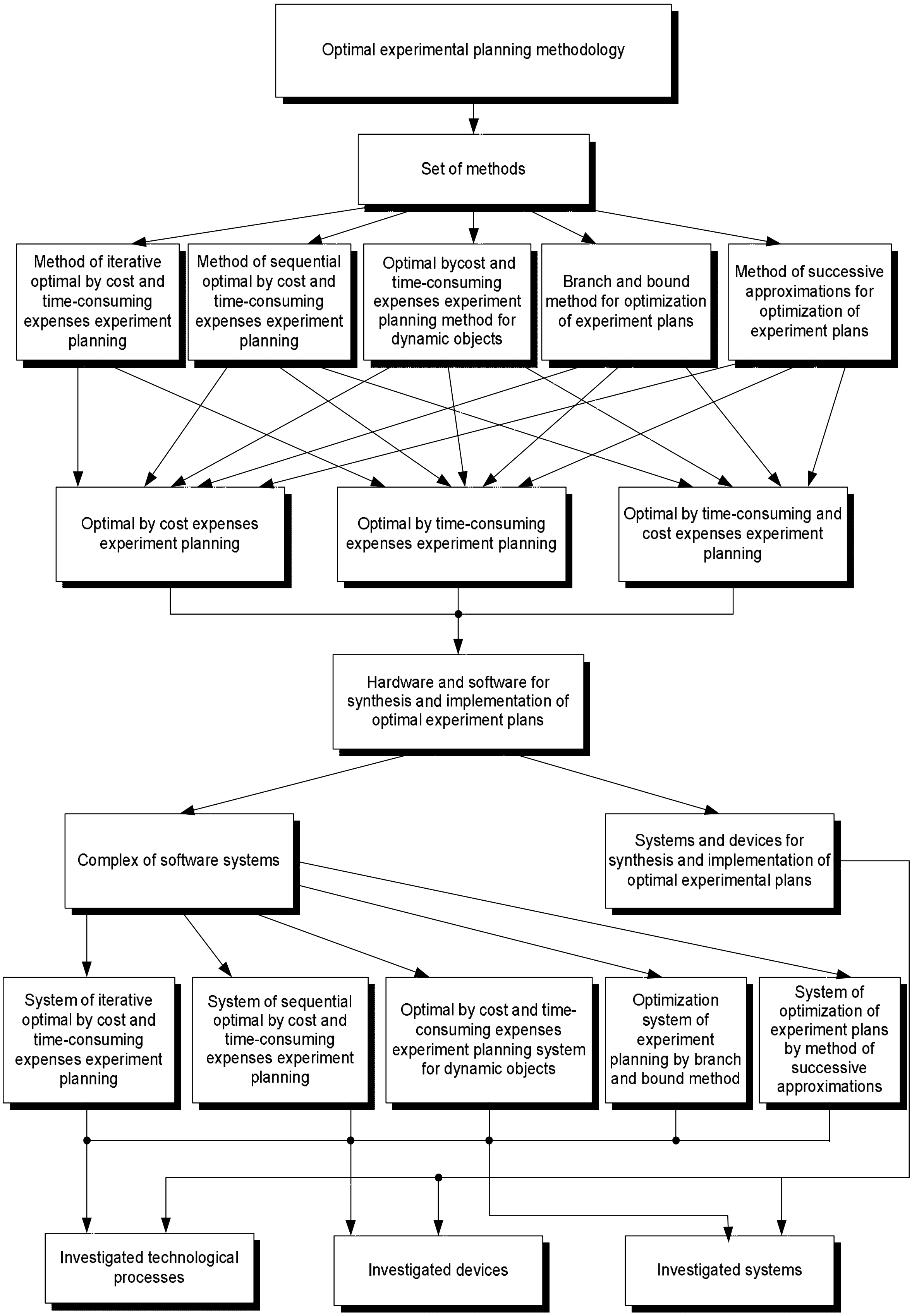

Fig. 1. Methodology for optimal planning of experiments

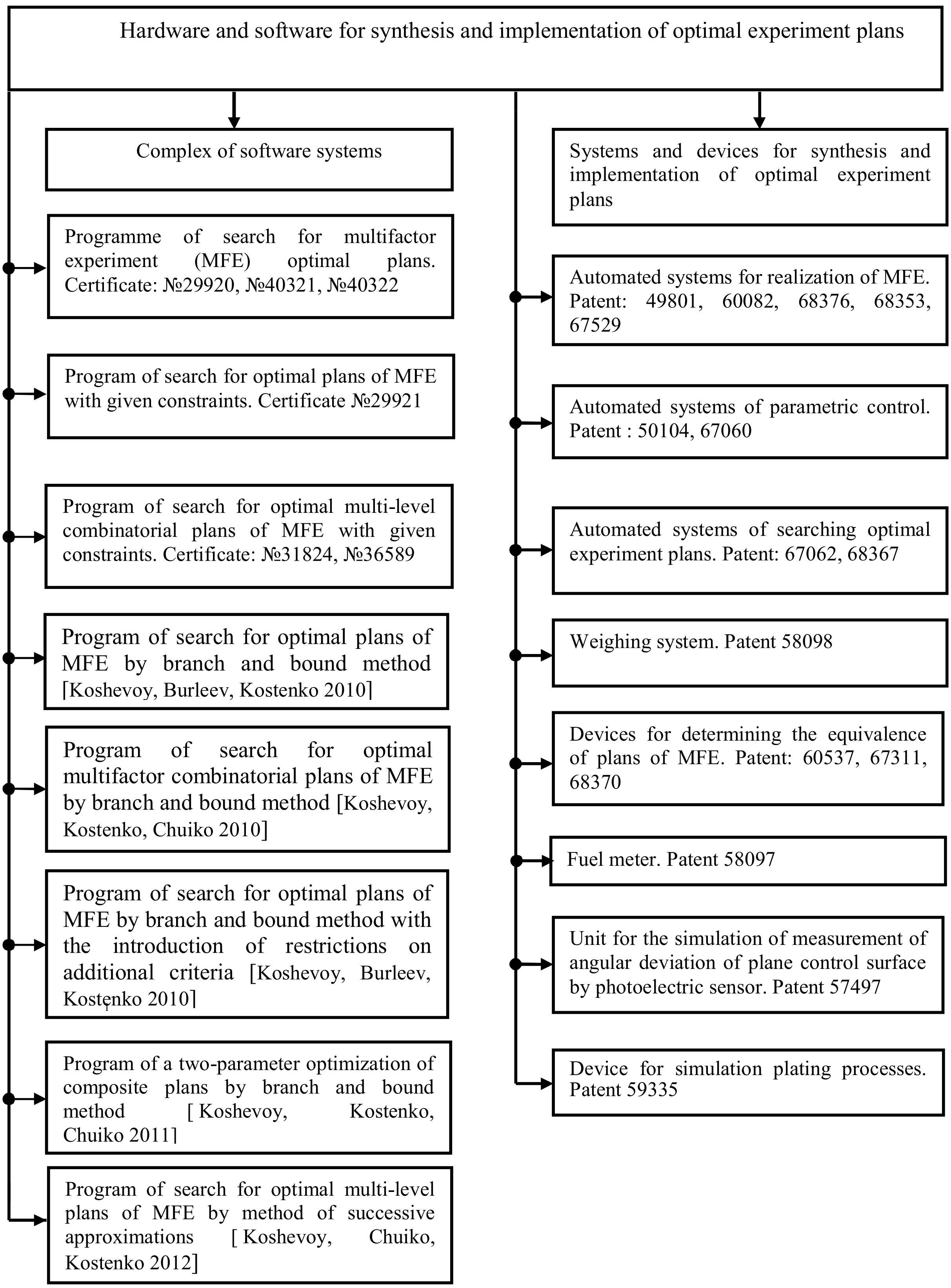

Fig. 2. Software and hardware of optimal experiment planning methodology

Table. Results of investigating software on a number of real and simulated devices

Object of study		Plan of the experiment	Number of factors K and experiments N	Optimization method	Gain in cost or time (times)
1		2	3	4	5
TECHNOLOGICAL PROCESSES	Calibration process of hydrometers [Koshevoy, Kostenko, Zabolotny, Pavlik, Tsehovskyy, Knish 2010]	Complite factor experiment (CFE)	K=2; N=4	Analysis of permutations	cost 1,14
	Process of electroplating copper plating of printed circuit boards [Koshevoy, Kostenko, Zabolotny, Pavlik, Tsehovskyy, Knish, 2010]	CFE	K=4; N=16	Analysis of permutations	cost 1,5
				Random search	cost 1,9
	Process of measuring the metallization area of printed circuit boards [Koshevoy, Kostenko, Zabolotny, Pavlik, Tsehovskyy, Knish, 2010]	Fractional factor experiment (FFE)	K=4; N=8	Analysis of permutations	cost 1,5
	Production of semiconductor devices [Koshevoy, Kostenko 2009]:				
	process of ultrasonic cutting of plates;	CFE	K=3; N=8	Analysis of permutations	cost 1,6
	fusion crystal process;	FFE	K=4; N=8	Analysis of permutations	cost 1,4
	etching process	Rotatable central composite planning (RCCP)	K=2; N=13	Analysis of permutations	cost 1,77
				Branch and bound:	
				algorithm 1;	cost 2,54
				algorithm 2	cost 3,06
	Process of forming the body cutters [Koshevoy, Kostenko 2009]	FFE	K=5; N=8	Analysis of permutations	cost 1,5
	Process of manufacture of the reinforced parts [Koshevoy, Kostenko, Gordienko, Syroklyn 2011]	FFE	K=4; N=8	Analysis of permutations	cost 2,21
	Process of testing electronic devices [Koshevoy, Kostenko, Gordienko, Syroklyn 2011]	Plakett-Berman	K=7; N=8	Analysis of permutations	
	stage 1				cost 3,37
	stage 2				cost 3,24
	Work of the radar station operator [Koshevoy, Kostenko 2010];			Branch and bound:	
	modes of operation;	RCCP	K=5; N=32	algorithm 1;	time 3,8
				algorithm 2	time 3,95
	resistant performance	FFE	K=5; N=16	Analysis of permutations	time 1,64
				Random search	time 7,40
	Work of the radioelectronic station operator [Koshevoy, Kostenko 2010]	RCCP	K=5; N=32	Branch and bound:	
				algorithm 1;	time 1,67
				algorithm 2	time 1,73

1		2	3	4	5
	Machines service with numerical program control [Koshevoy, Kostenko 2010]:				
	modes of operation;	RCCP	К=5; N=32	Branch and bound:	
				algorithm 1;	time 1,36
				algorithm 2	time 1,38
	productivity of the plant site	CFE	К=4; N=16	Analysis of permutations	time 1,17
				Random search	time 1,00
	Process of deep plasma-chemical etching [Koshevoy, Burleev, Kostenko 2010]	CFE	К=3; N=8	Branch and bound T_{lim}=150 min	cost 1,28
	The process of producing porous materials [Koshevoy, Chuiko, Kostenko 2011]	Orthogonal central composite planning (OCCP)	К=4; N=25	Branch and bound	Cost 5,47
					Time 7,33
	The process of preparation of mince [Koshevoy, Kostenko, Rozhnova 2010]	CFE	К=2; N=4	Analysis of permutations	Cost 2,57
	The process of making popcorn [Koshevoy, Dergachev, Burleev, Kostenko, 2011]	FFE	К=5; N=18	Successive approximation	Cost 3,36
				Analysis of permutations	Cost 1,37
				Random search	Cost 2,26
DEVICES	Contactless gauges of direct currents [Koshevoy, Kostenko, Zabolotny, Pavlik, Tsehovskyy, Knish 2010]:	CFE	К=2; N=4	Analysis of permutations	Cost
	voltage of 9 V;				1,33
	voltage of 5 V				1,34
	Eddy current gauges dielectric coatings [Koshevoy, Kostenko, Zabolotny, Pavlik, Tsehovskyy, Knish, 2010]	CFE	К=4; N=16	Analysis of permutations	Cost 1,81
				Random search	Cost 2,01
				Iterative planning	Cost 1,78
	Device for monitoring the quality of dielectric materials [Koshevoy, Kostenko, Zabolotny, Pavlik, Tsehovskyy, Knish 2010]	CFE	К=4; N=16	Analysis of permutations	Cost 1,2
				Random search	Cost 1,0
				Iterative planning	Cost 2,13
				Branch and bound	Cost 1,44
	Photoelectric transducers of angular displacements: placement of optical fibers [Koshevoy, Burleev O.L., Kostenko, 2010];	CFE	К=3; N=8	Analysis of permutations	Cost 1,3
	output parameters [Koshevoy, Kostenko, Zabolotny, Pavlik, Tsehovskyy, Knish 2010]	OCCP	К=3; N=15	Branch and bound	Cost 1,67
	Moisture meters of bulk materials [Koshevoy, Kostenko, Zabolotny, Pavlik., Tsehovskyy, Knish 2010]	CFE	К=3; N=8	Analysis of permutations	Cost 4,65

1		2	3	4	5
	Semiconductor thermo-regulator [Koshevoy Kostenko, 2009]	CFE	K=4; N=16	Analysis of permutations	Cost 1,5
				Random search	Cost 2,48
		Addition to RCCP	K=4; N=15	Analysis of permutations	Cost 1,99
				Random search	Cost 2,31
		RCCP	K=4; N=31	Branch and bound: algorithm 1;	Cost 3,05
				algorithm 2	Cost 4,19
	Weighing system [Koshevoy, Kostenko, Zabolotny, Pavlik., Tsehovskyy, Knish 2010]	CFE	K=3; N=8	Analysis of permutations	Cost 1,61
	System for determining fuel consumption of internal combustion engine [Koshevoy, Kostenko, Zabolotny, Pavlik., Tsehovskyy, Knish 2010]	CFE	K=2; N=4	Analysis of permutations	Cost 1,2–1,3
	Ship power plant unit [Koshevoy,Kostenko 2009]	CFE	K=3; N=8	Analysis of permutations	Cost 1,5
	Complex of technical systems [Koshevoy, Kostenko, 2010]: maintenance;	RCCP	K=4; N=31	Branch and bound: algorithm 1;	Time 1,5
				algorithm 2	Time 1,55
	shutdown system	FFE	K=5; N=16	Analysis of permutations	Time 1,35
				Random search	Time 2,85
	Tracking system [Koshevoy, Kostenko 2009]	CFE	K=3; N=8	Analysis of permutations	Cost 3,78

The developed methodology has been tested in the studying of a number of technological processes, devices and systems. In all the cases, while study the said objects cost and time-consuming expenses benefit has been gained compared with the initial plans of the experiment (table).

CONCLUSIONS

1. A methodology by the optimal cost and time-consuming expenses of experiment planning has been developed, which improves the efficiency of experimental studies aimed at modeling and optimization of real objects.
2. Software and hardware have been developed that enable to effective by use the developed methodology of optimal planning experiments.
3. The efficiency and effectiveness of the proposed methodology have been proved by testing it on a number of technological processes, devices and systems.

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ПРИМЕНЕНИЕ МЕТОДОЛОГИИ ОПТИМАЛЬНОГО ПЛАНИРОВАНИЯ ДЛЯ ИССЛЕДОВАНИЯ ТЕХНОЛОГИЧЕСКИХ ПРОЦЕССОВ, ПРИБОРОВ И СИСТЕМ

Ирина Кириченко, Николай Кошевой,
Елена Костенко, Виктория Рожнова

А н н о т а ц и я**.** Разработана методология оптимального планирования экспериментов по стоимостным и временным затратам. Для ее реализации предложены программно-аппаратные средства. Разработанная методология апробирована при исследовании ряда процессов, приборов и систем.
К л ю ч е в ы е с л о в а. методология, стоимость, время, оптимальный план эксперимента, программно-аппаратные средства.