OPTIMIZATION OF OPERATION SEQUENCING IN CAPP FOR CYLINDRICAL PART USING SUPER HYBRID GENETIC ALGORITHM-EXPERT SYSTEM (S-GENEX) APPROACH

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ABSTRACT

Computer-Aided Process Planning (CAPP) is an essential interlink between Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM) in the CIM environment. An issue in conventional CAPP framework is that the numerous planning assignments are dealt with in a direct approach. This prompts an over compelled in general arrangement space, and the last arrangement is regularly a long way from ideal or even non attainable. A solitary arrangement of activities may not be the best for every one of the circumstances in a changing creation condition with various destinations, for example, limiting the number of setups, boosting machine use, and limiting the number of hardware changes. All in all, the issue has combinatorial attributes and complex priority relations, which makes the issue more difficult to tackle. The primary commitment of this work is to build up a keen CAPP framework for shop-floor utilize that can be utilized by a normal administrator and to deliver comprehensively streamlined outcomes. In this paper, the practical arrangements of activities are created in view of the Priority Cost Framework (PCM) and Reward-Penalty Matrix (REPMAX) utilizing super Genetic Algorithm Expert System Approach (S-GENEX). Likewise, arrangement space diminishment philosophy in light of PCM and REPMAX updates the methodology to super hybridization. In this work, various benchmark contextual investigations are considered to exhibit the attainability and heartiness of the proposed super-hybrid algorithm. This Algorithm performs well on all the test issues, surpassing or coordinating the arrangement nature of the outcomes revealed in the writing. The fundamental commitment of this work centers around diminishing the ideal cost with a lesser computational time alongside age of more substitute ideal doable sequences. Also, the proposed S-GENEX coordinates arrangement space decrease, hybridization, catching out of nearby minima, vigor, and merging; it reliably outflanked both a customary genetic algorithm and an ordinary expert system.

KEYWORDS: *Optimization, CAPP, Precedence Cost Matrix, Genetic Algorithms & Expert System*

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1. INTRODUCTION

This area shows a concise diagram of the CAPP and significance of operation sequencing, a short depiction of the multifaceted nature of this class of issue, and the requirement for worldwide hunt methods to efficiently tackle it. Process planning is characterized as the movement of choosing which fabricating procedures and machines ought to be utilized to play out the different activities important to create a part, and the grouping that the procedures ought to take after. On the other hand, process planning is the methodical assurance of the point by point strategies by which parts can be made from crude material to the completed item.

The process planning movement incorporates elucidation of outline information, choice, and sequencing of activity to produce the part, choice of machines and cutting apparatuses, assurance of cutting parameters, selection of dances and installations, and estimation of machining times and expenses. CAPP is considered as the key innovation for CAD/CAM reconciliation. There are two fundamental ways to deal with CAPP: retrieval and generative. The retrieval approach utilizes aggregate innovation ideas like arrangement and coding frameworks to choose a non-exclusive process plan from the current ace process plan created for each part family and alters to suit the prerequisite of the part. In the generative approach, a process plan is generated by orchestrating the part information with the data from assembling databases and choice guidelines. In the ongoing years, process planning has gotten huge consideration from analysts, and various methodologies have been proposed keeping in mind the end goal to acquire ideal or close ideal arrangements of this unmanageable issue. Sadly, the accessible machining assets in the activity shop, geometrical and mechanical necessities of the part and priority connections among every one of the tasks make the directing of tasks determination and tasks sequencing all the while a combinatorial improvement issue.

Stochastic worldwide search algorithms such as genetic algorithms are utilized to assault difficult combinatorial advancement issues. Not with standing, genetic algorithms suffer from the absence of a merging confirmation. It is difficult to build up dependable calculation braking criteria without broad learning of the arrangement space. The proposed hybrid genetic algorithms join a genetic algorithm with the expert system to defeat the calculation union issue. The hybrid genetic algorithm was utilized effectively to tackle a task sequencing issue.

The two noteworthy errands in process planning are: operation choice and operation sequencing individually. The operation selection depends on the frame include geometry, its innovative prerequisites, and mapping these particulars to the proper task or arrangement of tasks [1]. Despite the fact that there subsist a colossal number of CAPP frameworks in the writing. In any case, a not very many of them have planned to give all inclusive streamlined activity successions. To decide the ideal succession, different established strategies like branch and bound techniques, direct programming, and flow programming have been widely talked about in detail [2– 4], and showed a procedure for CAPP in the single-machine case utilizing a component priority chart to speak to the relative expenses of set-up changes required for any two back to back activities. The slightest cost ideal process course was distinguished by Hamilton way of priority diagram. Further, they contrasted Latin duplication strategy and Kernighan heuristic for haphazardly created elective designs. Usher and Bowden [5] exhibited an approach for task arrangement coding that allows the utilization of genetic algorithm (GA) for fast assurance of ideal, or close ideal, activity groupings for parts having differing many-sided quality.

As the operation sequencing issue includes different related limitations, it is extremely difficult to plan and take care of this issue utilizing traditional systems alone. As of late, most works connected metaheuristics for taking care of

process arranging issues. Bhaskara Reddy et al. [6] applied the genetic algorithm to create the ideal succession of assembling activities. The practical arrangements are created from the element priority relationship in light of the priority and geometrical resistance imperatives. Turkey Dereli and Filiz [7] underscored the optimization of all machining parameters of the CAPP frameworks. He additionally introduced the philosophies utilized for the improvement of GA-based frameworks in charge of advancement of a succession of activities, enhancement of ATC-record positions, and streamlining of cutting parameters. Lee et al. [8] concentrated on the operation sequencing issue with the goal of limiting the aggregate of machine setup and instrument change costs.

Zhang et al. [9] built up an algorithm in light of GA to locate the ideal solution. In light of their investigations, they have presumed that the approach was more reasonable and conceivable to locate a worldwide ideal process plan. Foerster and Wascher [10] utilized simulated annealing for order spread minimization in sequencing cutting patterns (OSMP) which are named NP-finish issue and it can be considered as a summed up Traveling-Salesman Problem (TSP). Li et al. [11] researched the utilization of compelled based tabu scan approach for streamlining of process plans. Advance it was examined by Krishna and Rao [12] utilizing Ant colony algorithm (ACA) and found that the computational time has significantly decreased. Guo et al. [13] connected particle swarm optimization (PSO) for task sequencing issue, and inferred that there is as yet potential for assist change in calculation efficiency and optimality if presenting new administrators and qualities of different calculations. Besides, Salehi et al. [15] again applied a genetic algorithm to create the ideal grouping of assembling tasks in fundamental and point by point planning. Nallakumarasamy et al. [16] examined the task sequencing issue Simulated Annealing (SAT) and presumed that the SAT is better than GA and ACA. Wang et al. [17] connected hybrid particle swarm enhancement for process planning issue and proposed that the calculation has demonstrated the ability for achieving a decent nature of the arrangement. Ganesh and Punniyamoorthy [18] built up a hybrid GA SA algorithm and found that the algorithm performs better. Among these heuristic techniques, Genetic Algorithm and expert system speak to ground-breaking combinatorial streamlining strategies with reciprocal quality and shortcoming and are normally propelled.

Nonetheless, to the creator information, utilization of a hybrid heuristic algorithm using GA and Expert system consolidating solution space reduction technique (SSRT) has not been tended to. In this work, an endeavor has been made for building up an efficient seek a strategy to acquire possible ideal arrangement with a negligible computational time. A transformative algorithm which copy living beings in accomplishing ideal survival arrangements can regularly beat customary streamlining strategies. In the previous two decades, GA has been generally connected for taking care of complex assembling issues. GA works in general populace, and the hunting procedure might be caught in neighborhood optima, while Expert System is utilized for choosing the machining parameters for turning, facing and boring tasks for three kinds of materials. The quintessence of both the algorithm is combined to initiate the super hybrid algorithm.

2. MODELING OF PROCESS PLANNING PROBLEM

Computer- aided process planning includes the accompanying stages. Initially, the part drawing is assessed for perceiving the shape highlights to be machined, alongside subtle elements of geometric conditions and mechanical information, for example, resistance and surface complete necessities. This is taken after by the determination of machining tasks, machine apparatuses, cutting instruments, and slicing parameters required to create every one of the shape highlights. The priority relationship among the machining tasks is procured, thinking about different possibility imperatives, and is talked about in detail in the following section. A relative cost matrix is produced utilizing the feature

precedence and their characteristic qualities, such as machine change, instrument change, set-up change, and machining parameter change in light of the learning of different manufacturing processes and abilities of the machine apparatuses in the shop floor. The age of possible designs has the structure of the surely understood Traveling Salesman Problem (TSP) in graph theory writing.

2.1. Operation Sequencing

The idea of activity sequence generation is to create plausible and ideal succession necessities, incorporating part particulars in the outline, the given manufacturing assets, and certain goals related to cost or time. The assignment of task sequencing in CAPP is sequenced by various decisions in the activity or machine determination, as cited previously. In this manner, a mix of different decisions and imperatives makes process arranging a combinatorial issue [18].

2.2. Precedence Cost Matrix (PCM)

The Precedence Cost Matrix (PCM) is created for any combine of highlights in view of the fitting relative costs engaged with each property. These expenses reflect different parameters, for example, instrument change, machine change, datum, area, and precondition. Age of variable achievable arrangement joining the priority relations makes the issue NP-Complete. An efficient look heuristic will be very appropriate for endeavoring such issue. In this specific circumstance, a super hybrid heuristic inquiry named S-GENEX is favored for finding the worldwide ideal possible solution.

3. SUPER HYBRID GENEX ALGORITHM

In the previous two decades, GA has been generally connected for tackling complex assembling issues. GA works all in all populace, and the inquiry procedure might be caught in neighborhood optima, while Expert framework approach is utilized for mechanized determination of the machining parameters.

The proposed pattern is isolated into two stages: the GA and EX. Amid the primary stage, GA creates an underlying populace arbitrarily fusing SSRT. At that point, cross-over and mutation operators are forced for offspring age in view of the underlying populace. The cross-over and mutation sites are chosen arbitrarily. This procedure is rehased for a time of ages for accomplishing an ideal solution. At that point, the Expert System is utilized for choosing the machining parameters for turning, facing and boring operation for three sorts of materials. This hybrid system enhances the solution quality and decreases the computational time sensibly.

4. CASE STUDY 1

To demonstrate the importance of SSRT, a case study is considered from [6], as shown in Figure 1. The operations to be performed on the component are mentioned as A1, B1, B2, C1, D1, D2, D3, and E1. The technical specifications, dimensions, and geometrical tolerances are also indicated.

Figure 1: Part Drawing for Case Study 1 [6]

Based on the precedence graph, a precedence cost matrix is generated for each pair of features by taking into consideration of various attributes like machining parameter change, cutting tool change, set-up change, and machine tool change, and is given in Table 1. The symbol “—” indicates an invalid task. The operation precedence graph consisting of feasibility constraints are shown in Figure 2.

Figure 2: Operations Precedence Graph for Component Shown in Figure 1 [6]

As the component comprises of 8 operations, the total possible sequence of operations is 40320. However, after the incorporation of precedence constraints, the feasible sequence of operations is greatly reduced to 10 as illustrated in Figure 3.

Figure 3: SSRT-Based Feasible Sequences

Table 1: Precedence Cost Matrix for Component Shown in Figure 1 [6]

Succeeding Operations									
		→							
		1	2	3	4	5	6	7	8
(A1)	1	—	100	100	1	100	100	100	100
(B1)	2	11	—	0	100	1	100	100	100
(B2)	3	11	100	—	100	1	100	1	1
(C1)	4	100	100	100	—	100	100	100	100
(D1)	5	11	1	100	100	—	0	100	100
(D2)	6	11	1	100	100	100	—	100	100
(D3)	7	11	100	100	100	100	100	—	100
(E1)	8	11	1	100	100	100	100	1	—

Whereas, Bhaskara Reddy [6] generated sequences in the initial population which violates the precedence relations even though the final reported optimal solution is a feasible one for the same case study. As the total number of the feasible sequence is reduced to 10, even a search technique is not essential to find the optimal solution. The optimal sequence is the same as reported by [6] as illustrated in Table 2. However, the solution space reduction is 99.975%. Hence, the proposed work suggests to incorporate the precedence constraints for generation of any sequence at any stage of the program, which greatly reduces the computational time and it easily tends to global optima.

Table 2: Optimal Cost for Part Shown in Figure 1 Using SSRT

S. No	Sequence	Cost
1	5-2-3-6-8-7-1-4	214
2	5-2-6-3-8-7-1-4	214
3	5-2-6-8-3-7-1-4	314
4	5-6-8-2-3-7-1-4	114
5	5-6-2-3-8-7-1-4	15
6	5-6-2-8-3-7-1-4	214
7	2-5-6-3-8-7-1-4	115
8	2-5-6-8-3-7-1-4	214
9	2-5-3-6-8-7-1-4	314
10	2-3-5-6-8-7-1-4	114

4.1. Output Parameters for Case Study – 1

The various output parameters and optimal solutions obtained by S-GENEX for Case Study - 1 are presented in Table 3. The solutions are compared with the previous works and are listed in Table 4. The percentage improvements of

solutions are shown in Table 5. However, the computational time is greatly reduced to almost less than a second due to hybridization and SSRT. Figure 4 exhibits the convergence graph for Case study-1

**Table 3: Optimal Solutions Obtained by
S-GENEX [Case Study – 1]**

Parameter	Value
Optimal Cost	15
Optimal Sequence	5-6-2-3-8-7-1-4
Computational Time in Second	< 5s
Alternate Optimal Sequence	No
Whether Feasible or not?	Feasible

**Table 4: Comparison of S-GENEX Solutions with
Previous Works [Case Study – 1]**

	Bhaskara et al. (1999)	Krishna et al. (2006)	G. Nallakumarasamy et al. (2011)	Sneha Singh & Sankha Deb (2014)	Hybrid GENEX
Technique Used	GA	ACA	SA	ACA	Hybrid
Optimal Cost	15	15	15	15	15
Computational Time in Second	40s	30s	20s	11s	<5s
No. of feasible Sequence	11	3	1	1	1

**Table 5: Improvement Achieved by S-GENEX
Algorithm [Case Study – 1]**

Parameter	% Improvement
Optimal Cost	0
Computational Time in Second	90
Alternate Optimal Sequence	No
Whether Feasible or not?	Feasible

Figure 4: Convergence Graph for Case Study – 1

Figure 5: Comparison between Expected & Actual Count for Case Study – 1

5. CASE STUDY 2

To test the robustness of the algorithm, another case study of a cylindrical component is considered as shown in Figure 6. This component is a part with 10 operations done on a machining center. The operations to be performed on the component are mentioned as F0, F1, F2, F3, F4, F5, F6, F7, F8 and F9. The technical specifications, dimensions, and geometrical tolerances are also indicated. The precedence cost matrix for the newly proposed component is given in Table 6.

Figure 6: Part Drawing for Case Study 2

Table 6: Precedence Cost Matrix (PCM) for Figure 6

Features j i	F0	F1	F2	F3	F4	F5	F6	F7	F8	F9
F0	999	11	11	0	1	100	100	100	100	0
F1	0	999	1	0	1	100	100	100	100	0
F2	11	999	999	1	1	100	100	100	100	0
F3	0	11	11	999	1	100	100	100	100	0
F4	1	11	11	1	999	100	100	100	100	0
F5	100	100	100	100	100	999	0	1	1	100
F6	100	100	100	100	100	999	999	0	0	100
F7	100	100	100	100	100	999	999	999	0	100
F8	100	100	100	100	100	100	999	999	999	100
F9	1	11	11	1	1	100	100	100	100	999

The feasible strings are generated by initial_population () function. The total numbers of strings generated are twice the number of features. Here, numbers of features entered by user are 10, then total number of feasible string becomes 20. Next function population_cost () calculates the total cost of each feasible string. The generated sequence and their optima lcost is shown in table 7.

Table 7: Optimal Cost for Part Shown in Figure 6 using SSRT

S. No.	Sequence	Cost
1	0-1-2-3-4-5-6-7-8-9	214
2	9-0-4-3-5-6-1-2-7-8	304
3	3-1-5-2-0-6-9-7-4-8	722
4	1-4-3-9-2-5-0-6-7-8	313
5	9-1-4-0-5-3-6-2-7-8	513
6	9-5-4-1-6-3-7-0-8-2	811
7	3-4-1-9-5-6-2-0-7-8	323
8	3-0-4-1-5-9-2-6-7-8	323
9	0-1-5-2-6-4-9-7-3-8	711
10	9-5-1-6-0-7-8-3-4-2	612
11	1-9-3-2-5-0-4-6-7-8	313
12	9-4-1-0-2-3-5-6-7-8	124
13	0-4-1-9-5-2-6-7-3-8	512
14	9-5-3-4-1-2-0-6-7-8	324
15	9-0-1-3-5-6-4-2-7-8	323
16	5-1-6-3-0-2-4-9-7-8	412
17	4-3-1-2-5-0-9-6-7-8	313
18	4-9-0-3-1-5-6-7-2-8	312
19	3-5-0-4-1-9-2-6-7-8	323
20	9-3-5-4-6-0-7-1-8-2	801

5.1. Output Parameters for Case Study-2

The various output parameters attained for Case Study - 2 by super hybrid algorithm S-GENEX are presented in Table 8. The solutions are compared with the previous works and are listed in Table 9, and it is observed that the present hybrid algorithm gives number of optimal feasible sequences and with a lesser computational time for the same optimal cost. The percentage improvements of solutions are shown in Table 10. The alternate sequences generated by S-GENEX in addition to those reported by previous literatures are listed in Table 11 and highlighted. From the result, it is inferred that the S-GENEX algorithm generates number of alternate feasible sequences. Figure 7 shows the convergence graph for Case study-2 and Figure 8 shows the comparison between the expected & actual count for case study-2.

Table 8: Optimal Solutions Obtained by S-GENEX [Case Study – 2]

Parameter	Value
Optimal Cost	103
Optimal Sequence	Refer Table 11
Computational Time in Second	8s
Alternate Optimal Sequence	3
Whether Feasible or not?	Feasible

Table 9: Comparison of S-GENEX Solutions with Previous Works [Case Study – 2]

	Bhaskara et al. (1999)	Krishna et al. (2006)	G. Nallakumarasamy et al. (2011)	Sneha Singh & Sankha Deb (2014)	Hybrid GENEX
Technique Used	GA	ACA	SA	ACA	Hybrid
Optimal Cost	103	103	103	103	103
Computational Time in Second	30s-40s	25s-30s	15s-20s	10s-15s	8s
No. of feasible Sequence	4	2	6	-	3

Table 10: Improvement Achieved by S-GENEX Algorithm [Case Study – 2]

Parameter	% Improvement
Optimal Cost	0
Computational Time in Second	110
Alternate Optimal Sequence	20
Whether Feasible or not?	Feasible

Figure 7: Convergence Graph for Case Study – 2 **Figure 8: Comparison between Expected & Actual Count for Case Study – 2**

**Table 11: Optimal Sequences Obtained by
S-GENEX [Case Study – 2]**

S. No.	Optimal Sequence	Cost
1.	1-2-4-9-3-5-6-7-8	103
2.	1-2-3-0-9-4-5-6-7-8	103
3.	1-2-4-3-0-5-6-7-8	103

From the above-mentioned results, it is evident that the present novel hybrid S-GENEX algorithm improves all the output parameters of the process planning system (Optimal cost, alternate feasible sequence, Computational time). The present S-GENEX algorithm integrates solution space reduction, hybridization, trapping out of local minima, robustness, and convergence; it consistently outperformed both a conventional genetic algorithm and a conventional expert system.

6. CONCLUSIONS

In a computer-aided process planning system, an efficient search is required to explore the large solution space of valid operation sequence under various interacting constraints. The present work has shown that a genetic algorithm is a viable means for searching the solution space of operation sequence providing a computational time on the order of few seconds. The advantage of this method of operation sequencing is the ability to generate an optimal sequence which is difficult in a real manufacturing environment. The sequence generated is near optimal when it is successful in minimizing the cost i.e. minimizing the number of setups and minimizing the number of manufacturing tool changes. One of the important aims of this work is to develop a prototype to demonstrate the feasibility of machining planning & accordingly, select cutting data. Generally, an optimum set of parameters refers to the condition which will offer the most economical tool for life. The present work is only subjected to the components with rotational features and provides the parameters for turning, facing, boring operations, only for three types of work materials. The rule base can be easily expanded to handle other tool and work material combinations. The comparison shows that the results are better on the basis of cost and time than the previous work reported by various authors.

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REFERENCES

1. R. Weill, G. Spur, and W. Eversheim, "Survey of computer aided process planning systems". *Annals of CIRP*, vol. 31, no.2, pp. 539–551, 1982.
2. C. J. Lin and H. P. Wang, "Optimal operation planning and sequencing: minimization of tool change overs". *International Journal of Production Research*, vol. 31, no. 2, pp. 311–324, 1993.
3. C. Koulamas, "Operations sequencing and machining economics". *International Journal of Production Research*, vol. 31, no. 4, pp. 957–975, 1993.
4. S. A. Irani, H. Y. Koo and S. Ranam, "Feature based operation sequence generation in CAPP" *Production Research*, vol. 33, pp. 17–39, 1995.

5. J. M. Usher and R. O. Bowden, "The application of genetic algorithms to operation sequencing for use in computer-aided process planning". *Computers and Industrial Engineering*, vol. 30, no. 4, pp. 999–1013, 1996.
6. S. V. Bhaskara Reddy, M. S. Shunmugam, and T. T. Narendran, "Operation sequencing in CAPP using genetic algorithms". *International Journal of Production Research*, vol. 37, no. 5, pp. 1063–1074, 1999.
7. T. Dereli and I. H. Filiz, "Optimisation of process planning functions by genetic algorithm". *Computers and Industrial Engineering*, vol. 36, no. 2, pp. 281–308, 1999.
8. D. H. Lee, D. Kiritsis, and P. Xirouchakis, "Branch and fathoming algorithms for operation sequencing in process planning" *International Journal of Production Research*, vol. 39, no. 8, pp. 1649–1669, 2001.
9. F. Zhang, Y. F. Zhang, and A. Y. C. Nee, "Using genetic algorithms in process planning for job shop machining" *IEEE Transactions on Evolutionary Computation*, vol. 1, no. 4, pp. 278–289, 1997.
10. H. Foerster and G. W. Ascher, "Simulated annealing for order spread minimization in sequencing cutting patterns". *European Journal of Operational Research*, vol. 110, no. 2, pp. 272–281, 1998.
11. W. D. Li, S. K. Ong, and A. Y. C. Nee, "Optimization of process plans using a constraint-based tabu search approach". *International Journal of Production Research*, vol. 42, no. 10, pp. 1955–1985, 2004.
12. A. G. Krishna and K. M. Rao, "Optimisation of operations sequence in CAPP using an ant colony algorithm". *Advanced Manufacturing Technology*, vol. 29, no. 1-2, pp. 159–164, 2006.
13. Y. W. Guo, A. R. Mileham, G. W. Owen, and W. D. Li, "Operation sequencing optimization using a particle swarm optimization approach". *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture*, vol. 220, no. 12, pp. 1945–1958, 2006.
14. Devi, K. D., Babu, K. S., & Reddy, K. H. Optimization Of Cutting Force And Tool Temperature Using Ann Based Multi Objective Genetic Algorithms In Turning Heat Treated Beryllium Copper Alloy.
15. M. Salehi and R. Tavakkoli-Moghaddam, "Application of genetic algorithm to computer-aided process planning in preliminary and detailed planning". *Engineering Applications of Artificial Intelligence*, vol. 22, no. 8, pp. 1179–1187, 2009.
16. G. Nallakumarasamy, P. S. S. Srinivasan, K. Venkatesh Raja, and R. Malayalamurthi, "Optimization of operation sequencing in CAPP using simulated annealing technique (SAT)". *International Journal of Advanced Manufacturing Technology*, vol. 54, no. 5-8, pp. 721–728, 2011.
17. Y. F. Wang, Y. F. Zhang, and J. Y. H. Fuh, "Using hybrid particle swarm optimization for process planning problem", in *Proceedings of the International Joint Conference on Computational Sciences and Optimization (CSO '09)*, pp. 304–308, Sanya, China, April 2009.
18. K. Ganesh and M. Punniyamoorthy, "Optimization of continuous—time production planning using hybrid genetic algorithms—simulated annealing," *The International Journal of Advanced Manufacturing Technology*, vol. 26, no. 1-2, pp. 148–154, 2005.