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SOLUTION FOR N QUEENS PROBLEM USING A PHOTOSYNTHETIC ALGORITH

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Abstract: The process of the reaction of carbon molecules in the dark reaction of photosynthesis was chosen as a BDA (Biosystem-Derived Algorithm). In this study, the BDA was referred to as the 'Photosynthetic Algorithm (PA)'. The PA utilizes the rules governing the conversion of carbon molecules from one substance to another in the Benson-Calvin cycle and Photorespiration reactions. In this paper, the principles of the PA are presented in detail. The Queen’s problem was selected as a typical optimization problem to demonstrate the performance of the PA. *Copyright © 2002 IFAC*

Keywords: photosynthetic algorithms, biosystem derived algorithm, dark reaction, Benson-Calvin cycle, photorespiration, local minimum trap, optimization methods.

1. INTRODUCTION

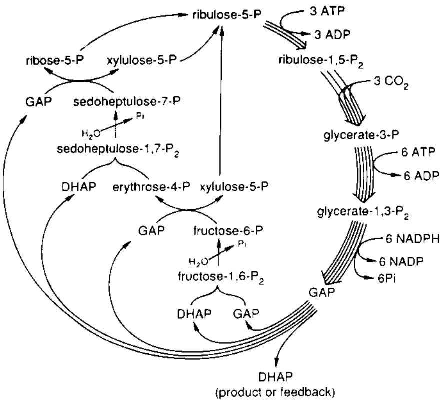
A number of problems found in the agricultural engineering discipline involve various types of optimization of operating systems such as drainage and irrigation systems, crop scheduling, handling and blending of materials. Such operating systems typically depend upon decision parameters that can be chosen by the system designer or operator. An inappropriate choice of decision parameters causes the performance of such a system to be seriously flawed, as measured by some relevant objective or fitness function. Another problem often encountered in the discipline of agricultural engineering lies in the field of testing and fitting quantitative models. Engineering or scientific research in any problem area classically consists of the iterative process of building explanatory or descriptive models, collecting data, testing the models and, when discrepancies are found, modifying the models and then repeating the process until the problem is solved. The problems that deal with optimizing operating systems and fitting quantitative models eventually require some treatment or processing by adaptive search procedures or optimization techniques. There are many search techniques such as exhaustive techniques (random walk), calculus-based techniques (gradient methods), partial knowledge techniques (hill climbing), knowledge-based techniques (production rule systems, heuristic methods), stochastic techniques (simulated annealing) and biosystem originated algorithms (genetic algorithm, immune system algorithm). In realistic systems, the interactions between the parameters are not generally amenable to analytical treatment, and the researcher must resort to appropriate search techniques. Recently, genetic algorithms (GA) and immune system algorithms are receiving attention, due to their ability to locate very good approximate solutions in extremely large search spaces with a reasonable amount of computational effort.

It is interesting to note that if one carefully tries to look at plant systems or phytosystems, many different biosystem- derived algorithms (BDA) can be found. In thee phytosystem the photosynthesis is one of the most important biochemical phenomenon. The most interesting reactions of photosynthesis consist of the set known as the 'dark reactions'. The dark reactions comprise a biochemical process consisting of a combination of the Benson-Calvin cycle and photorespiration. The product of the dark reactions is carbohydrate. The biochemical balance between the Benson-Calvin cycle and photorespiration can be viewed as a natural implementation of an optimization procedure that maximizes the efficiency of sugar production under the continuous variation of energy input from the sun. It is sometimes maintained that a plant is not optimized by nature to function as an energy conversion device, because of its very low energy conversion efficiency of about three percent. Comparisons are made to man-made devices such as photovoltaic cells and photoelectrochemical cells, which transform the sun's energy into an electrical current, or chemical fuels with an efficiency as high as 25 percent. This is not a fair comparison, however, because plants are under heavy functional constraints to maintain the diverse set of biological activities necessary for their survival and for the preservation of their species. A fair comparison would require that only those biochemical pathways in the plant directly related to energy conversion be considered when calculating energy conversion efficiency.

In the present study the process of the reaction of carbon molecules in the dark reaction of photosynthesis is chosen as a BDA. The BDA is referred to as the 'Photosynthetic Algorithm (PA)'. In the next section, the principles of the PA are presented. Subsequently, the application of the PA to typical optimization problems is discussed

2. PRINCIPLE OF PHOTOSYNTHETIC ALGORITHME

Figure 1 shows a diagram of the Benson-Calvin cycle (Bowyer and Leegood ,1997). In this diagram, each line represents the conversion of one molecule of each metabolite. The cycle can be divided into three phases.



Fig,1. RuBP is one of substances produced n the biochemical reactions in photosynthesis.

The first phase of the Benson-Calvin Cycle is a carboxylation, catalyzed by Ribulose Bisphosphate Carboxylase (Rubisco). The second phase is the reductive phase in which glycerate-3-P is reduced to triose-P by the actions of glycerate-3-P kinase and NADP-dependent glyceraldehyde-P dehydrogenase. The third phase involves the regeneration of the acceptor, ribulose-1,5-P of the sugar phosphate shuffle, in which five C3 units are converted into three C5 units.

Rubisco is a bifunctional enzyme which catalyzes both the carboxylation and the oxygenation of RuBP. Oxygenation of RuBP leads to the production of one molecule of glycerate-3-P (3PG) and one of glycolate-2-P. Figure 2 shows the part of the photorespiratory pathway that is dependent upon Rubisco.

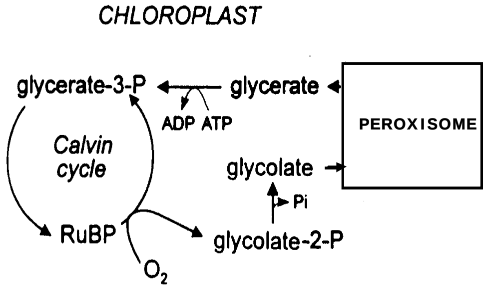


Fig. 2. Photorespiration

The PA utilizes the rules governing the conversion of carbon molecules from one substance to another in the Benson-Calvin cycle and Photorespiration reactions. Figure 3 illustrates the variation of recombination of carbon molecules appearing in the PA. The first phase of the Benson-Calvin cycle and the reaction taking place in the chloroplast subcellular compartment for photorespiration were utilized for the algorithm. The product of photosynthesis, DHAP as shown in Fig. 1, serves to provide the knowledge strings of the algorithm. Optimization is attained when the quality of the products no longer improves. The quality of a product is evaluated based on the fitness value. The fitness value can be obtained by calculating the difference between the output value of the system using parameters currently given by the PA and the training output data. The process start with the random generation of light intensity. CO2 fixation rate is then evaluated by Eq. 1 based on the light intensity. Depending on the fixation rate, either Benson-Calvin cycle or photorespiration cycle is chosen for the next process. In the both cycles, Sixteen bits strings are shuffled according to carbon molecules recombination rule in photosynthetic pathways. After some iterations, GAPs which are intermediate knowledge strings are produced. Each GAP consists of 16 bits. The fitness of these GAPs are then evaluated. The best fit GAP remains as a DHAP (current estimated value). One of the unique features of the algorithm is that the stimulation function is provided. The stimulation occurs due to randomly changing light intensity which alters the degree of influence on renewing the elements of RuBP by photorespiration. The frequency of the stimulation cycle by photorespiration can be calculated by the CO2 fixation rate given by Eq.1

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$$C = Vmax / (1 + A/L) \qquad (1)$$

where:
C: CO$_2$ fixation rate
Vmax:Maximum CO$_2$ fixation rate
A:Affinity of CO$_2$
L:Light intensity.

The parameters involved in Eq.1 are all determinable, but these values can be assigned within a realistic range and need not be empirical. When executing the PA, the light intensity (L) should be generated randomly by computer. Alternatively, the actual light intensity varying with time through an on-line measuring system might be used. The variation of the light intensity as a stimulation is effective in reducing the occurrence of local minimum traps in the search process. The CO_2 concentration in the leaf varies depending on the CO_2 fixation rate. The ratio of O_2 concentration and CO_2 concentration is evaluated to determine the ratio of the calculation frequency of the Benson-Calvin cycle to that of the photorespiration cycle.

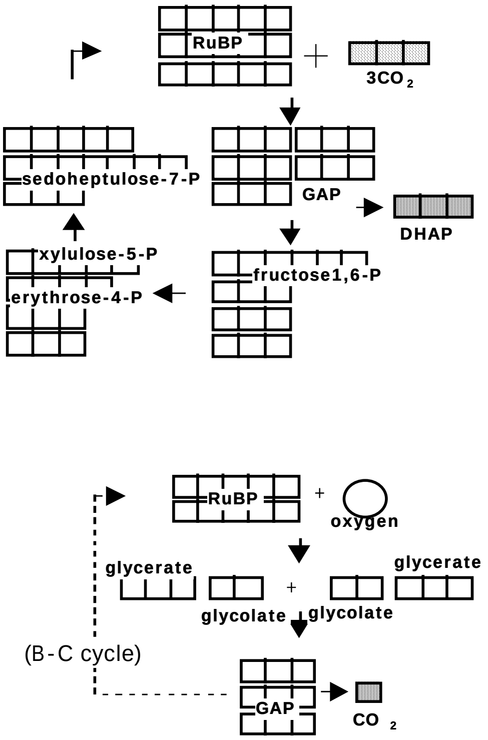
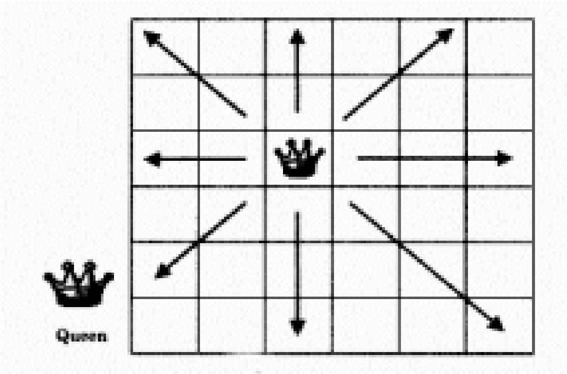


Fig.3. Recombination of carbon molecules.

3. N QUEENS PROBLEM

In chess, a queen is a piece that can move horizontally, vertically, or along either diagonal, as shown in Fig. 4. This problem typically involves arranging N queens on an N x N broad, so that none can capture another queen. Fig.5. shows an invalid solution, while Fig. 6. shows a satisfactory one. Although the original N requires finding all the satisfactory solutions, in this study the goal was to find one good situation with 16 queens. When N is 16, there are approximately 2.0922 x 10^{13} (16!), possible positions and 14,722,512 correct solutions. In order to code this problem for the Photosynthetic Algorithm, we use several ideas. In this N Queens Problem, we consider a RuBP as knowledge string. So a RuBP is needed to express each queen's position. If we exclude all cases where two or more queens are on the same file, we can express the queens' positions as a permutation. For example, the queens' positions in Fig.7 are expressed as 1-7-5-8-2-4-6-3. In order to eliminate invalid strings when one RuBP exchanges a part of itself for part of another RuBP, we have to use one more idea, which is used in coding the Genetic Algorithm. In the example 1-7-5-8-2-4-6-3, 1 is the highest line of the board, so we express this position as 1. Then we exclude the 1st line and the remaining lines on which we can place queens are 2-3-4-5-6-7-8. Since 7 is 6th line remaining, we express the 2nd position as 6. Continuing with the same procedure, we obtain 1-6-4-5-1-2-2-1 (Table 1.). RuBP still stands, when we exchange part of one RuBP for part of another.



.Fig. 4. Valid motion of Queen.

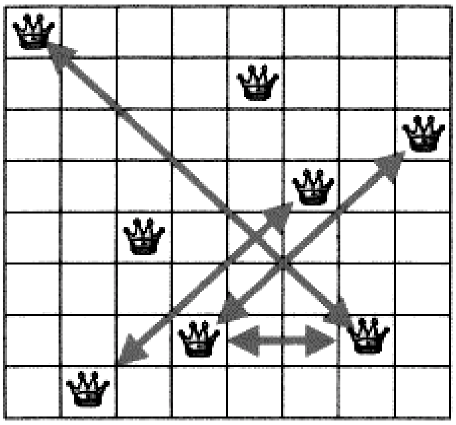
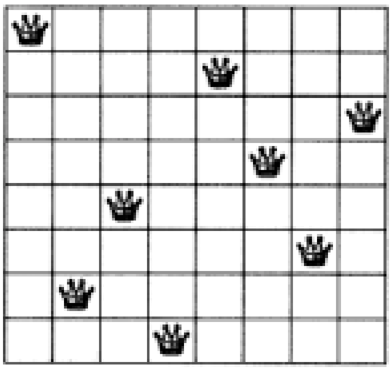


Fig. 5. Invalid solution..

Fig. 6. Valid solution.

Table 1 Ordes and locations

Position	Order	RuBP code
1	**1** 2 3 4 5 6 7 8	1
7	2 3 4 5 6 **7** 8	6
5	2 3 4 **5** 6 8	4
8	2 3 4 6 **8**	5



2	**2** 3 4 6	1
4	3 **4** 6	2
6	3 **6**	2
3	3	1

4. RESULTS AND DISCUSSION

We solved the 16 Queens Problem using the Photosynthetic Algorithm. RuBP consists of 16 bits. In the Benson-Calvin cycle, RuBPs exchange parts with other RuBPs. Fig. 8. shows the result A random search was only 20% of optimum at 5000 iterations, while the PA was over 90%. The photosynthetic algorithm developed in this exercise was used to solve the N Queens Problem. The test revealed the potential of the photosynthetic algorithm as an optimization technique.

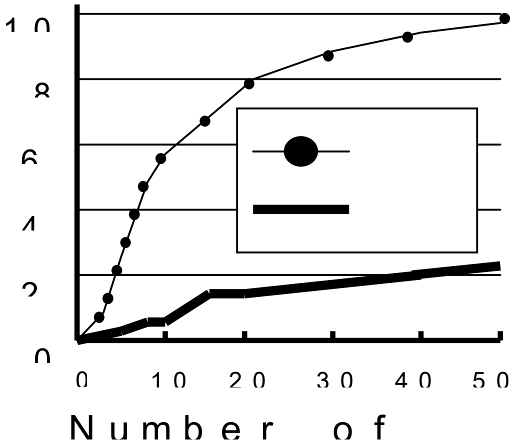


Fig. 7. Comparison of the level of optimisation between PA and Random search.

5. CONCLUSION

The effectiveness of the PA in optimization was demonstrated in this study. The Photosynthetic algorithm is a newly developed algorithm that can be used for solving problems in search and optimization. The importance of this study is that the Photosynthetic algorithm is derived from a biosystem. In our biosystem there are many different natural phenomena, many of which are very peculiar and impressive. The genetic algorithms, the immune system algorithms and the photosynthetic algorithms are all biosystem-derived algorithms. There are surely many other algorithms represented in biosystems that might prove useful in engineering applications. Seeking useful engineering principles exemplified in biosystems is likely to be a fruitful path to advancements in bioengineering.

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