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Deoxyribonucleic Acid Computing Used to Solve Path Problems with Conditions

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Abstract: Deoxyribo Nucleic Acid (DNA) computing is a new computing technique. In this technique, the information is stored in DNA molecules and computational tools are available in the form of biochemistry operations. In computer science, different models of DNA computing are available in which some are equivalent to a classic turing machine. The researchers worked on improving error rates in this technique. Limited work has been found that the researchers also tried to solve real-life applications by using this technique and tried to find the practical feasibility of DNA computers, i.e., to break Data Encryption Standard (DES), to solve NP-complete and hard computational problems). In this study, different techniques have been studies for solving path problems using DNA computing and found the best technique by comparison. Also devised a new technique to solve the given path problems.

Key words: NP-problems, path problems, DNA strand, nucleotide, technique, solve

INTRODUCTION

In 1994, Leonard Adleman's performed the 1st experiment on DNA computing in laboratory and successfully solved Hamiltonian Path Problem (HPP) (Adleman, 1994). There are algorithms available which solve the hamiltonian path problems but all these required exponential time complexity. Hamiltonian path problems belong to NP-complete class of complexity, so, there is no such algorithm found which can solve these problems in polynomial time. Therefore, the traditional silicon computers require a lot of resources to solve these problems which is found impractical. Algorithm designers are trying to find the efficient methods to solve such problems. Researchers are working onalternative methods to solve NP problems which solve these problems at a reasonable cost in term of time, hardware and other recourses. This was an important result because HP belongs to NP-complete problem set. It means that all problem belong to NP-complete problem set can be reduced to HP and then solved in polynomial time by DNA computing techniques.

Furthermore, other researchers also solved other hard computational problems by applying similar algorithms, tying to devise more efficient computation schemes such as SAT, clique, clustering, independent set, travel sales man problem (Adams, 1998; Sridhar and Balasubramaniam, 2011), vertex coloring problem (Hasudungan and Bakar, 2013a, b; Xu *et al*., 2011), distribution centers location problem and so on (Hasudungan and Bakar, 2013a, b).

Electronic computers use binary string but DNA computing data of DNA molecule is encoded with difference of bases. There are four bases (Adenine (A), Guanine (G), Thymine (T) and Cytosine (C)) in each nucleotide of DNA (Anonymous, 2014a, b).

MATERIALS AND METHODS

Vertex cover problem: Figure 1 shows a subset of vertices such that every edge is incident to at least one of these vertices (Anonymous, 2014a, b). For example in the given graph the vertices A, B and D form a vertex cover of size 3.

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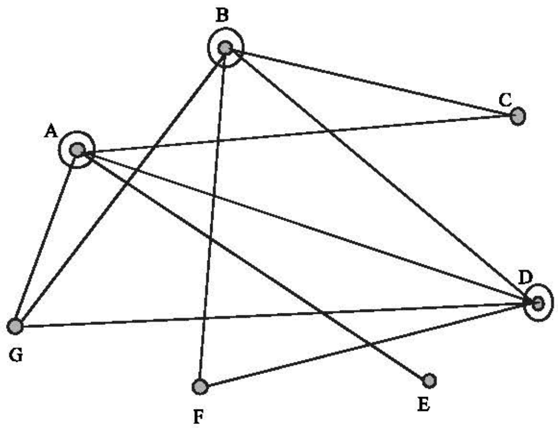

Fig. 1: Vertex cover problem (Graph with vertex cover: A, B and D)

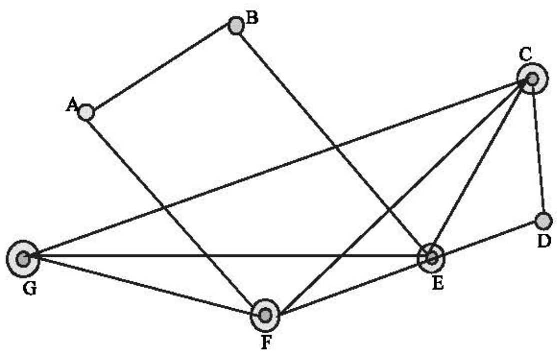

Fig. 2: Clique problem (Clique of size 4 in G (C, E, F, G))

Clique problem: Clique is a subset of vertices with the property: there's an edge between every pair of vert ices (Anonymous, 2016). For example a graph has clique of size 4 (the vertices C, E, F, G) given in Fig. 2. These problems are solved by DNA computing technique in four following steps.

- Step 1: Problem
- Step 2: DNA encoding
- Step 3: Computation
- Step 4: Results

RESULTS AND DISCUSSION

Design analysis: Our today's silicon computer need time in years to solve some of the complexity classes of NP problems for the specific input size. Therefore, algorithm designers are trying to solve these problems at reasonable cost. They are finding the other ways of computation to solve thesen problems. One of the alternate methods is DNA computing. All NP problems can be solved in polynomial time by using DNA computing techniques. The steps of design analysis are given in Fig. 3.

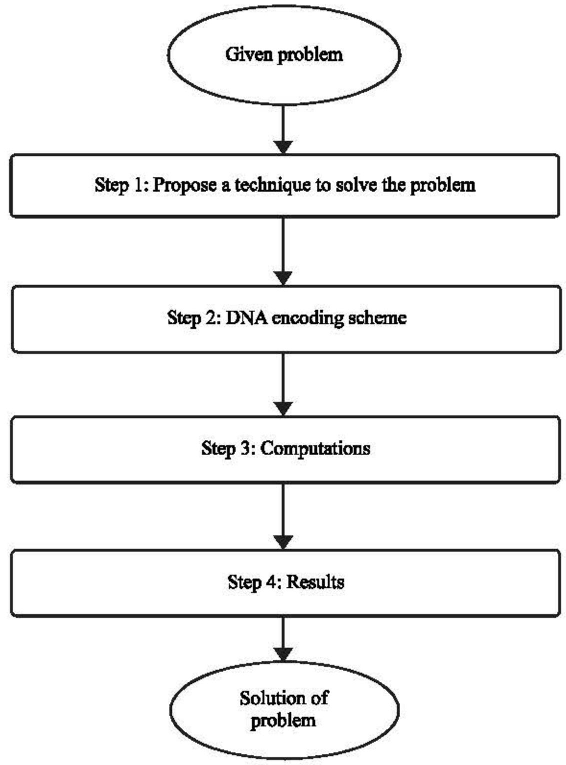

Fig. 3: Steps of design analysis

Steps of design analysis: Different DNA computing techniques are studied to solve the path problems. A methodology involving 4 steps is proposed here for analysis of these problems.

Step 1; Problem:

- Define the given problem
- Define its elements like vertices, edges and others
- Propose a technique to solve the problem
- Conditions to solve the problem

Step 2; DNA encoding:

- Define an encoding scheme to represent the problem
- Define conditions for this encoding scheme
- Representation of vertices, edge and other elements
- Conditions for all strands of DNA defined

Step 3; Computation:

- Define an encoding scheme for the computations
- Define initial solution space and conditions for this computation
- Define operations with the help of which computation will be performed
- Perform hand computations by following the conditions. It will result into a diagram

Table 1: Representation of vertices andedges

Vertex	DNA strand	Edge	DNA strand
A	ATCG AGCT	A→C	TCGA CTCT
B	TGGA CTAC	C→A	GGTC CTCT
C	GAGA CCAG	A→D	GGTC GCTA
D	CGAT GCAT	D→A	CGTA CGAT
E	AGCT AGCT	A→E	CTGA TCGA
F	GCTA GACT	E→A	TCGA CGAT
G	CTGT TAGC	A→G	TCGA TAGC
		G→A	TCGA ACCT
		B→C	GATG CGAT
		C→B	TCGA ACCT
		B→D	GATG GCTA
		D→C	CGTA CGAT
		B→F	GATG CCAT
		F→D	CTGA GCTA
		B→G	TCGA ACCT
		G→B	TCGA ACCT

Table 2.representation of vertices and edges

Vertex	DNA Strand	Edge	DNA strand
A	ATCG AGCT	A→B	TCGAACCT
B	TGGA CTAC	A→F	TCGACGAT
C	GAGA CCAG	B→E	GATGTCGA
D	CGAT GCAT	C→D	GGTCGCTA
E	AGCT AGCT	C→E	GGTCTCGA
F	GCTA GACT	C→F	GGTCCGAT
G	CTGT TAGC	C→G	GGTCGACA
		D→E	CGTATCGA
		E→F	TCGACGAT
		E→G	TCGAGACA
		F→G	CTGAGACA

Step 4; Results:

- Find the results from computations
- A path of solution will be obtained and by using path of solution, the solution will be produced.

Solution of the problems

Step 1: Problem

Vertex cover problem: There are 7 vertices in the graph (A, B, C, D, E, F, G) and 10 edges (AC, AD, AE, AG, BC, BD, BF, BG, DG, DF).

Clique problem: There are 7 vertices in the graph (A, B, C, D, E, F, G) and 11 edges (AB, AF, BE, CD, CE, CF, CG, DE, EF, EG, FG).

Step 2; DNA encoding

DNA encoding for vertex cover: All vertices are encoded randomly. All Edges are encoded by 2nd half complement of 1st node+1st half complement of 2nd node. All vertices and edges are encoding by DNA computing scheme in Table 1.

DNA encoding for clique problem: All vertices are encoded randomly. All Edges are encoded by 2nd half complement of 1st node+1st half complement of 2nd node. All vertices and edges are encoding by DNA computing scheme in Table 2.

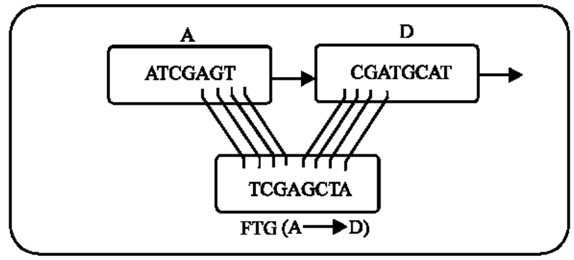

Fig. 4: Initial solution space for computation

Step 3; Computation: One node will have a path to another node through an edge by following scheme in Fig. 4.

Step 4; Results: From this computation a graph will be obtained which is the solution of the given problem.

CONCLUSION

The following two results are concluded from this study. Analysis of five techniques Hamiltonian path problem, vertex coloring problem, DNA computing model for Hamiltonian graph using 3 colors, distribution centre location problem, travelling sales person problem) performed. Comparison of different techniques for data encoding shows that the technique used in Hamiltonian path problem was simple. It uses the DNA encoding data and its complements. Its computation form exact shape of double helix structure as Watson and Crick Model. Its encoding scheme uses the minimum data as compared to other techniques. So, this technique may be used as a standard for data encoding and its implementation in the future.

Two problems (vertex cover problem and clique problem) were solved by a DNA technique. Vertex cover problem belong to NP-hard problems and Clique problem which is converted with conditions is NP-complete problem. However, both problems produced the same result. It shows that, we don't need to convert these problems.We can solve all NP problems directly by DNA computing.

RECOMMENDATIONS

DNA computing is at its early stage. There is no standard available for data representation as in silicon computer system binary numbers are used for data representation. All researchers in this field are using their own data representing scheme. Majority of people has been working theoretically but not practically in this field. Adleman performed his 1st experiment in a lab but to execute such algorithm, needs resources which are expensive and not easily available. So, this field still needs of practical use so the algorithms can be verified and experiments can be performed easily. Therefore, a long and hard work needs to do in this field.

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