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Appendix A

Definitions of Some Important Terms

- ❖ **Band:** Adjacent minigrids in the same row of a Sudoku puzzle forms a Band.
- ❖ **Biometrics:** Biometric is a mean by which a person can be uniquely identified by evaluating one or more distinguishing biological traits. Unique identifiers include fingerprints, hand geometry, earlobe geometry, retina and iris patterns, voice waves, DNA, and signatures. The oldest form of biometric verification is fingerprinting. Historians have found examples of thumbprints being used as a means of unique identification on clay seals in ancient China. Biometric verification has advanced considerably with the advent of computerized databases and the digitization of analog data, allowing for almost instantaneous personal identification.
- ❖ **Cell:** In a Sudoku puzzle, each location is known as cell. For a given Sudoku instance cell can be either blank or already filled in (clue).
- ❖ **Clique of the graph:** A clique of any graph can be defined as the maximal complete sub-graph of a graph. The clique cover of a graph can be defined as the number of cliques required to cover the graph, where the cliques are disjoint from each other.
- ❖ **Cluster:** A group of same or similar elements gathered or occurring closely together is known as Cluster.
- ❖ **Clue:** In a Sudoku instance the filled in cells are known as Clue.
- ❖ **Decryption:** Decryption is the process of transforming data that has been rendered unreadable through encryption back to its unencrypted form. In decryption, the system extracts and converts the garbled data and transforms it to texts and images that are easily understandable not only by the reader but also by the system. Decryption may be accomplished manually or automatically. It may also be performed with a set of keys or passwords.
- ❖ **Degree of a vertex:** In graph theory, the **degree** (or **valency**) of a vertex of a graph is the number of edges incident to the vertex, with loops counted twice.

- ❖ **Digital Watermark:** A Digital Watermark is a kind of marker covertly embedded in a noise-tolerant signal such as audio or image data. It is typically used to identify ownership of the copyright of such signal. "Watermarking" is the process of hiding digital information in a carrier signal; the hidden information should, but does not need to contain a relation to the carrier signal.
- ❖ **Encryption:** Encryption is the conversion of electronic data into another form, called cipher text, which cannot be easily understood by anyone except authorized parties.
- ❖ **Graph:** A graph is a representation of a set of objects where some pairs of the objects are connected by links. The interconnected objects are represented by mathematical abstractions called vertices, and the links that connect some pairs of vertices are called edges. Typically, a graph is depicted in diagrammatic form as a set of dots for the vertices, joined by lines or curves for the edges. Graphs are one of the objects of study in discrete mathematics.
- ❖ **Grid:** A network of lines that cross each other to form a series of squares or rectangles.
- ❖ **Hidden single:** Sometimes there are blank cells that do, in fact, have only one possible value based on the situation, but a simple elimination of candidate in that cell's row, column, and minigrid does not make it obvious. This kind of possible value is known as a hidden single.
- ❖ **Isomorphic graph:** Two graph, which contain the same number of graph vertices connected in the same way are said to be isomorphic. Formally, two graphs G and H with graph vertices $V_n = \{1, 2, \dots, n\}$ are said to be isomorphic if there is a permutation p of V_n such that $\{u, v\}$ is in the set of graph edges $E(G)$, if and only if $\{p(u), p(v)\}$ is in the set of graph edges $E(H)$.
- ❖ **Locked candidate:** Sometimes it can be observed that a minigrid where the only possible position for a number is in one row (or column) within that block, although the position is not fixed for the number. That number is known as a locked candidate.
- ❖ **Lone ranger:** Lone ranger is a term that is used to refer to a number that is one of multiple possible values for a blank cell that appears only once in a row, or column, or minigrid.

- ❖ **Minigrid:** Sudoku cells are grouped into small partitions. They are popularly known as Minigrid. For a Sudoku puzzle of size 9×9 , 3×3 cells are grouped into 9 minigrids. Similarly 16×16 Sudoku puzzle, 4×4 cells are grouped into 16 minigrids. That means if the size of the Sudoku puzzle is $n \times n$, the size of the minigrid is $\sqrt{n} \times \sqrt{n}$. In each minigrid the number 1 to n will occur only once.
- ❖ **Naked single:** For any given Sudoku cell, imagine listing of all the candidates from 1 to 9 in each unfilled cell. Then, for every cell, whose value v is determined, cross off every instance of v as a possible candidate in the row, column, and minigrid to which that cell belongs to. The remaining values in each cell represent possible values that could possibly be inserted there. If, after such an elimination of the impossible candidates, only a single possible value remains, that situation is referred to as a naked single.
- ❖ **NP (Non-deterministic Polynomial time computable):** This class of problem is that problem whose solution for some instance of such a problem is to be guessed but verification of the solution as correct or not could be performed in polynomial time.
- ❖ **Permutation:** A permutation is an arrangement of all or part of a set of objects, with regard to the order of the arrangement.
- ❖ **Pixel:** In digital imaging, a pixel, pel, or picture element is a physical point in a raster image or the smallest addressable element in an all points addressable display device; so it is the smallest controllable element of a picture represented on the screen. The address of a pixel corresponds to its physical coordinates.
- ❖ **Quad:** Analogous to triplet, a quad consists of a set of four possible values and these values are present in some form in four blank cells in a row (or column) of the Sudoku instance.
- ❖ **Solution Space:** In mathematical optimization, a solution space is the set of all possible points of an optimization problem that satisfies the problem's constraints.
- ❖ **Stack:** Adjacent minigrids in the same column of a Sudoku puzzle forms a Stack.
- ❖ **Steganography:** Steganography (pronounced STEHG-uh-NAH-gruhf-ee, from Greek *steganos*, or "covered", and *graphie*, or "writing") is the hiding of a secret message within an ordinary message and the extraction of it at its destination. Steganography takes

cryptography a step farther by hiding an encrypted message so that no one suspects it exists.

- ❖ **Sub graph:** A Sub graph S of a graph G is a graph whose set of vertices and set of edges are all subsets of G .
- ❖ **Sudoku Instance:** A Sudoku puzzle where some values are given as clues and some cells are blank.
- ❖ **Symmetric graph:** A Symmetric graph is a graph that is both vertex- and edge-transitive. Symmetric graphs are always regular graphs.
- ❖ **Template:** A Template (also called *biometric template*) is a digital reference of distinct characteristics that have been extracted from a biometric sample. Templates are used during the biometric authentication process.
- ❖ **Tree:** In computer science, a tree is a widely used abstract data type (ADT) or data structure. Implementing this ADT that simulates a hierarchical tree structure, with a root value and sub-trees of children, represented as a set of linked nodes. A tree data structure can be defined recursively (locally) as a collection of nodes (starting at a root node), where each node is a data structure consisting of a value, together with a list of references to nodes (the "children"), with the constraints that no reference is duplicated, and none points to the root.
- ❖ **Triplet:** If three cells in a row (or column) are marked with a set of same three possible values, they are referred to as triplet.
- ❖ **Twin:** If two same possible values are present for two blank cells in a row (or column) of a Sudoku puzzle, they are referred to as twin.
- ❖ **Undirected graph:** An Undirected graph is a graph i.e. a set of objects (called vertices or nodes) that are connected together, where all the edges are bidirectional.
- ❖ **Valid Sudoku Instance:** The instances of a Sudoku puzzle which is having at least one solution that is known Valid Sudoku Instance.

Appendix B

List of Publications

A. International Journals

1. A. K. Maji and R. K. Pal, Yet Another Organized Move towards Solving Sudoku Puzzle, *International Journal of Advanced Research in Computer Science* (ISSN: 0976-5697), vol. 1, no. 10, pp. 370-375, Oct. 2010.
2. A. K. Maji, S. Roy, and R. K. Pal, A Novel Algorithmic Approach for Solving Sudoku Puzzle in Guessed Free Manner, *European Academic Research* (ISSN: 2286-4822), Romania, vol. 1, no. 6, pp. 1126-1154, Sep. 2013.
3. A. K. Maji, S. Jana, and R. K. Pal, An Algorithm for Generating only Desired Permutations for Solving Sudoku Puzzle, *Procedia Technology Journal* (ISSN: 2212-0173), *ScienceDirect, Elsevier*, doi: 10.1016/j.protcy.2013.12.375, vol. 10, pp. 392-399, Sep. 2013.
4. A. K. Maji, S. Jana, S. Roy, and R. K. Pal, An Exhaustive Study on different Sudoku Solving Techniques, *International Journal of Computer Science Issues (IJCSI)* (ISSN 1694-0784), Mauritius, vol. 11, no. 2, pp. 247-253, Mar. 2014.

B. Book Chapter

1. A. K. Maji and R. K. Pal, A Novel Biometric Template Encryption Scheme Using Sudoku, Volume 2, *Applied Computation and Security Systems* (ISBN: 978-81-322-1987-3 (Print) 978-81-322-1988-0 (Online), Springer Publication, pp. 109-128, 2014.

C. International Conference

1. A. K. Maji and R. K. Pal, “A Systematic Approach for Solving Sudoku Puzzle”, *International Conference on Computing & Systems-2010*, pp 168-174, Burdwan University, 2010.
2. A. K. Maji, S. Jana, S. Roy, and R. K. Pal, An Exhaustive Study on Elimination based Sudoku Solver, *4th International Conference on Technical and Managerial Innovation in Computing and Communications in Industry and Academia (IEMCON 2013)*, pp. 234-239, Institute of Engineering & Management, Kolkata, Aug. 23-24, 2013.

3. A. K. Maji, S. Roy, and R. K. Pal, A Novel Steganographic Scheme using Sudoku, *IEEE International Conference on Electrical Information and Communication Technology (ICEICT 2013)*, pp. 116-121, KUET, Khulna, Bangladesh, Feb. 13-15, 2014. (Published in IEEE Xplore).
4. A. K. Maji and R. K. Pal, Sudoku Solver using Minigrid based Backtracking, *4th IEEE International Advance Computing Conference (IACC-2014)*, pp. 36-44, ITM University, Gurgaon, Feb. 21-22, 2014. (Published in IEEE Xplore).