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A minesweeper game-based steganography scheme

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A B S T R A C T

Steganography is a way of communication between the transceivers by hiding the secret message in innocuous medium, so that no one doubts the secret communication. In this paper we put forth a novel method to embed secret data in the game, "Minesweeper", as minesweeper is a very popular game in standalone system and is also available to be played online. The proposed method generates a minesweeper grid which is visually indistinguishable by humans from other minesweeper games currently present online. The game has several properties, using which, steganography can be performed. Here, we have used position of mines present in the minesweeper grid to hide the secret message. The phenomenon of camouflage starts with the player's first click on the minesweeper grid. To place the mines on the minesweeper grid in a scattered way, different matrix traversal approaches and rules to be followed are also designed to prevent the game from raising suspicion to the intermediary. The statistical analysis of different properties also shows resemblance of the proposed game to other online and offline minesweeper games. The game simulator is given with embedded message within it.

1. Introduction

Steganography is the art of secret communication where users conceal their information by using various kinds of cover media. In the review of earlier literature, text (e.g. Bennett, 2013; Bergmair, 2004; Desoky, 2010), images (e.g. Cheddad et al., 2010; Morkel et al., 2005), audio (e.g. Djebbar et al., 2011), and video etc. are the most popular cover media to hide information. In recent times, researchers are considering computer games (e.g. Hernandez-Castro et al., 2006; Desoky and Younis, 2009; Farn and Chen, 2009a, 2009b; Kieu et al., 2009; Lee et al., 2008, 2010; Ou and Chen, 2014) also to be suitable means of cover media to practice steganography.

Hernandez-Castro et al. (2006) proposed a steganography technique based on the moves in a game by assuming that a searching algorithm will give a winning score for every move. The more favorable the move is, the higher the score will be. The score generated during the game is the basis of the method to give a sorted move sequence. To send the secret message 'i', the player chooses the i^{th} move in the sorted move sequence. Thus, sometimes optimal move cannot be chosen which generates abnormal move because 'i' is to be in between 1 and n. The abnormal move can detect the steganography method which is used to hide the data. Different forms of games need different searching algorithms, and their development is difficult.

Kieu et al. (2009) proposed an image-based steganography of the game of Sudoko using spatial domain. Here each pixel pair (i, j) of the cover image hides secret number S ε {1, 2… 9}. The authors solved Sudoko with 9 × 9 matrix and expanded it to 261 × 261 look-up table by multiplying 29 × 29 times assuming the gray values of the pixel pair (i, j) as (v_i, v_j) which was

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considered as an index for the look-up table. If it does not match the secret number S, then the scheme searches for the nearest element (v_i', v_j') in the look-up table for S which replaces the pair (i, j) with (v_i', v_j') yielding the Sudoko matrix property values to change as ($v_i - v_i'$, $v_j - v_j'$) which is approximately very less (±2, ±2). The problem associated with this method is that the sender and receiver share the same Sudoku grid information. Moreover, this scheme cannot tolerate compression attacks.

Farn and Chen (2009a) proposed a steganographic method based on jigsaw puzzle image, where secret message is hidden in each attached semi-cycle on the basis of its positions and types. They also made a steganography method based on jigswap puzzle game using piece permutation (Farn and Chen, 2009b). These methods can tolerate compression attacks because pixel value is not considered to embed the secret message. However, these methods are limited by the size of a puzzle image as the size of a puzzle piece is to be recognizable to the players.

Desoky and Younis (2009) proposed steganography method based on chess game. In this method the message is concealed in chess related covers, which do not exploit noise nor produce a detectable noise. In this approach no key is employed, thus a public approach is implemented. Chess data regarding this content include chess board positions, pieces, results and players etc. But, chess-stega may alert an adversary due to the presence of contradictions in the chess cover, such as finding inaccurate details about a game or some naive move made by a professional player.

Using perfect maze game Lee et al. (2008, 2010) proposed a steganography method to hide secret data. A maze contains cells, walls, a starting cell and an end cell. It is a puzzle with complex multipath network, in which the player has to find a path from the starting cell to the end cell. A perfect maze is a rectangular maze with $m \times n$ cell in which only one path between any two cells is present. They proposed an improved algorithm to increase the embedding capacity and preserve the perfect property. The generated perfect mazes cannot be distinguished visually by humans from other perfect mazes which are commonly used.

Ritchey and Rego (2012) presented a general framework for exploiting covert channels in combinatorial games. The authors demonstrated that the adversary cannot accurately distinguish stego-games from clean games, through application of the strict requirement of forcing perfect play. The authors applied the Tic-Tac-Toe game for experimental analysis. The framework is applicable to other multiplayer games such as Dots and Boxes, Battleship, Chess, Go and Connect Four etc.

Recently Ou and Chen (2014) introduced a new steganographic method using Tetris game. In this method the secret message is embedded in the termino sequences. A sender uploads a Tetris game on the Internet by using the embedding method and the receiver obtains the secret message using extracting algorithm. It also requires a pre-shared secret key to be transmitted using a secure communication channel.

In this paper a novel steganography method based on minesweeper game is introduced. The proposed method is based on the position of mines on the minesweeper grid. The whole phenomena of camouflaging start with the first click by the player as illustrated in Section 2. As per knowledge of the authors up until now no research has been done for steganography based on minesweeper game. In our observation we can say that minesweeper game can be used to generate cover minesweeper game with hidden secret message within its different features. In this paper we proposed an algorithm to embed secret data in minesweeper game to be played online, which generates minesweeper cover that does not raise suspicion and cannot be distinguished visually by players from other minesweeper games commonly used.

The rest of the paper is organized as follows. Section 2 discusses about minesweeper basics. Section 3 describes the proposed algorithm. Section 4 illustrates the experimental results for the embedding, extracting algorithm, depicts scenario and simulation of the proposed minesweeper game. Section 5 describes steganalysis validation and conclusion is provided in Section 6.

2. Minesweeper basics

The game RelentlessLogic (RLogic) (Conway et al, 2014) was the first game to introduce the concepts of today's minesweeper. RLogic used to take place on a grid of 9×15 squares over which 10 to 40 mines are spread randomly with the objective to navigate a marine safe from the top-left to the bottom right corner of the grid using the arrow keys without stepping on a mine. Stepping on a mine declares that the player loses the game. In 1987 Tom Anderson developed advanced version of RLogic called (Anderson et al, 2014), which was the first clone of RLogic to use a pointing device (mouse). It introduced many features such as customizable grid size, numbers in the cells and the options to mark squares safe or unsafe which is found in today's minesweeper game. On October 1990 Microsoft published the first Windows Entertainment Pack (2014), a collection of games that run in Windows OS which included Minesweeper along with other games such as Tetris, TicTactis etc. From that time Microsoft has been releasing Minesweeper with every new version of Windows OS with many features.

In minesweeper game, there are a certain number of mines spread over a grid of $X \times Y$ squares. The player has to guess and click on squares that do not contain a mine. If the player hits a mine, the game is lost. There are three levels in this game with Beginner, Intermediate and Advanced levels that have 10, 40, 99 mines in 9×9, 16×16, 16×30 tile grid respectively shown in Fig. 1 (a)–(c). Custom option is also present with varying height, width and mines.

When we start a game, each time we click on a cell, we can find a number which tells about the number of mines to be present on the cells adjacent to the clicked cell or a mine or a blank cell. For example in Fig. 2 (a), number 3 tells that three out of surrounding eight cells have mines and five cells are safe to click.

Based on the numbers present in the cells the player can conclude whether mines may be present or not. Sometime players may be in dilemma to guess about the presence or absence of mine. Player has to guess if the scenario is not clear about the presence or absence of mine. For example, consider the scenario given in Fig. 2 (a) and (b). Suppose the player has already clicked the cells which are showing the numbers