

Technical Section

Automated generation and visualization of picture-logic puzzles

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Abstract

A picture-logic puzzle is a game that takes the form of an $N \times M$ grid, with numbers situated on the left of its rows and on the top of its columns, which give the clues for solving the puzzle. These puzzles have gained popularity in the last years all over the world, and there are companies involved in the commercialization of products related to them, mainly magazines, on-line puzzles via the web and games for mobile phones. The main problem with selling picture-logic puzzles is the need to generate a large number of picture-logic puzzles per month, or even per week, so automating the generation process of such puzzles is an important task. In this paper we propose algorithms for the automated generation of picture-logic puzzles (both black and white and color puzzles), starting from any digital RGB color image. We also present a visualization interface which provides several useful tools for finishing the puzzle generation process, like the possibility of changing colors and displaying the process of puzzle solution. We show the performance of the algorithms for generating picture-logic puzzles with several examples.

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1. Introduction

Puzzles, board games and computer games in general have been studied for many years in the Computer Science, Mathematics and Artificial Intelligence fields, including in image processing [1–7]. Nowadays, the logic type puzzles (Sudoku, Picture-logic (Nonograms), Kakuro, Divide-by-squares, etc.) are quickly spreading over the world, and there are many companies involved in the process of commercializing these puzzles [8–10], including the most important newspapers of the world. In addition, puzzles and logic games in general are also sold to be played as games for mobile telephones or as web pages on the Internet, in a market with a turnover of millions of dollars per year.

The work we present here is related to one of this logic-type puzzles, specifically the one known as a *Picture-logic*

puzzle, which has become popular in the last few years. There are several companies [8,9] that publish magazines and sell mobile phone games based on picture-logic puzzles. In general, these companies need an automated processes to generate hundreds or even thousands of puzzles per week. This generation process is, however, a difficult task, since it applies methods from image processing, optimization and heuristics.

1.1. Picture-logic puzzles

A picture-logic puzzle takes the form of an $N \times M$ grid, some of the cells of which are to be colored to form an image. In the grid there are numbers situated on the left of its rows and on the top of its columns. There are two types of picture-logic puzzles, black and white (B/W) and color puzzles. In B/W picture-logic puzzles [12–19], the numbers in the rows and columns represent, in the order they appear, how many cells in the corresponding row or column of the grid must be filled. If there are two or more numbers, each filled group of cells must be separated by at

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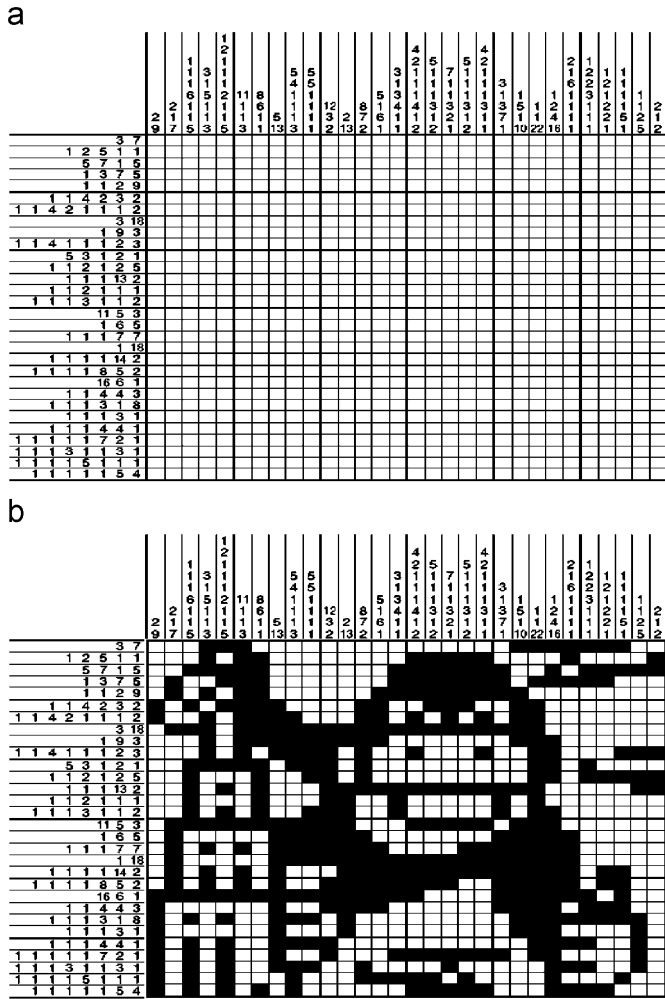


Fig. 1. Example of a B/W picture-logic puzzle; (a) grid with conditions; (b) solution.

least one blank. For example, Fig. 1(b) shows the solution to the picture-logic puzzle displayed in Fig. 1(a). Note that in the first row, 3 and then 7 cells must be filled, whereas in the second row 1, 2, 5, 1 and 1 cells should be filled, with at least one blank cell between them. Columns in the puzzle follow the same rules. When all the requirements in rows and columns are satisfied, the puzzle is solved, and a nice picture can be seen, in this case the picture of King-Kong on top of the Empire State Building in New York. Color picture-logic puzzles [8,20] follow similar rules to B/W puzzles, but taking into account that cells of the same color must be separated by at least one blank cell, and cells of different color may or may not be separated by blank cells. Fig. 2 shows an example of a color picture-logic puzzle (a), and its solution in (b).

Picture-logic puzzles were independently created by Non Ishida, a graphics editor, and Tetsuya Nishio, a professional puzzler, in 1987. Picture-logic puzzles are also known as *Japanese puzzles*. Soon after that, the puzzles started appearing in several Japanese puzzle magazines and gaining popularity, until 1990, when the newspaper *The Sunday Telegraph* started publishing them on a weekly

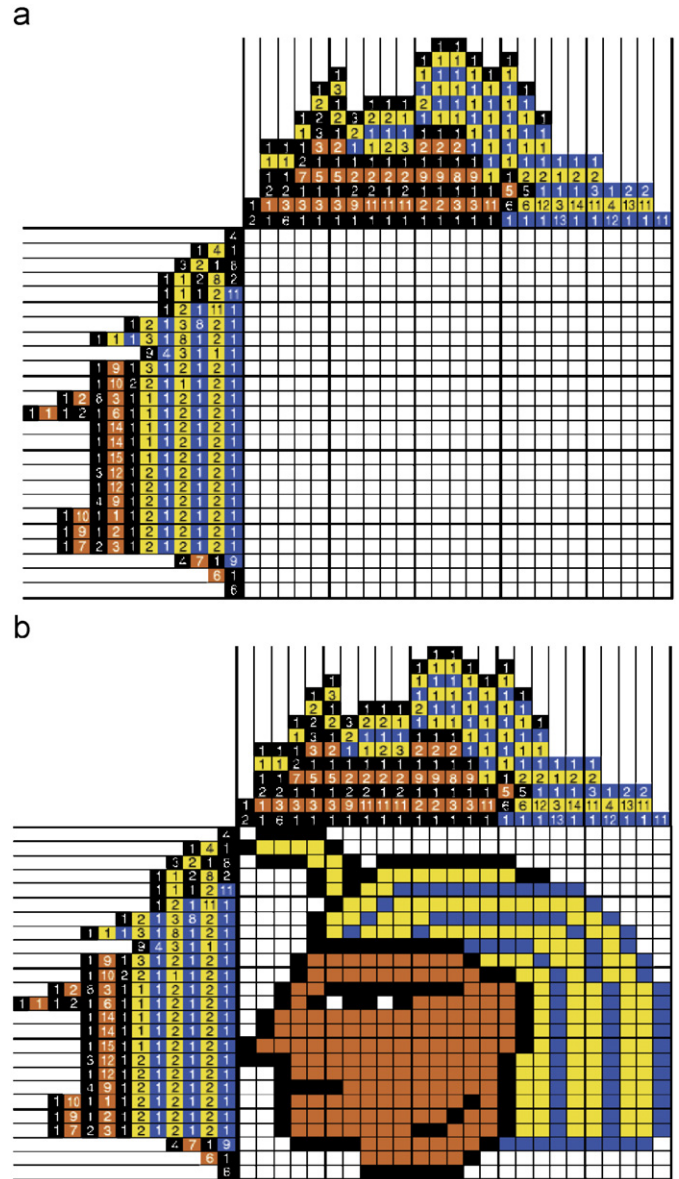


Fig. 2. Example of a color picture-logic puzzle; (a) grid with conditions; (b) solution.

basis. In the United Kingdom the name given to this kind of puzzles was *Nonograms* [11]. In the last few years the popularity of these puzzles has increased a lot. There are several companies which publish magazines and web pages exclusively devoted to picture-logic puzzles [8–10], in countries such as Spain, Germany, The Netherlands, Italy or Finland.

1.2. Paper objectives and structure

In this paper we propose algorithms for the automated generation of picture-logic puzzles, both B/W and color puzzles. In all cases a good solver is needed to generate the puzzles. Initial RGB images are processed prior to using the solver as a puzzle generator. Then, a threshold to decide the percentage of B/W cells in the puzzle is applied,

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