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NONOGRAM TOURNAMENT IN OLYMPIAD YOKOHAMA 2013

Lung-Pin Chen[5], Der-Johng Sun,[6] and Wen-Jie Tseng[7]

A Nonogram solver tournament was held as part of the 17th Computer Olympiad, which took place in Keio University, Yokohama, Japan, from Aug 12th to 18th, 2013. Table 1 lists the participants and the final standings.

Rank	Program Name	Author(s)	Affiliation(s)	#Problem(s) Solved
1	LALAFROGKK	Kan-Yueh Chen, Ching-Hua Kuo, Hao-Hua Kang, and Der-Johng Sun	National Chiao Tung University (NCTU), Taiwan	1000
2	THUNONO	Lung-Pin Chen, Lin Ku Wei	Tunghai Univ, Taiwan	297
3	THEUNINITIATED	Kuo-Chen Huang	National Taichung University of Education, Taiwan	1

Table 1: The programs and scores of the Nonogram solver tournament in ICGA 2013.

Nonograms

Nonograms are logic grid puzzles in which cells in a grid must be painted according to the given *row clues* and *column clues*. Players are requested to paint each grid cell into either "white" or "black", such that the segments constituting of consecutive black cells in each row (or column) matches the corresponding row clue (or column clue). For example, Figure 1 shows a Nonogram puzzle and a feasible painting that matches all the clues. In this puzzle, the second row clue "3 3" indicates that row two contains two segments of size three that are separated by at least one white cell.

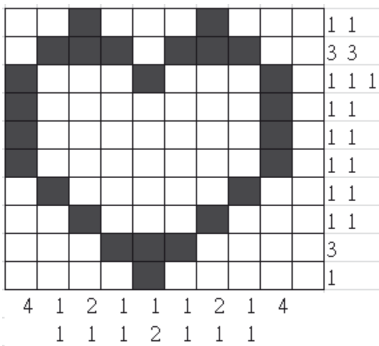

Figure 1: A Nonogram puzzle and a feasible painting.

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According to Wikipedia (2013), a Japanese graphics editor, Non Ishida, invented Nonograms in 1988. Since then, many Nonogram puzzles have been published in magazines and newspapers. Today, many commercial and freeware Nonogram games have been developed for web and mobile platforms.

The problem of solving Nonogram puzzles is proved to be NP-complete by Ueda and Nagao in 1996. The Nonogram tournaments have been held since the 15th Computer Olympiad in 2010. Then they were held in TAAI 2011, TCGA 2012, and TAAI 2012. Note that the Nonogram tournaments are similar to the competition *Crafted* and *Random* held in the SAT 2011 Competition (2011), for the well-known NP-complete SAT problems.

ICGA 2013 Nonogram Tournament

In the ICGA 2013 Nonogram tournament, the official organizer prepared a random puzzle generator (Wu, 2011), which was pre-announced in publicity. To ensure fairness and security, the generator produced 1000 25x25 puzzles with a random seed which is the sum of the numbers that are input by all participants on-site.

According to Batenburg and Kosters (2009), the higher density of black cells (more than 35%), the easier the puzzles are. They also concluded that the most difficult but solvable puzzles contain about 20~35% black cells. The generator of the ICGA 2013 Nonogram tournament produces 1,000 puzzles with densities of black cells ranging from 50% to 35% linearly in order. Thus, the generated puzzles are roughly from easy to difficult ones in that order.

In the tournament, the winner is the program which correctly solves most puzzles. If there are several programs, which solve the same number of puzzles, the winner is determined by comparing execution times. The solution of a generated puzzle may not be unique. However, the competing programs only need to report one solution. In fact, the problem of solving a second solution is known as the *Another Solution Problem* and is also NP-complete (Ueda and Nagao, 1996).

As shown in Table 1, LALAFROGKK won the gold of Nonogram Tournament of ICGA 2013 by solving all 1000 puzzles. As shown in Figure 2, for LALAFROGKK only 1% of the problems were solved with more than 200 seconds and 5% of problems with more than 10 seconds. This remarkable result came from the effect of the new approach proposed by Wu *et al.* (Wu *et al.* 2013). THUNONO won the silver by solving 297 puzzles. It was stuck on the 298th puzzle (see Figure 3) until the time elapsed. **LALAFROGKK** solved 298th puzzle within 2 seconds.

Most computer programs try to find a maximal painting of a Nonogram puzzle by inducing colors of cells from the given clues or previous paintings. However, after all the inductions are completed, for those cells remaining unpainted, a combinatorial search is required to be performed to explore all possible answers. Clearly, the scale of the search space is exponential to the number of unpainted cells because each cell can have two possible colors. Figure 3 shows the 826th puzzle which requires an exhaustive search for finding an answer. According to the execution log, LALAFROGKK spends more than 230 seconds to solve 826th puzzle.

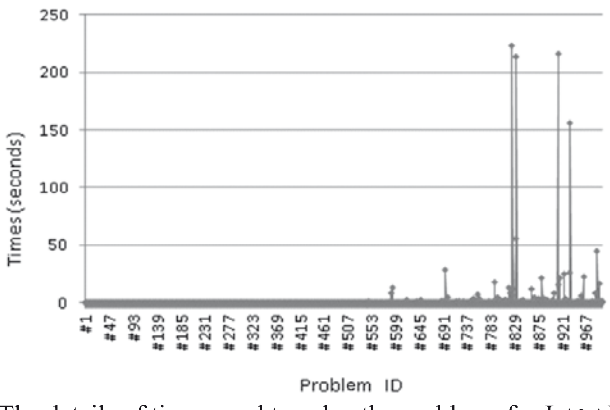


Figure 2: The details of times used to solve the problems for LALAFROGKK.

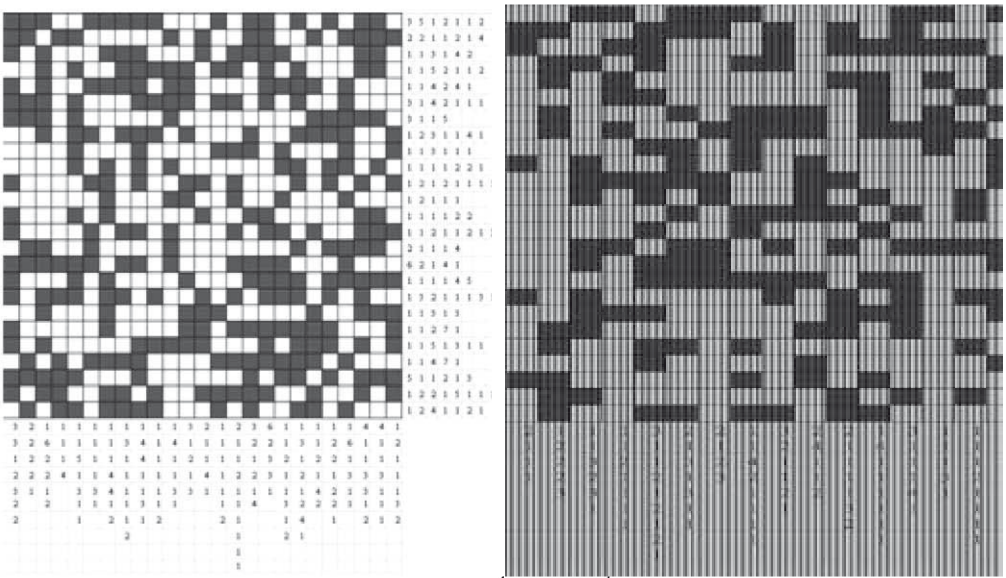
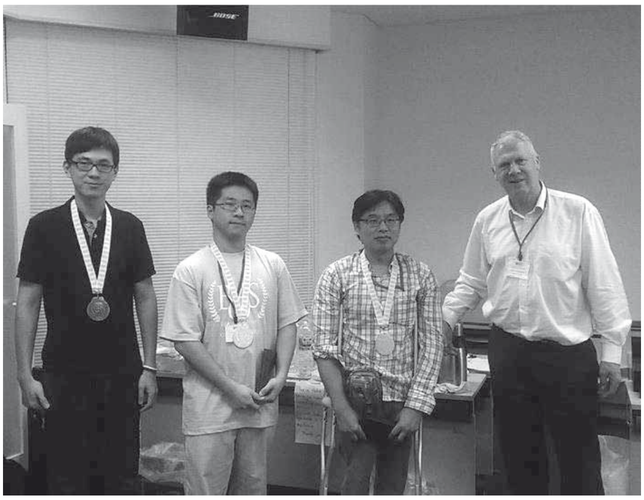


Figure 3: The 298th and 826th puzzle.



F.l.t.r. Wen-Jie Tseng (THEUNINITIATED), Tin-Fu Liao (LALAFROGKK),
Lung-Pin Chen (THUNONO), and H.J. van den Herik.

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