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PREFACE

The activities of the International Conference is in line and very appropriate with the vision and mission of the UBL to promote training and education as well as research in these areas.

On behalf of the First International Conference of Engineering and Technology Development (ICETD 2012) organizing committee; we are very pleased with the very good responses especially from the keynote speakers and from the participants. It is noteworthy to point out that about 45 technical papers were received for this conference

The participants of conference come from many well known universities, among others: Universitas Bandar Lampung, International Islamic University Malaysia, University Malaysia Trengganu, Nanyang Technological University, Curtin University of Technology Australia, University Putra Malaysia, Jamal Mohamed College India, ITB, Mercu Buana University, National University Malaysia, Surya Institute Jakarta, Diponegoro University, Unila, Universitas Malahayati, University Pelita Harapan, STIMIK Kristen Newmann, BPPT Lampung, Nurtanio University Bandung, STIMIK Tarakanita, University Sultan Ageng Tirtayasa, and Pelita Bangsa.

I would like to express my deepest gratitude to the International Advisory Board members, sponsors and also welcome to all keynote speakers and all participants. I am also grateful to all organizing committee and all of the reviewers which contribute to the high standard of the conference. Also I would like to express my deepest gratitude to the Rector which give us endless support to these activities, such that the conference can be administrated on time.

Bandar Lampung, 20 Juni 2012

Mustofa Usman, Ph.D
ICETD Chairman

PROCEEDINGS
The First International Conference in
Engineering and Technology Development
(ICETD 2012)

UNIVERSITAS BANDAR LAMPUNG
Bandar Lampung, Indonesia
June, 20-21 2012

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Solving Pixel Puzzle Using Rule-Based Techniques and Best First Search

Dina Stefani^{#1}, Arnold Aribowo^{#2}, Kie Van Ivanky Saputra^{#3}, Samuel Lukas^{#3}

^{#1}Informatics Engineering Department

^{#2}Computer Systems Department

^{#3}Applied Mathematics Department

Universitas Pelita Harapan

UPH Tower, Lippo Karawaci, Tangerang, 15811, Indonesia

¹stefani_dina@hotmail.com

²arnold.aribowo@uph.edu

³kie.saputra@uph.edu

⁴samuel.lukas@uph.edu

Abstract—Pixel puzzle is a logic puzzle which consists of a blank grid with clues on the left of every row and on the top of every column. The objective is to paint blocks in each row and column so their length and sequence corresponds to the clues, and there is at least one empty square between adjacent blocks. There are many possible solutions to paint blocks in each row and column. Solving the puzzle manually gives the possibility to fill cells yield erroneously. Therefore an attempt to solve the puzzle with the aid of computer software is performed.

In this paper, rule-based techniques and best-first search are utilized to solve the puzzle. According to experiments have been conducted, it can be concluded that rule-based techniques and best-first search are able to solve the Pixel Puzzle. The result also indicates that the larger size of pixel puzzle, the longer average time to solve is needed. Moreover, the average time to solve one cell of pixel puzzle depends on the size itself except for the 10 × 10 and 15 × 15 pixels.

Keywords— Pixel Puzzle, Heuristics, Rule-Based, Best-First Search, Puzzle Solver

I. INTRODUCTION

Solving a puzzle is one of a challenging activity during the leisure time. One of the popular puzzles is Pixel puzzle. Pixel puzzle is also called as Nonogram or Japanese Puzzle. Pixel puzzle is a logic puzzle which consists of a blank grid with clues on the left of every row and on the top of every column. The objective is to paint blocks in each row and column so their length and sequence corresponds to the clues, and there is at least one empty square between adjacent blocks. Usually the result of filled cells forms an image.

Solving the puzzle needs a lot of patience due to the fact that there are many possibilities to paint blocks in each row and column. Solving the puzzle manually also gives the possibility to fill cells erroneously. Therefore an attempt to solve the puzzle with the aid of computer software is needed. Rule-based techniques and best-first search are applied to solve the puzzle. Rule-based techniques which are applied to solve the problem

consist of simple boxes, simple spaces, forcing, and contradiction. When rule-based techniques can not solved the problem, the process of finding the solution will be continued by using best-first search. Although some pixel puzzle enable cells to be filled with various color, however, in this paper, cells is filled with black or white color. The maximum size of pixel puzzle is 25x25. To give a more insight about the pixel puzzle, an example of 12x9 pixel puzzle is depicted in the following figure 1:

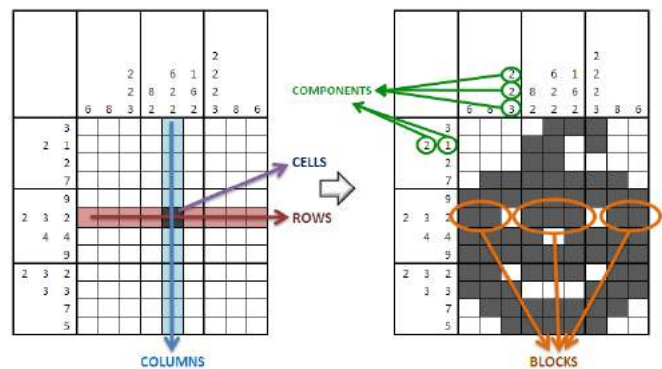


Figure 1. An example of *pixel puzzle* (left picture is the problem while right picture is the solution)

There are several papers which discuss how to solve the pixel puzzle. In [5], ad-hoc heuristics is implemented. It uses the information in rows, columns, and puzzle's constraints to obtain the solution of the puzzle. In [4], logical rules and depth first search algorithm are implemented. In [1], many pixel puzzle are solved, however some puzzle can not be solved well.

II. PIXEL PUZZLE

Nonograms are picture logic puzzles in which cells in a grid have to be coloured or left blank according to numerical clues given at the side and top of the grid in order to reveal a hidden picture. In this puzzle type, the numbers measure how many unbroken lines of filled-in squares there are in any given row or column [3]. For example, a clue of "4 8 3" would mean there are sets of four, eight, and three filled squares, in that order, with at least one blank square between successive groups.

Nonograms are also known by many other names, including Paint by Numbers, Griddlers, Pic-a-Pix, Picross, Shady Puzzles, Pixel Puzzles, Crucipixel, Edel, FigurePic, gameLO, Grafilogika, Hanjie, Illust-Logic, Japanese Crosswords, Japanese Puzzles, KareKarala!, Logic Art, Logic Square, Logicolor, Logik-Puzzles, Logimage, Obrazkilogiczne, Zakódovanéobrázky, Malovanékřížovky, Oekaki Logic, Oekaki-Mate, Paint Logic, ShchorUftor, Gobelini, and Tsunami. These puzzles are often black and white but can also have some colours.

This paper discusses the black and white Pixel Puzzle. There is no theoretical limit on the size of a pixel puzzle, and they are also not restricted to square layouts. Pixel puzzle was originally invented in 1987 by both Non Ishida, a Japanese graphics editor, and Tetsuya Nishio, a professional Japanese puzzler (although with no connection between them). Pixel puzzle now appear in many newspapers and gaming publications, along with other popular puzzles such as crosswords and Sudoku. Basically, pixel puzzle rules are described as follows:

- 1) Fills cells in a grid with black colour or left blank according to numerical clues given at the side and top of the grid in order to reveal a hidden picture.
- 2) There is at least one blank square between successive filled squares.

There is no method to determine precisely the difficulty level of problems in this puzzle. However, there are basically two factors which influence this, namely the size of puzzle and the ratio between the block length and the size. The more pixels, the harder the puzzle will be. In addition to that, the more relatively long blocks there are the easier the puzzle will be. There are several rules which can be employed to solve pixel puzzle, for instance simple boxes, simple spaces, forcing, glue, joining and splitting, mercury, and contradiction [3]. In this paper, glue, joining and splitting, and mercury are not used to solve the problem.

A. Simple Boxes

Simple Boxes is basically used to determine as many boxes as possible at the beginning. This method uses conjunctions of possible places for each block of boxes. It is important to note that boxes can be placed in cells only when the same block overlaps. The following figure illustrates the simple boxes rule:

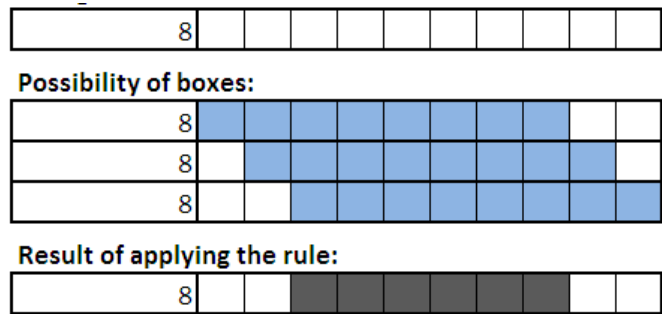


Figure 2. Simple Boxes

B. Simple Spaces

This method consists of determining spaces by searching for cells that are out of range of any possible blocks of boxes. The simple spaces rule can be depicted in the following figure:

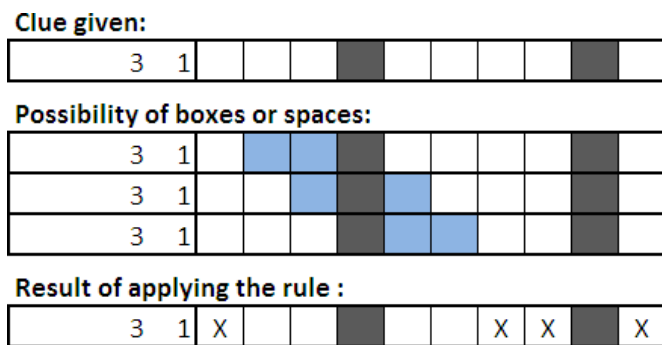


Figure 3. Simple Spaces

C. Forcing

In this method, the significance of the spaces will be shown. A space placed somewhere in the middle of an uncompleted row may force a large block to one side or the other. Also, a gap that is too small for any possible block may be filled with spaces. The forcing rule can be depicted in the following figure:

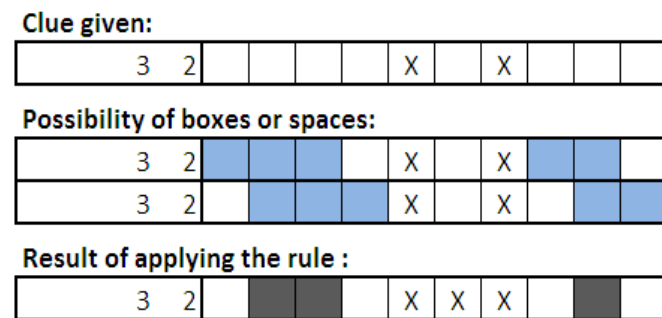


Figure 4. Forcing

D. Contradiction

Some more difficult puzzles may also require advanced reasoning. When all simple methods above are exhausted, searching for contradictions may help (Figure 5). It is wise to

use a pencil (or other colour) for that in order to be able to undo the last changes. The procedure includes:

1. Trying an empty cell to be a box (or then a space).
2. Using all available methods to solve as much as possible.
3. If an error is found, the tried cell will not be the box for sure. It will be a space (or a box, if space was tried).

The problem of this method is that there is no quick way to tell which empty cell to try first. Usually only a few cells lead to any progress, and the other cells lead to dead ends. Most worthy cells to start with may be:

- cells that have many non-empty neighbours;
- cells that are close to the borders or close to the blocks of spaces;
- cells that are within rows that consist of more non-empty cells.

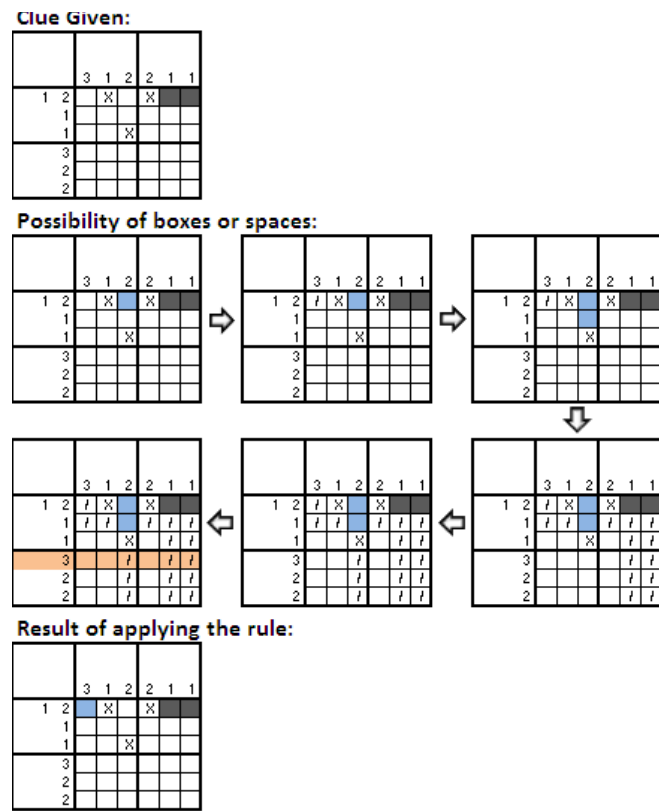


Figure 5. Contradiction

III. MODELLING OF PIXEL PUZZLE

The size of pixel puzzle is represented by $b \times k$, where b is number of rows and k is number of columns respectively. Both are positive integer. In this paper, b and k are 10, 15, 20 or 25. Each number clue in the left side of cells is denoted by $b(u,v)$,

which means v th component of u th row. Each number clue in the top is symbolized by $k(m,n)$, which means m th component of n th column. According to the rule of pixel puzzle, each component in rows and column must be separated by empty spaces. Thus, there is a maximum component for each row and column. The maximum component of v for u th row, denoted by $v_{max}(u)$, equal to $\lceil k/2 \rceil$. In the same way, the maximum component of m for n th column, denoted by $m_{max}(n)$, equal to $\lceil b/2 \rceil$. According to the following figure, the value of u, v, n and m , can be defined more detail in the following way:

$$u=1,2,\dots,b \quad n=1,2,\dots,k$$

$$v=1,2,\dots,v_{max} \quad m=1,2,\dots,m_{max}$$

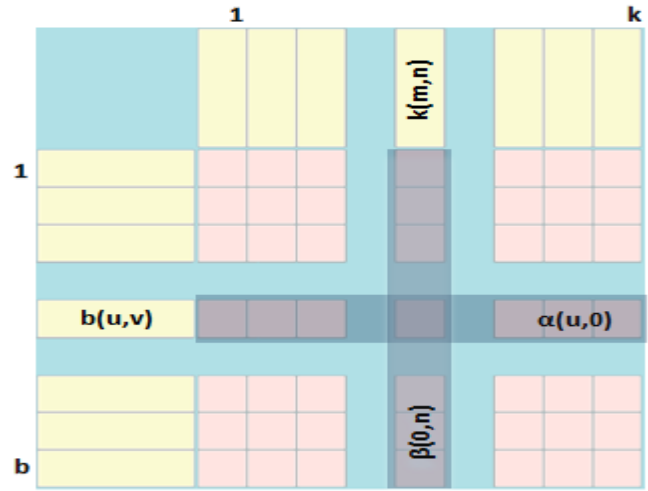


Figure 6. General representation of Pixel Puzzle

In the previous figure, $\alpha(u,0)$ and $\beta(0,n)$ are $(1 \times k)$ and $(1 \times b)$ row vectors respectively.

Each block in each row and column is separated by one or more spaces. A number of boxes for v th component of u th row is equal to $b(u,v)$. Due to the fact that there are several possibilities of boxes, the possible starting boxes for each $b(u,v)$ is defined. In this paper, the first starting possible boxes of $b(u,v)$ is symbolized by $firstrow(u,v)$ and the last starting possible boxes of $b(u,v)$ is denoted by $lastrow(u,v)$. In the same way, the first and last starting possible boxes for columns are denoted by $firstcolumn(m,n)$ and $lastcolumn(m,n)$. $firstrow(u,v), lastrow(u,v), firstcolumn(m,n)$ and $lastcolumn(m,n)$ variables can be defined in the following formula :

$$firstrow(u,v) = \begin{cases} v + \sum_{i=1}^{v-1} b(u,i) & \text{otherwise} \end{cases}$$

$$lastrow(u,v) = k - \left[b(u,v) - 1 + \sum_{j=v+1}^{v_{max}(u)} (b(u,j) + 1) \right]$$

$$firstcolumn(m,n) = \begin{cases} 1 & m = 1 \\ m + \sum_{j=1}^{m-1} k(j,n) & \text{otherwise} \end{cases}$$

$$lastcolumn(m,n) = b - \left[k(m,n) - 1 + \sum_{j=m+1}^{m_{max}(n)} (k(j,n) + 1) \right]$$

After defining the first and starting possible boxes for rows and columns, the vectors are composed containing all possible values for each component in rows and columns. An element of the vector which has the value of 1 means box, while an element with the value of 0 means space. Functions $k: R \rightarrow R$ and $b: R \rightarrow R$: for row and column are defined in the following way:

$$\alpha(u,v) = (x_1 \ x_2 \ \dots \ x_{k-1} \ x_k)$$

$$x_i = \begin{cases} 1 & firstrow(u,v) \leq i \leq lastrow(u,v) + b(u,v) - 1 \\ 0 & \text{otherwise} \end{cases}$$

$$\beta(m,n) = (y_1 \ y_2 \ \dots \ y_{b-1} \ y_b)$$

$$y_i = \begin{cases} 1 & firstcolumn(m,n) \leq i \leq lastcolumn(m,n) + k(m,n) - 1 \\ 0 & \text{otherwise} \end{cases}$$

For each row and column, there are also $\alpha(u,0)$ and $\beta(0,n)$ functions which are the result of the puzzle. Each element in $\alpha(u,0)$ and $\beta(0,n)$ has the value of 1 for box, 0 for space, and 2 for undefined cell. It can be concluded that for each pixel puzzle, given $b(u,v)$ and $k(m,n)$ where $u = 1, 2, \dots, b$ and $n = 1, 2, \dots, k$, $\alpha(u,0)$ and $\beta(0,n)$ shall meet the following conditions:

$$\forall u,v \ \alpha(u,v) \rightarrow \sum_{i=1}^k x_i = b(u,v)$$

$$\forall m,n \ \beta(m,n) \rightarrow \sum_{j=1}^b y_j = k(m,n)$$

And therefore the following conditions hold.

$$\forall u \ \alpha(u,0) = \sum_{i=1}^{v_{max}} \alpha(u,i)$$

$$\forall n \ \beta(0,n) = \sum_{j=1}^{m_{max}} \beta(j,n)$$

A. Simple Boxes

The simple boxes rule for v^{th} component of u^{th} row can be specified as follows:

Given: $b(u,v)$, $\alpha(u,v) = (x_1 \ x_2 \ \dots \ x_k)$, first = first index of $\alpha(u,v)$ element with value of 1, and last = last index of $\alpha(u,v)$ element with value of 1 :

$$\forall u,v, ((first + b(u,v) - 1) \geq (last - b(u,v) + 1)) \rightarrow$$

$$\forall x_i \in \alpha(u,v), ((last - b(u,v) + 1) \leq i \leq (first + b(u,v) - 1)) \rightarrow x_i = 1$$

$$\forall i, y_u \in \beta(0,i), ((last - b(u,v) + 1) \leq i \leq (first + b(u,v) - 1)) \rightarrow y_u = 1$$

The simple boxes rule for m^{th} component of n^{th} row can be specified as follows:

Given: $k(m,n)$

and $(,)$ $\beta(m,n) = (y_1 \ y_2 \ \dots \ y_b)$, first = first

index of $\beta(m,n)$

element with value of 1, and last = last

index of $\beta(m,n)$

element with value of 1 :

$$\forall m,n, ((first + k(m,n) - 1) \geq (last - k(m,n) + 1)) \rightarrow$$

$$\forall \in (0,), ((- (,) + 1) \leq (+ (,) - 1)) \rightarrow = 1 \ \forall \beta(n, last \ k \ m \ n \ i \ first \ k \ m \ n \ y)$$

$$\forall \in (0,), ((- (,) + 1) \leq (+ (,) - 1)) \rightarrow = 1 \ \forall \alpha(i, last \ k \ m \ n \ i \ first \ k \ m \ n \ x)$$

B. Simple Spaces

If the i^{th} component at $\alpha(u,v)$ is symbolized by $z(u,v,i)$

and the j^{th} at $\beta(m,n)$ symbolized by $w(m,n,j)$, then the

following holds.

1. For row :

$$\forall u,i \ \sum_{v=1}^{v_{max}} z(u,v,i) = 0 \rightarrow z(u,0,i) = 0 \wedge w(j,i,u) = 0, \ j = 0, 1, 2, \dots, m_{max}$$

$$\forall u,i, \exists v, z(u,v,i) = 1 \wedge z(u,0,i) = 1 \rightarrow$$

$$(z(u,v,j) = 0, \ j = 1, 2, \dots, i - b(u,v)) \wedge (z(u,v,j) = 0, \ j = i + b(u,v), \dots, k)$$

2. For column:

$$\forall n,i \ \sum_{m=1}^{m_{max}} w(m,n,i) = 0 \rightarrow w(0,n,i) = 0 \wedge z(i,j,n) = 0, \ j = 0, 1, 2, \dots, v_{max}$$

$$\forall n,i, \exists m, w(m,n,i) = 1 \wedge w(0,n,i) = 1 \rightarrow$$

$$(w(m,n,j) = 0, \ j = 1, 2, \dots, i - k(m,n)) \wedge (w(m,n,j) = 0, \ j = i + k(m,n), \dots, b)$$

C. Forcing

If the i^{th} component at $\alpha(u,v)$ is symbolized by $z(u,v,i)$ and the j^{th} at $\beta(m,n)$ symbolized by $w(m,n,j)$, then the following holds.

1. For row :

$$\forall u,v,i \quad z(u,v,i)=0 \wedge i \leq b(u,v) \rightarrow z(u,v,j)=0, \quad j=1,2,\dots,i-1$$

$$\forall u,v, \exists i,j, \quad z(u,v,i)=0 \wedge z(u,v,j)=0 \wedge ((i-j) \leq b(u,v)) \rightarrow$$

$$z(u,v,p)=0, \quad p=i+1,i+2,\dots,j-2,j-1$$

$$\forall u,v,i \quad z(u,v,i)=0 \wedge ((i+b(u,v)) > k) \rightarrow z(u,v,j)=0, \quad j=i+1,i+2,\dots,k$$

If s = first index of $\alpha(u,v)$ element with value of 1 and e = last index of $\alpha(u,v)$ element with value of 1 :

$$\forall u,v, \sum_{i=1}^k z(u,v,i) = b(u,v) \rightarrow$$

$$z(u,p,q)=0, \quad 1 \leq p < v, \quad q = s-1, s, \dots, k$$

$$z(u,r,t)=0, \quad v < r \leq v_{\max}, \quad t = 1, \dots, e+1$$

2. For column:

$$\forall m,n,i \quad w(m,n,i)=0 \wedge i \leq k(m,n) \rightarrow w(m,n,j)=0, \quad j=1,2,\dots,i-1$$

$$\forall m,n, \exists i,j, \quad w(m,n,i)=0 \wedge w(m,n,j)=0 \wedge ((i-j) \leq k(m,n)) \rightarrow$$

$$w(m,n,p)=0, \quad p=i+1,i+2,\dots,j-2,j-1$$

$$\forall m,n,i \quad w(m,n,i)=0 \wedge ((i+k(m,n)) > b) \rightarrow w(m,n,j)=0, \quad j=i+1,i+2,\dots,b$$

If s = first index of $\beta(m,n)$ element with value of 1 and e = last index of $\beta(m,n)$ element with value of 1 :

$$\forall m,n, \sum_{i=1}^b w(m,n,i) = k(m,n) \rightarrow$$

$$w(p,n,q)=0, \quad 1 \leq p < m, \quad q = s-1, s, \dots, b$$

$$w(r,n,t)=0, \quad m < r \leq m_{\max}, \quad t = 1, \dots, e+1$$

D. Contradiction

This rule is applied when the simple boxes, simple spaces and forcing are not sufficient to solve the puzzle. Initially, $kemBaris(u,v)$ as a set containing column index which possibly is a first starting possible boxes of $b(u,v)$ and $kemKolom(m,n)$ as a set containing row index which possibly is a first starting possible boxes of $k(m,n)$ are defined. If $|kemBaris(u,v)|=1$ then $b(u,v)$ has only one possible solution.

The same condition occurs if $|kemKolom(m,n)|=1$.

Contradiction rule is applied when $|kemBaris(u,v)| > 1$ or $|kemKolom(m,n)| > 1$. Contradiction rule is implemented by trying an empty cell to be a box or a space. All possible rules are then applied to solve as much as possible. If an error is found, the tried cell will not be the box. However, it will be a space or a box.

E. Best-First Search

The best first search is performed if all logical rules applied have not given yet the solution. Basically, best-first search is implemented initially by generating tree gradually consisting of components which have more than one solution. Then the logical rules are implemented repeatedly until allows and columns component has one solution.

IV. EXPERIMENT RESULT

In this paper, there are three options to solve the puzzle, namely by using only Rule-Based method, only Best-First Search method after applying Rule-Based method, and the execution of Rule-Based continued by Best-First Search method directly. Solving puzzle only by using Rule-Based method means solving puzzle by employing *simple boxes*, *simple spaces*, *forcing*, and *contradiction* rules. The problems which can be and can not be solved by using only Rule-Based method are depicted in the following two figures respectively.

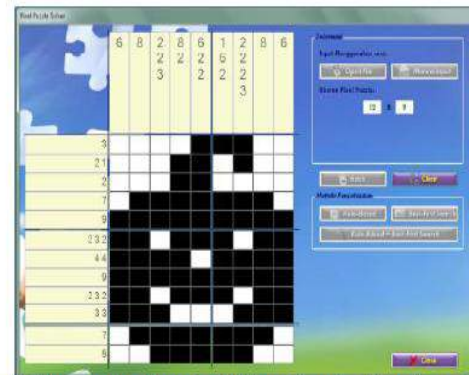


Figure 7. An example of puzzle which can be solved by using only Rule-Based method

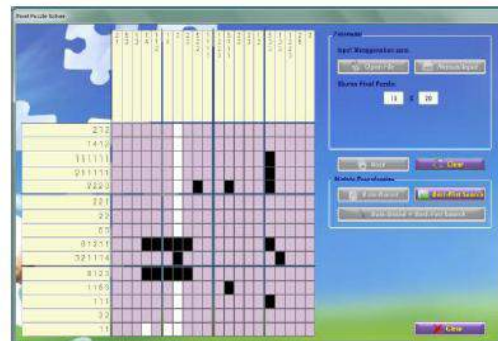


Figure 8. An example of puzzle which can not be solved by using only Rule-Based method

After the process of solving the above puzzle using Rule-Based method which can not be accomplished, solving the puzzle is then continued by implementing Best-first search method (Figure 9).



Figure 9. Applying Best-First Search method to complete the solving process

In the testing phase, 40 kinds of puzzle with 4 different sizes are analyzed. Table below gives the comparison of the time needed for solving puzzles by using only the Rule-Based method in milisecond.

Table I Comparison Of The Time Needed For Solving Puzzles By Using Only The Rule-Based Method InMilisecond

Puzzle number	Puzzle size			
	10 x 10	15 x 15	20 x 20	25 x 25
1	16	25	30	951
2	20	31	54	1307
3	21	45	80	1805
4	23	60	327	1925
5	24	66	477	3829
6	26	78	1118	4553
7	28	89	1135	4568
8	29	271	1179	6710
9	31	303	2027	7626
10	63	397	3768	12654

According to the previous table, it can be seen that the different problem with the same size can be solved in the different time. The different problem with the different size can also be solved in the different time and the bigger size does not always mean the longer the time is needed to solve. Table above shows only the time needed to solve a puzzle by implementing only Rule-Based method. The time needed to solve a puzzle by using Rule-Based and Best-first search is not analyzed because the usage of contradiction rule affects very few puzzles can be solved using *best-first search*. Most of puzzles can be solved after implementing *contradiction* rule and therefore in this paper the time needed to solve puzzles using Best-first search method is not analyzed further. In this section, it will be shown that in average, the long time is needed to solve the bigger size puzzles using Rule-Based method. To conduct a testing about the average time needed to solve puzzles using Rule-Based method, *Student's T-Test* is used with $\alpha = 5\%$. According to a series of computation, it implies that individually, solving puzzle with bigger size is faster than puzzle with smaller size, but

entirely, solving puzzle with smaller size is faster than puzzle with bigger size. The second test is conducted to see whether solving one cell in puzzle with bigger size is longer according to the following table:

TABLE 2
COMPARISON OF THE TIME NEEDED FOR EACH CELL
IN PUZZLES TO BE SOLVED
BY USING ONLY THE RULE-BASED METHOD IN
MILISECOND

Puzzle number-	Puzzle size			
	100	225	400	625
1	0.160	0.111	0.075	1.522
2	0.200	0.138	0.135	2.091
3	0.210	0.200	0.200	2.888
4	0.230	0.267	0.818	3.080
5	0.240	0.293	1.193	6.126
6	0.260	0.347	2.795	7.285
7	0.280	0.396	2.838	7.309
8	0.290	1.204	2.948	10.736
9	0.310	1.347	5.068	12.202
10	0.630	1.764	9.420	20.246

By implementing *Student's T-Test* with $\alpha = 5\%$, according to a series of computation, the average time to solve each cell is linear with the size of *pixel puzzle*, except for 10×10 and 15×15 .

V. CONCLUSIONS AND FUTURE WORKS

In summary, we have shown the system which is able to solve pixel puzzle using Rule-Based Techniques and Best First Search. The Rule-Based Techniques applied consist of *simple boxes*, *simple spaces*, *forcing*, and *contradiction*. Two kinds of testing are performed by analyzing the time needed in milisecond for solving puzzles by using only the Rule-Based method. The first test shows that the bigger the puzzle, the longer time needed to solve the puzzle.

The second test shows that the average time needed to solve each cell in puzzle is linear with the size of *pixel puzzle*, except for 10×10 and 15×15 . Problems which need to be solved with *best-first search* is done longer than problems which is solved with only Rule-Based technique because of heuristics process performed repeatedly. In the future, the system can be extended by categorizing difficulty level of problems and applying other method to enhance Rule-Based technique.

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REFERENCES

- [1] (2011) ANONIM, NONOGRAM SOLVER [ONLINE] AVAILABLE:
[HTTP://WWW.GRIDDLER.CO.UK/SOLVE.ASPX](http://www.griddler.co.uk/solve.aspx)
- [2] (2011) ANONIM, THE GREAT NONOGRAM HUNT [ONLINE] AVAILABLE:
[HTTP://RAVENSPPOINT.WORDPRESS.COM/2010/06/15/THE-GREAT-NONOGRAM-HUNT/](http://ravenspoint.wordpress.com/2010/06/15/the-great-nonogram-hunt/)
- [3] (2011) ANONIM, WHAT IS NONOGRAM?. [ONLINE] AVAILABLE:
[HTTP://WWW.SUDOKU-PUZZLES.NET/NONOGRAM-PUZZLES/NONOGRAM/WHAT-IS-NONOGRAM.HTML](http://www.sudoku-puzzles.net/nonogram-puzzles/nonogram/what-is-nonogram.html)
- [4] MIN-QUAN JING, CHIUNG-HSUEH YU, HUI-LUNG LEE, LING-HWEI CHEN,
—SOLVING JAPANESE PUZZLES WITH LOGICAL RULES AND DEPTH FIRST
SEARCH ALGORITHM, *PROCEEDINGS OF THE EIGHTH INTERNATIONAL
CONFERENCE ON MACHINE LEARNING AND CYBERNETICS, BAODING, 2009.*
- [5] SALCEDO-SANZ, S., ORTIZ-GARCIA, E.G., PEREZ-BELLIDO, A.M.,
PORTILLA-FIGUERAS, A., XIN YAO, —SOLVING JAPANESE PUZZLES WITH
HEURISTICS, *IEEE SYMPOSIUM ON COMPUTATIONAL INTELLIGENCE AND
GAMES (CIG 2007), 2007.*

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