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A Logic Puzzle Solver by Selecting Smallest Branching Factor

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Abstract

We made a puzzle solver for logic puzzles such as zebra-problem. We suggest an idea of a state space search by Selection of the Smallest Branching Factor. This idea is used to solve puzzles, and has the effect of decreasing the amount of the search. This idea is to make small branching factor the root of a search tree. And we use reasoning puzzles that is a kind of logic puzzle for evaluation. We show effectiveness of this idea by solving reasoning puzzles.

1. Introduction

The performance of the computer goes up, and it is possible to solve it at time a little as for a large-scale search problem in recent years. But, for example, there is a problem that called hexomino that is a kind of the problem putting pieces on the box. This problem cannot be solved at efficient time because the number of solutions of this problem is larger than 10^{20}. Therefore, cutting branches is necessary in a search tree. We propose an idea that all the numbers of nodes are decreased by taking the node that has the smallest branching factor to the root of the search tree.

2. Selection of the Smallest Branching Factor

There is a problem that pieces of blocks which are different size each other must be put in a box of a limited size, everyone will usually put from a large piece. Because if the large one is put in the box first, a small things can be put in remaining space. Oppositely, when putting it from a small thing, some large things will be noticed not to enter by lack of space.

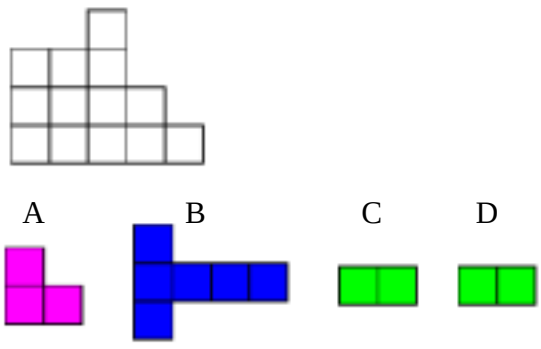


Fig 1. A puzzle to put all pieces below in the box above

A basic idea of Selection of the Smallest Branching Factor is to put a piece that cannot be put easily in the box earlier than pieces that can be put easily. In the puzzle shown in Fig 1, the possibility that each piece is put on the empty box is counted. Then, there are 23 kinds of A, 2 kinds of B, and 17 kinds of C or D can be put. Therefore, piece B is put easily. Then, piece B is put first as shown in Fig 2.

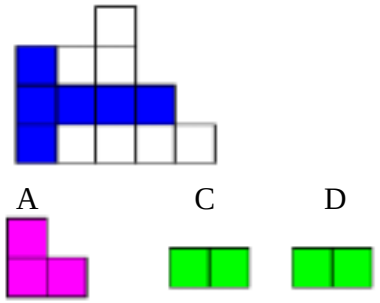


Fig 2. Piece B was put

Next, the possibility that pieces of the remainder are put is counted in this state as shown in Fig 2. Then, there are 1 kind of A, and 4 kinds of C or D can be put. Therefore, the piece A is put in this state as shown in Fig 3.

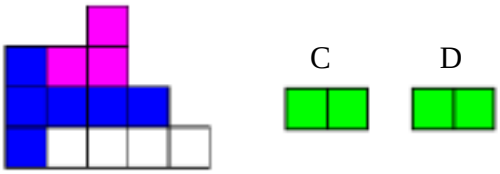


Fig 3. Piece A was put

Thus, there is a possibility of becoming peace that is not put easily even if first it is put easily by the state's changing. By the way, we call the method that pieces are put in order with little number when parts are put in empty box Method of Sorting at First.

Fig 4 shows the search tree when this idea is used. Note that the new piece is put every two depth. The pieces are chosen when the depth is 2n (n=0,1,2…). And the way of piece are chosen when the depth is 2n+1.

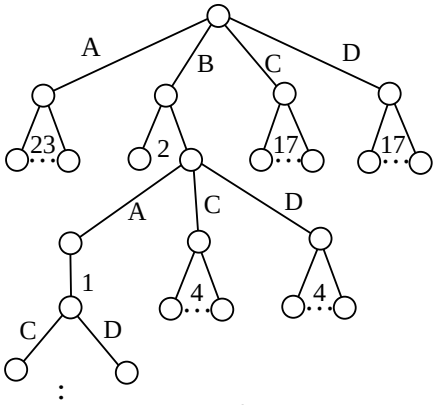


Fig 4. The search trẻe by Selection of the Smallest Branching Factor

3. Application of Selection of the Smallest Branching Factor to the Reasoning Puzzle

We use the Reasoning Puzzle to evaluate this idea. The Reasoning Puzzle is a kind of a logic puzzle that is representated by the “zebra problem”. This can be solved with similar method of the problem of putting pieces on the box.

The Reasoning Puzzle is a problem of requesting the relation of some things from some hints. Fig 5 shows a example of the Reasoning Puzzle.

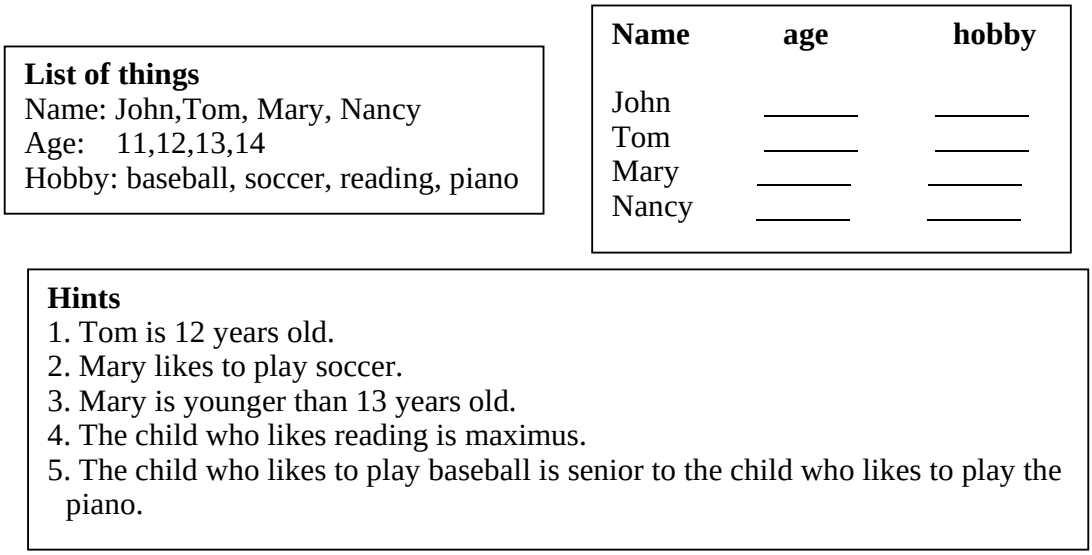
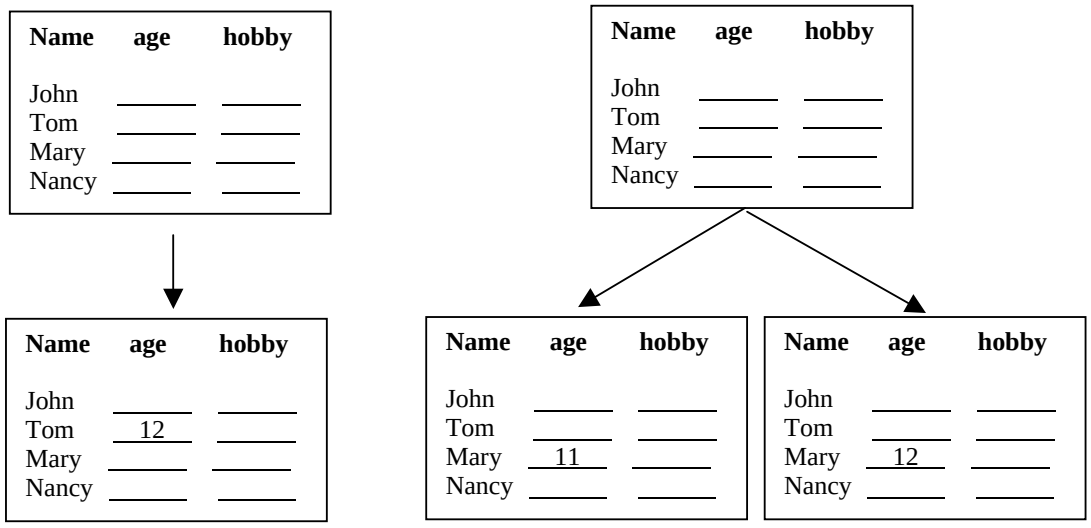


Fig 5. Example of the Reasoning puzzle

At first, a list of solution is not decided excluding one (to prevent the solution from overlapping). If there is a hint "Tom is 12 years old", then place of age concerning Tom is writen "12" as shown Fig 6(a). On the other hand, if there is a hint "Mary is younger than 13 years old", then place of age concerning Mary is writen "11" or "12" as shown Fig 6(b). In a word, each hint of the Reasoning Puzzle is each piece of the problem of putting pieces on the box. And allocating things by the hint are allocating pieces in the box.



(a) Tom is 12 years old

(b) Mary is younger than 13 years old

Fig 6. The transition of the state by the hint

For an application of Selection of the smallest branching factor to the Reasoning Puzzle, At first, each hint is used to the empty list of solution, and the number that things are allocated by the hint is counted. For the hint of Fig 5, this number of the hint1 and hint2 is 1, hint3 is 3, hint4 is 4, and hint5 is 72. Each of these numbers are branching factors of each hint in the first state. By the way, in the Method of Sorting at First, these hints are used in order with little this number. The example of this number of several kinds of hints are shown as table 1.

Table 1. The example of branching factor of a hint in the problem of Fig 5

Hint	Branching factor
Tom is 13 years old.	1
Tom is maximus.	1
Tom is younger than 13 years old.	2
Tom likes sports.	2
Tom is not 13 years old.	3
Tom is not maximus.	3
The child who likes reading is 13 years old.	4
Tom is younger than Mary.	6
The child who likes reading is not 13 years old.	16
The child who likes to play baseball is senior to the child who likes to play the piano.	72

4. Evaluation

For we evaluate this idea, we compare the number of nodes that requires it so that the system may solve the problem. Because the calculation cost of this idea is equal to an increase of the number of nodes. The system is compared three kinds, Selection of the Smallest Branch Factor, Method of Sorting at First, and method of not changing the order of hint. A graph of result is shown as Fig 7.

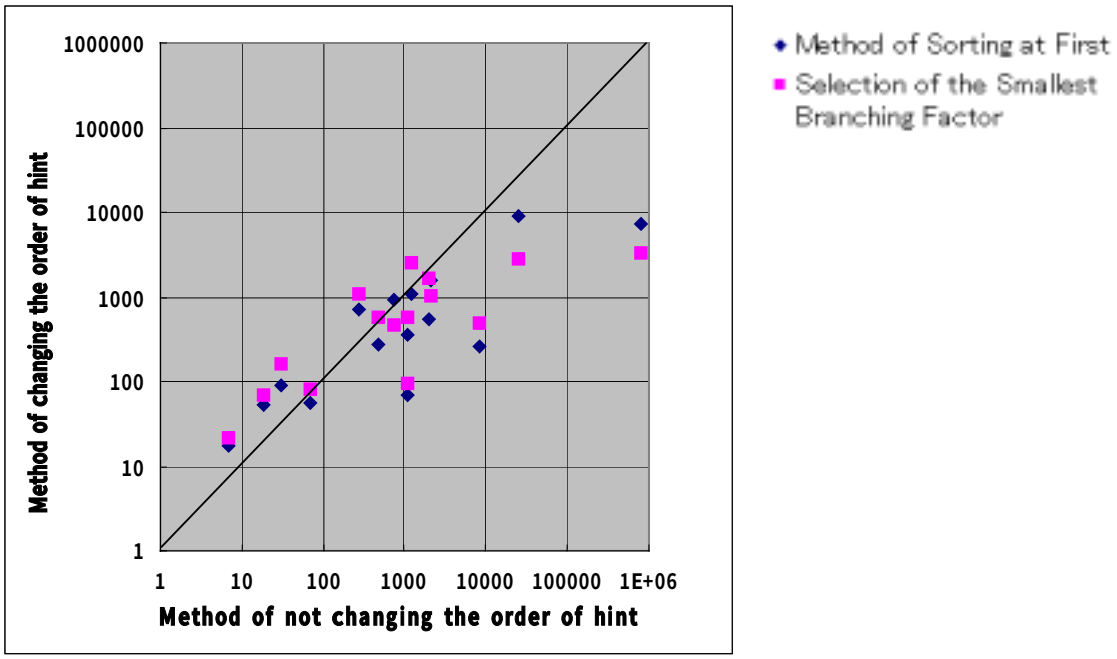


Fig 7. Comparison of numbers of nodes

And the result of margin is shown table 2.

Table 2. Comparison of numbers of nodes (result of margin)

Result 1

System	Number of nodes
Method of not changing the order of hint	Over 3,485,000
Method of Sorting at First	508,240
Selection of the Smallest Branching Factor	5,959

Result 2

System	Number of nodes
Method of not changing the order of hint	Over 3,765,000
Method of Sorting at First	Over 3,690,000
Selection of the Smallest Branching Factor	722,081

In easy problems, that is, little amount of search, the number of nodes of not changing the order of hint is the least. In problems of medium difficulty, the number of nodes of Sorting at First is the least. In hard problems, that is, large amount of search, the number of nodes of Selection of the Smallest Branching Factor is the least. Because in Selection of the Smallest Branching Fanctor, the calculation of the branching factor of each hint is needed every depth in the search tree. Therefore, the ratio of a decrease in number of nodes by cutting branch is few when amount of search is a little. On the other hand, when amount of search is large, the ratio of a decrease in number of nodes by cutting branch is large. Then all the number of nodes decrease. Therefore, it is effective to be large the amount of the search as for this method.

5. Conclusion and Future works

We suggested an idea of state space search by Selection of the Smallest Branching Factor. And we showed that this idea can decrease the amount of the search when amount of the search is large.
We will apply this idea to another problems, especially, like as pentomino or hexomino. In addition, we think that this idea can be applied also to game search using proof number.