Water-Jug Puzzles

In the water-jug puzzle we are given a 4-liter jug, and a 7-liter jug. Initially, both jugs are empty. Either jug can be filled with water from a tap, and we can discard water from either jug down a drain. Water may be poured from one jug into the other. There is no additional measuring device. We want to find a set of operations that will leave precisely x liters of water in either one of the jugs.

i. Set up a state-space search formulation of the water jug puzzle:
   a) Given the initial iconic state description as a data structure.
   b) Give a goal condition on states as some test on data structures.
   c) Name the operators on states and give precise descriptions of what each operator does to a state description.

ii. Find whether the goals $x = \{1, 2, 3, 4, 5, 6, 7\}$ can be accomplished in 8 or fewer steps.

Hint: Use breadth-first search.

Water-Jug Puzzle

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a) (A B)     // A is the amount in the 4-liter jug
             // B in the 7-liter jug
b) (A == x) or (B == x)

c)  FA: (4 B),
    FB: (A 7)
    EA: (0 B),
    EB: (A 0)

    PAB: if ((A+B)<= 7)    then  (0 A+B)
                           else  (A+B-7 7)
    PBA: if ((A+B)<=4)     then  (A+B 0)
                           else  (4  A+B-4)
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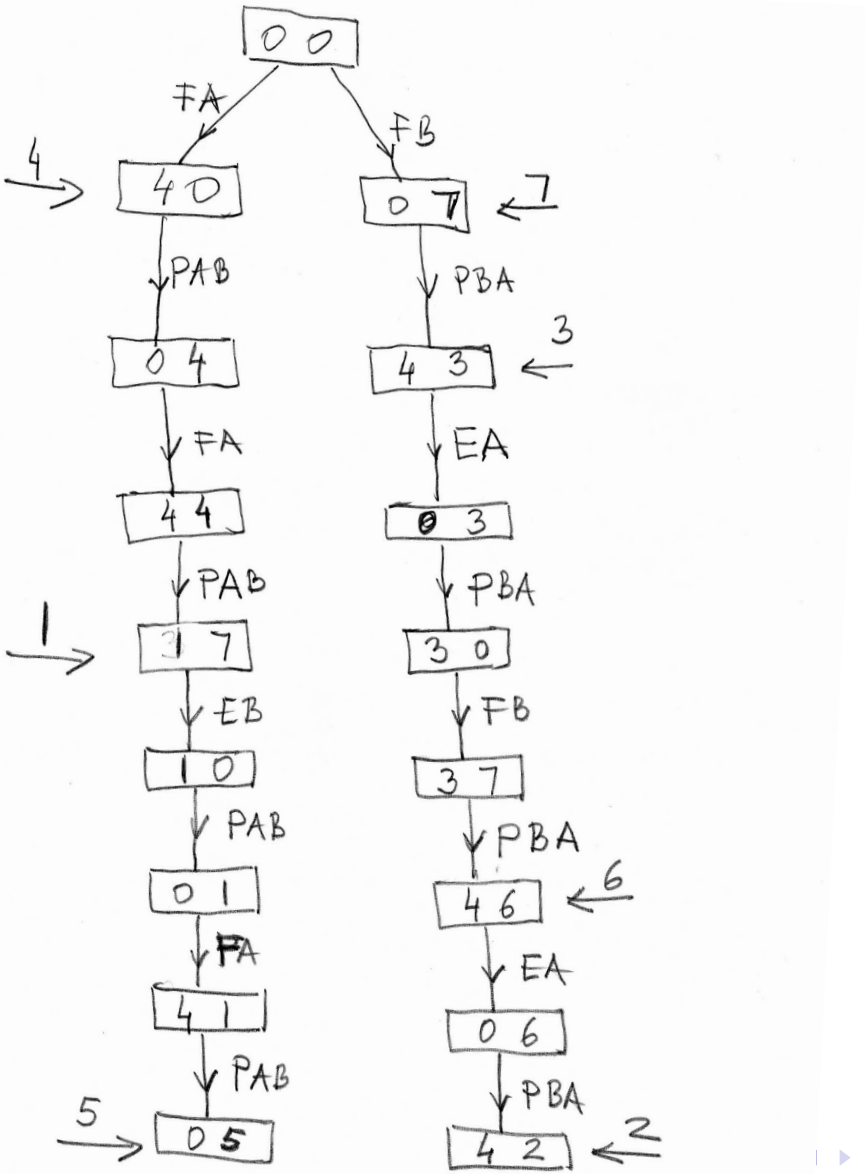
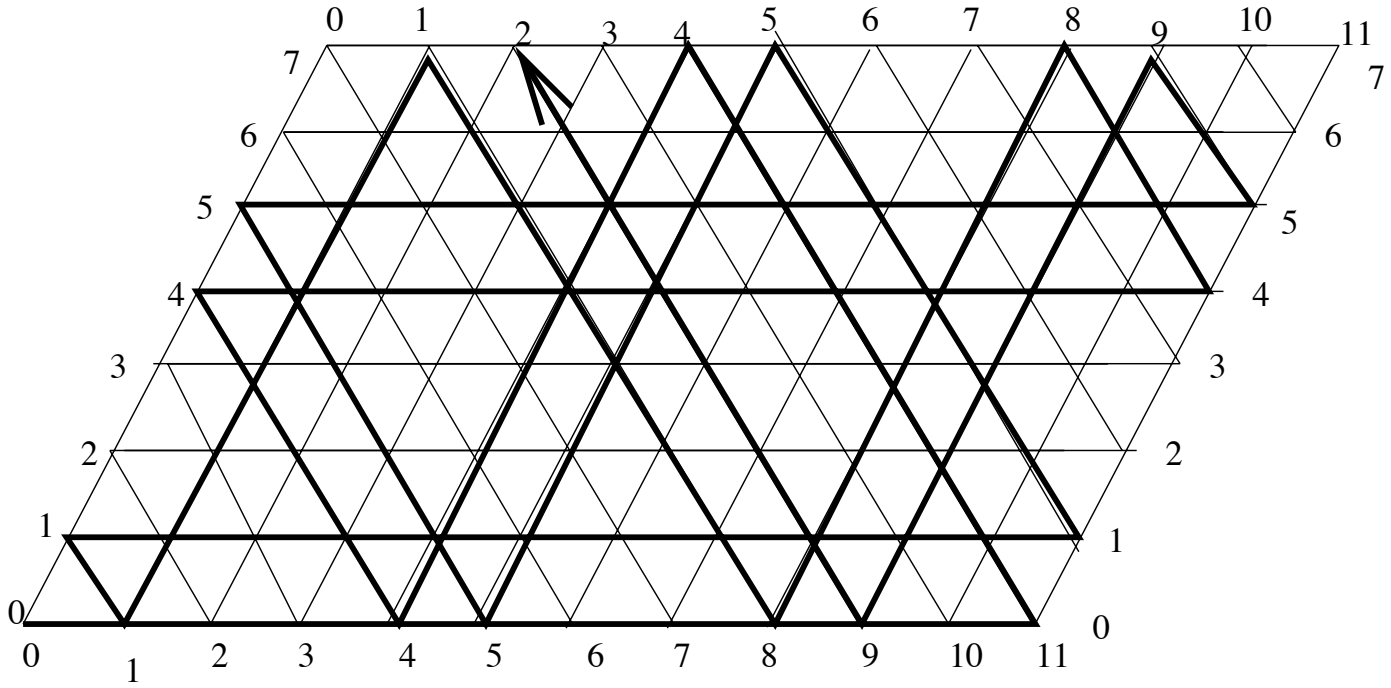
Water-Jug Puzzle Solution



Bouncing Ball Solution

Graphing the paths of balls bouncing inside *rhomboidal* tables



11–PINT VESSEL	11	4	4	0	11	8	8	1	1	0	11	5	5	0	11	9	9	2
7–PINT VESSEL	0	7	0	4	4	7	0	7	0	1	1	7	0	5	5	7	0	7

7-pint and 11-pint jugs. Readings on the horizontal axis represent the amount of water in the 11-pint vessel at any time and readings on the vertical axis tell how much water is in the 7-pint vessel.

The angle of vertical to the horizontal side is 60°.

To use this graph, imagine a ball at point 0 in the lower left corner. It travels to the right along the base of the rhomboid until it strikes the right-hand cushion at a point labeled 11 on the base line: the 11-pint vessel has been filled and the 7-pint jug remains empty. After bouncing off the right-hand cushion the ball travels up to the left until it hits the top cushion at point 4 on the horizontal coordinate and on the seventh line on the side coordinate. This plot indicates that 7 pints have been transferred from the 11-pint vessel to the 7-pint vessel, leaving 4 pints in the larger vessel.

If you continue to follow the bouncing ball until it strikes a point marked 2, keeping a record of each step, you will obtain the 18-step answer shown below the graph. This is actually not the shortest answer. An alternative procedure is to begin by filling the 7-pint vessel. This is graphed by starting the ball at the 0 point and rolling it up along the table's left side. If you trace the ball's path until it strikes a 2 point, keeping a record of the steps, you will find that this ball computer bounces out a solution in 14 steps—the minimum.