Basic Strategies to solve Disentanglement Puzzles

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Do you like disentanglement puzzles?

From the experience with other puzzlers that I had during the last decade I can tell that there are several puzzlers that would clearly answer this question with "yes" – and I am also this kind of puzzler. Maybe it's because of the fact that you can generate a fairly difficult puzzle by combining only a few simple pieces like ropes, rings, balls, discs. Or maybe it's because you have to see the solution *before* working on the puzzle – otherwise you will wind up getting the pieces into a state where you don't know how to escape from there again. But – as a matter of fact – there are some other puzzlers that are not that enthusiastic about disentanglement puzzles. With this article I want to pave the way for those puzzlers, and introduce them to the way of thinking for disentanglement puzzles.

In general this article is designated to compile a set of basic strategies that should allow you to understand and solve many of the classic disentanglement puzzles. This is done by first giving the ***definition*** of a disentanglement puzzle. Then the most ***fundamental concept*** of "bending the puzzle & the 3D-space" is introduced. This leads to six strategies, which are presented here.

Definition of a Disentanglement Puzzle

If you are looking for a classification of mechanical puzzles, there are two main sources: One has been made by Jerry Slocum and another one by Dalgety/Hordern. Among several other puzzle categories that they describe in their classifications, disentanglement puzzles are defined like this:

Extract from the "Mechanical Puzzle Classification by Jerry Slocum"

4. Disentanglement Puzzles: Disentangle & re-entangle to solve puzzle
    - 4.1 Cast iron & sheet metal
    - 4.2 Wire
    - 4.3 String
    - 4.4 Miscellaneous disentanglement puzzles

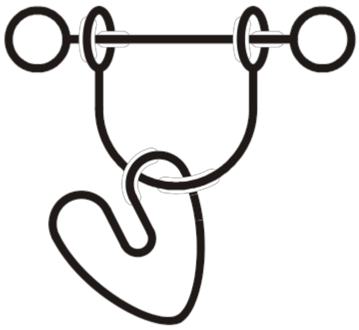
Extract from "Mechanical Puzzle Classification by Dalgety/Hordern"

> TANGLEMENT PUZZLES (TNG) have parts that must be linked or unlinked. The linked parts, which may be flexible, have significant freedom of movement in relation to each other, unlike the parts of an interlocking puzzle.

Many disentanglement puzzles consist of wire and/or string parts that have the aforementioned freedom of movement. The difficulty in a puzzle of this kind, lies in exactly deducing this freedom and implementing it into a working solution.

Fundamental Concept

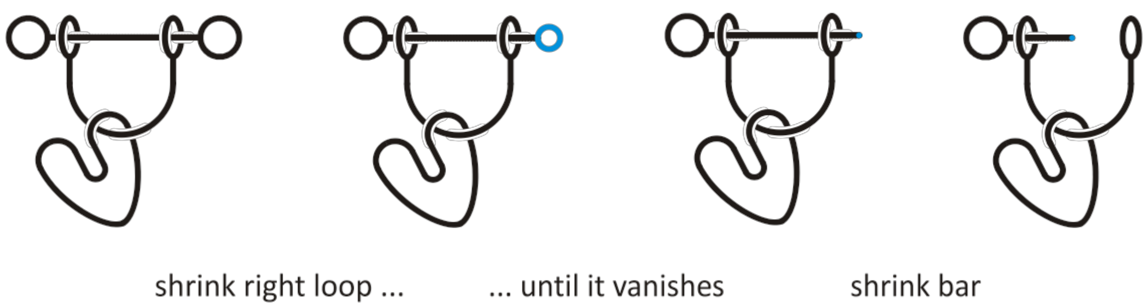
I would like to use a classic puzzle as a guide to walk you through this chapter. So let's look at the following puzzle (see picture 1).



picture 1: heart puzzle. Objective: free the heart.

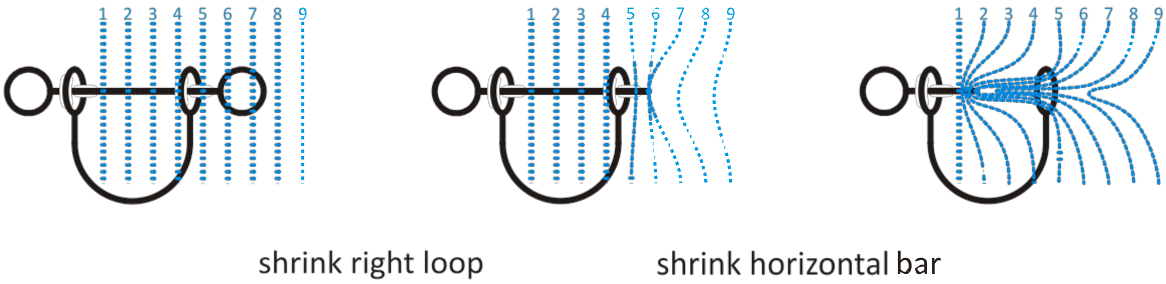
The puzzle is completely made out of wire and consists of a closed heart-shape piece, a U-shape piece and a horizontal bar, that interlocks with the U because of the size of its loops at its ends. The objective is to free the heart from the rest. How to solve it? Let's first have a quick look at the following concept:

[Rubber Concept] The fundamental concept that can be applied to many of the disentanglement puzzles assumes that all puzzle pieces are completely made out of rubber material. This allows us to continuously deform, bend, stretch, squeeze and shrink all parts as we want. For sure the deformations/transformations are only done theoretically and not to the real mechanical puzzle. The ability to shrink these parts allows us to make these parts smaller and smaller, until they are only the size of a single point. This means that this part has 'vanished'. All transformations done to the puzzle are valid as long as no piece intersects other ones. By consecutively applying many of those transformations the whole puzzle can sometimes be transformed into a completely different looking puzzle. But because none of the parts were crossed, this different looking puzzle is still the same puzzle as the original one; as long as lengths and other mechanical restrictions that might be obstacles later on are not involved. Picture 2 shows some of the mentioned transformations applied to our reference puzzle: we first shrink one of the loops (e.g. the right one) of the horizontal bar such that it shrinks to a point – and so the loop vanishes. The next step is to shrink the length of the horizontal bar such that the right end of the bar moves out of the right loop of the U-shaped piece. With these two transformations we basically removed the horizontal bar as an obstacle.



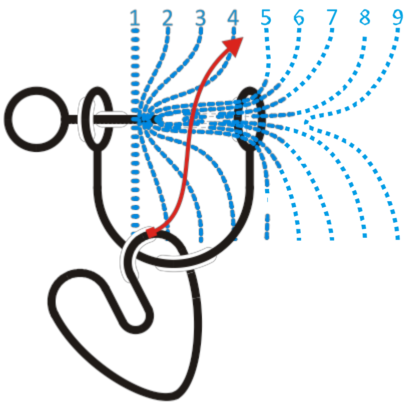
picture 2: Transformations

[Transforming 3D space] The rubber concept describes the valid transformations done to the puzzle. But what about the 3D space the puzzle is living in? All our mechanical puzzles are always embedded in our 3D world, and so all the transformations done to the puzzle result in transforming the 3D space as well. For our sample puzzle I added some vertical grid lines to make the transformations visible (see picture 3, the heart has been omitted in these drawings).



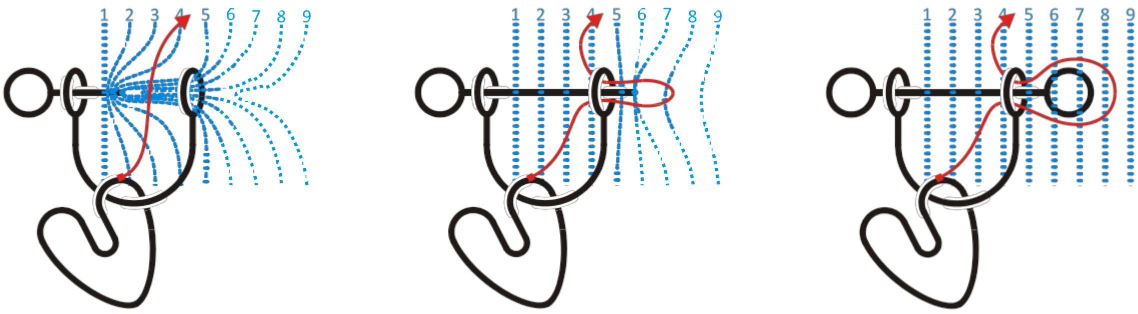
picture 3: Transformations done to the puzzle (heart omitted) as well as to the 3D space (grid lines)

[Finding a solution path] Why do we do all this? Well, the goal is to apply a series of transformations in such a way to get the puzzle into a state where the solution can be seen clearly, i.e., so that it is clear which part has to be moved into which direction to disassemble/assemble the puzzle. With the preparations done so far, we now see the solution path in our (transformed) puzzle: Move the heart upwards through the opening to get it free. Picture 4 shows all preparations done so far including the solution path.



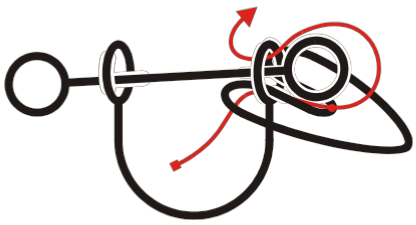
picture 4: transformed puzzle, transformed 3D space AND solution path

[Reversing the transformations] But how does this help to solve our real puzzle? Well, applying the rubber concept, transforming the 3D space and finding a solution path at least lets us know that there *is* a solution. For sure we cannot apply the solution at this stage because we do not have the transformed puzzle in our hand. So why don't we just roll back all the transformations done so far, and also apply them to the solution path? Let's see what the solution path, which is part of the 3D space, will look like. Picture 5 shows these steps.



picture 5: Reversing all transformations to the puzzle, the 3D space AND the solution path

By finishing the last step we finally got a solution path for our real mechanical puzzle! The next problem we have to face is how we are going to achieve this move. The answer is shown in picture 6: Because the shape was intentionally chosen as a heart, we can use the inward pointing part of the heart to insert it into the right loop of the U-piece, to go around the right loop of the horizontal bar, and exit the loop of the U-piece. Now the heart is free.



picture 6: Initial step of the solution

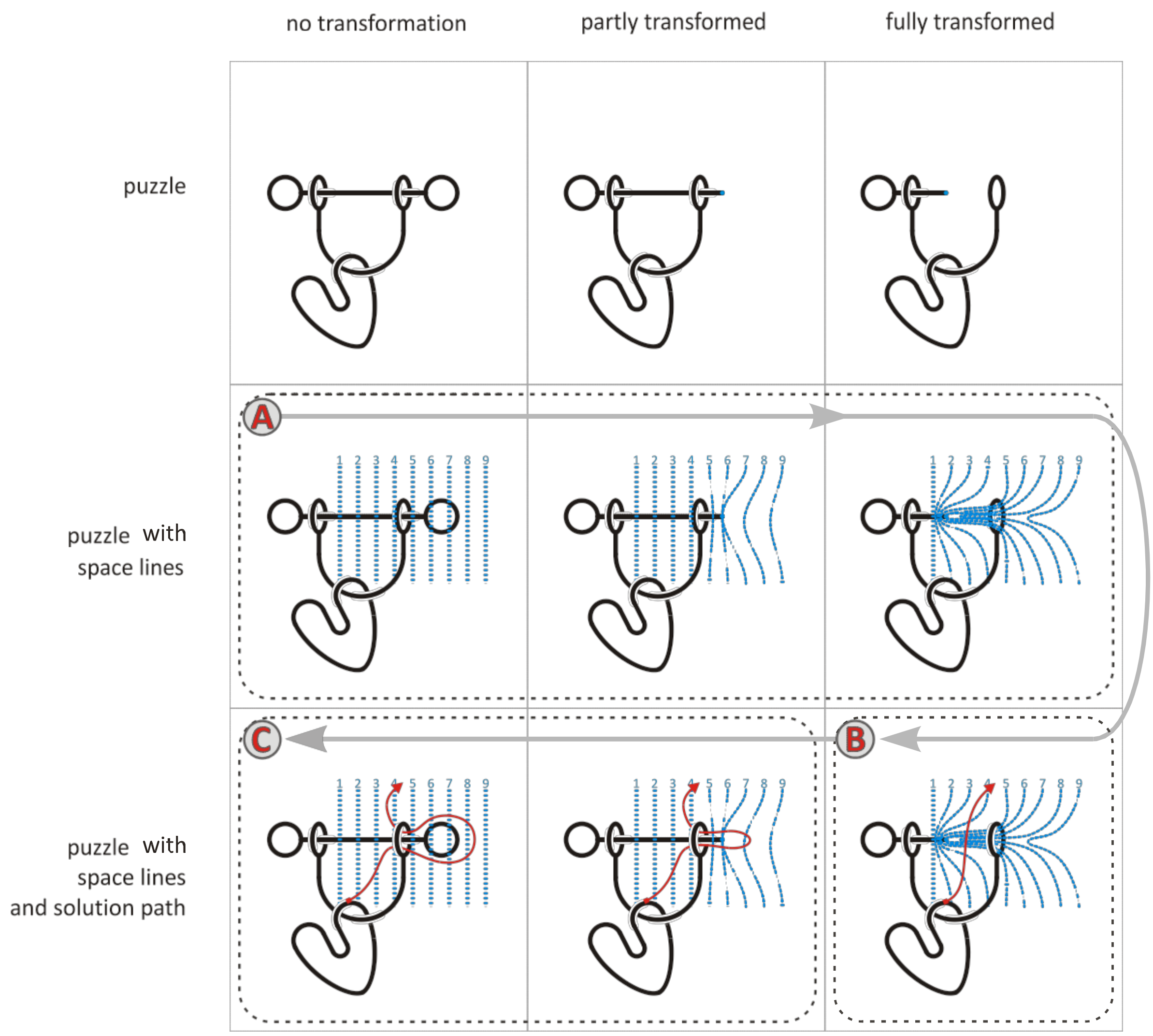
All the steps of this **Fundamental Concept** done so far can be summarized into the following three steps:

Step A:	***Rubber method & Transforming 3D space***	Use continuous and valid transformations to the puzzle and the 3D-space to get the puzzle into a state where the solution path can be drawn.
Step B:	***Finding a solution path***	Draw the solution path (embedded in the 3D space).
Step C:	***Reversing the transformations***	Reverse all transformations done to the puzzle in step A and the 3D-space, including the solution path. You will get a solution path for the original puzzle.

Picture 7 shows an overview of all discussed steps of this **Fundamental Concept** on the example of the heart puzzle. There the three steps (A, B, C) are highlighted and the train of thought is indicated by a big arrow. Please take the time to have a close look at this overview to adopt this concept.

The Fundamental Concept established the foundation for working on a solution to a disentanglement puzzle. Unfortunately, for more elaborate puzzles it gets confusing very quickly because of the complexity of all transformations that you have to keep track of.

Therefore the intention of the following chapters is to show some of the consequences of the fundamental concept, so you can use it like virtual tools in your toolbox and crack many standard disentanglement puzzles.



picture 7: Overview of the Fundamental Concept (including Steps A, B, C) using the Heart Puzzle

Some additional remarks on the heart puzzle itself:

1) If the wire heart were exchanged by a closed loop made of rope, the solution would be exactly the same. Because of the flexibility of the rope the mechanical process of solving the puzzle sometimes becomes even easier.

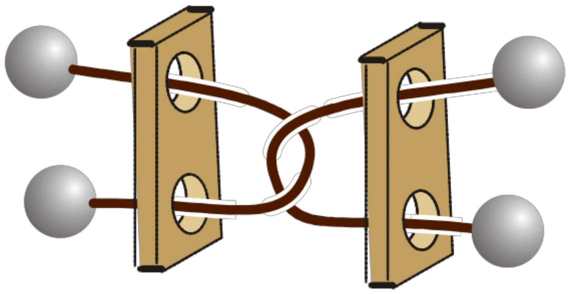
2) Sometimes this puzzle is manufactured with two different sizes of loops at the ends of the horizontal bar. To mechanically solve this kind of puzzle you have to choose the smaller loop for the heart to go around. In many cases the bigger one prevents to heart from passing around.

Strategy 1: Eliminate a crossing by going around an end

As previously mentioned, the fundamental concept supplies the foundation for finding a solution. It is definitely something you should be very familiar with, and should always be applied if needed. But doing all the necessary transformations forward and backward in your head (or alternatively on a piece of paper) is sometimes very cumbersome and can be very time-consuming.

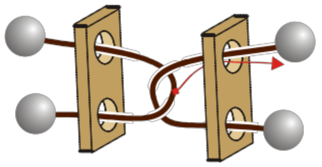
Therefore, we will first concentrate on looking at the result (the solution path) of the fundamental concept. And then we will go one step further to see which cases it can be applied to – namely for all cases where you want to eliminate (or to add) a crossing. And when dealing with disentanglement puzzles you definitely want to lose and/or add crossings permanently. For simple puzzles the next steps might look *too* easy, but when it comes to a more difficult puzzle, then it will be "just" a small part of the solution process that you have to know very well.

So again, let’s start very simple by having a look at the following puzzle (see picture 8). It consists of two pieces which each consist of a rectangular wooden plate with a rope that goes through the two holes. At each end of the rope there is a ball such that it cannot go through the hole. The two pieces are entangled with their ropes as shown in the picture. How can we separate the two pieces?

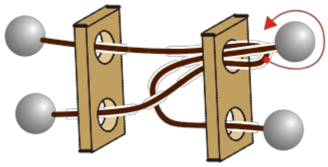


picture 8: Objective: Separate the two pieces

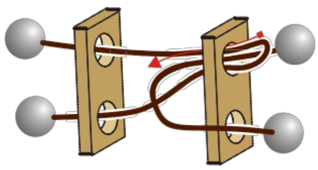
If we look at the top right hole with the piece of rope going through it and the ball at its end, it looks familiar and like the puzzle discussed above (see picture 1). If we identify the top right ball to be our “end” we can use the rope of the left piece to go around this end (see step-by-step solution in picture 9).



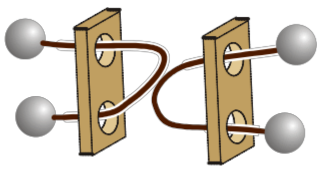
… follow the rope to its end …



… walk around the end …
(to change to the opposite side of the rope)



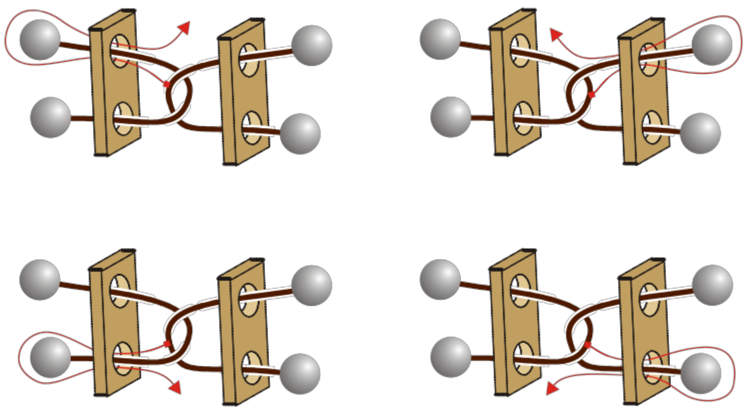
… follow the rope back close to the starting position
(but always stay on the opposite side of the rope).



We have eliminated the crossing of the two ropes from the beginning. Both pieces now are separate.

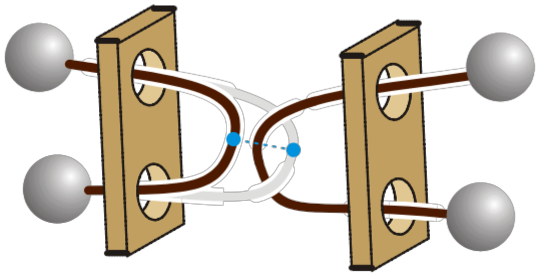
picture 9: Step-by-Step solution

Alternatively we also could have chosen the bottom right ball as our “end”, or the top left ball or the bottom left ball. For each of the four “ends” the solution is shown in picture 10.



picture 10: all four possibilities for solving this puzzle

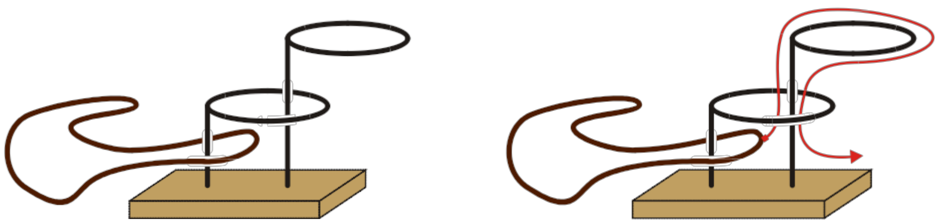
[Result of strategy 1] Basically, what we can achieve in each of those four cases is the elimination of the crossing of the two ropes in the middle (see picture 11). We get this done by following with one rope to the end of the other rope, walking around the end, and following the rope back on its other side. By reversing this step we also can add a crossing. This way of eliminating/adding a crossing by going around an end is very useful and will be used in the proceeding chapters extensively.



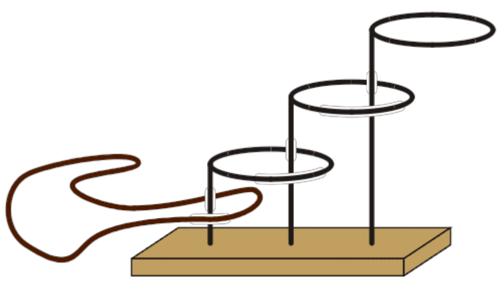
picture 11: Final result of this strategy: Eliminate a crossing by just going around the end

Strategy 2: Recursive use of strategies

Although we have only now been presented with one strategy, it already is possible to use it recursively. This means that while performing a move you have to do another one in between and come back to the first one to finish it. Let's have a look at an example (see picture 12, left). The puzzle used to demonstrate this behavior consists of two pieces of wire glued into a wooden plate. The objective is to remove the brown rope, which is hooked into the left piece of wire. Having learned strategy 1, you now should be able to solve this puzzle without further help. For the sake of completeness, the diagram on the right shows the solution.

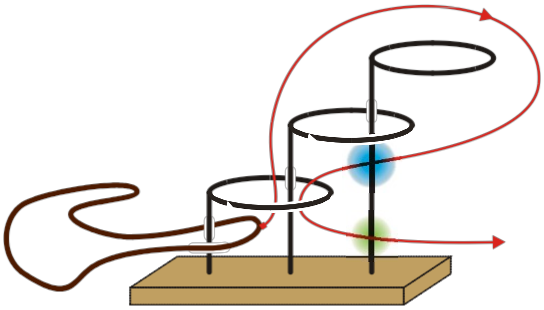


picture 12: Free the rope (puzzle without/with solution)

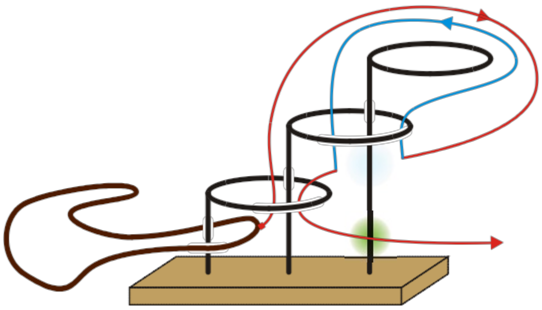


Now we impose a tremendous amount of drama by adding a third piece of wire (see picture on the left). Would you now be able to release the rope?

Using the rubber-theory, we could shrink the loop of wire down until it becomes but a point, and then shrink the rod down into the wooden plate so that the whole third piece of wire does not exist anymore. This at least proves the existence of a solution. But how can it be realized?

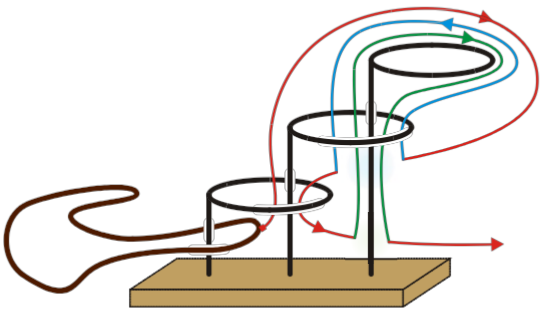


IF we tried the solution with the two wire pieces for the puzzle with the three wire pieces (see picture on the left) we would run into two problematic situations (marked with a blue and a green dot). But in both situations the rope has to cross a piece of wire. This definitely can be solved using strategy 1 again. And so let's first solve the blue situation by …



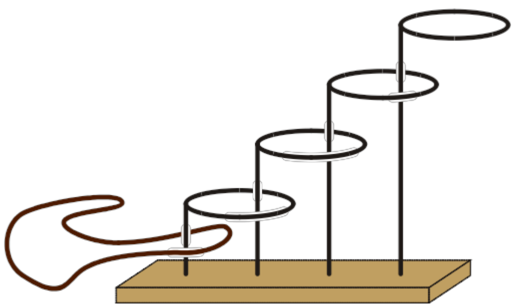
… going around the end.

The green crossing also can be solved by using strategy 1 by …

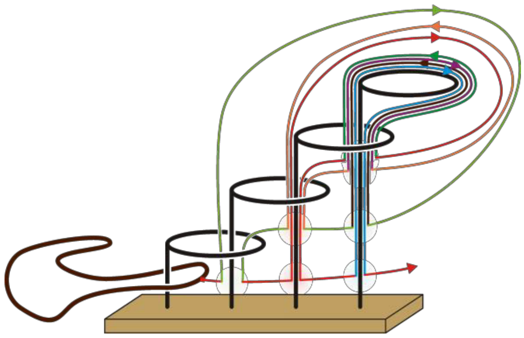


… going around the end.

Voilà. This solves the puzzle with three pieces of wire using strategy 1 recursively: While doing the red solution path, we had to use an additional blue one and a green one as well.



Test: According to the modular construction of this puzzle, it is very simple to add another piece of wire as shown in the picture on the left. But it definitely adds some more drama. With all the knowledge that you have right now, would you accept the challenge to solve this puzzle only in your head (or using paper & pencil)?



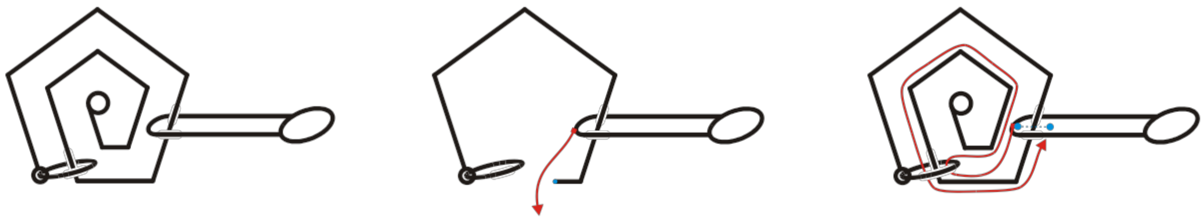
On the left you see the solution diagram.

The modular concept of this puzzle makes it easy to add more and more pieces of wire. By doing so, the amount of 'moves' nearly doubles with each new piece of wire. Using about eight pieces of wire leads to a puzzle that can be solved within a reasonable amount of time (for an experienced puzzler).

And just for fun, here's another common wire disentanglement puzzle. In this one, the long piece of wire has to be removed from the pentagonal piece of wire.

picture 13: Free the wire handle from the pentagonal piece of wire

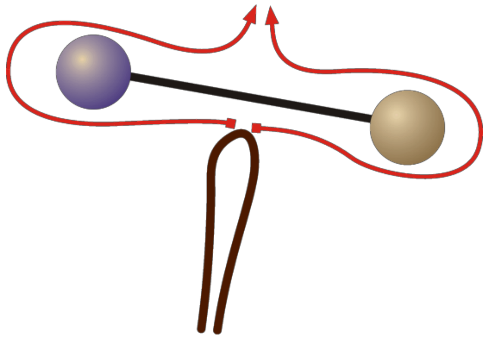
And here the solution:



picture 14: left: start configuration. middle: transformed puzzle with solution path.
right: solution path for the untransformed puzzle = eliminate a crossing by going around the end.

Strategy 3: Choose the *correct* end

This strategy sounds obvious, but sometimes it can be difficult to detect if this strategy is applicable while solving a puzzle. The strategy is (see picture 15): ***Whenever you have to cross 'something' you always have the choice of either going around the 'left end' or the 'right end'***. In many cases one of those ends cannot be done due to some mechanical restrictions (e.g. the rope is too short), and therefore the other end has to be chosen to solve the puzzle.

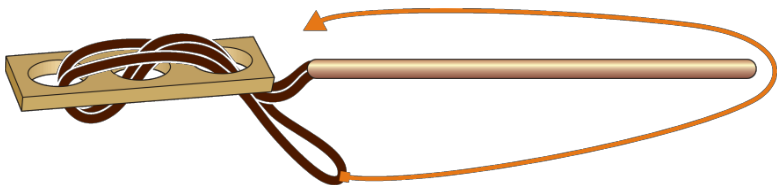


picture 15: If the loop has to cross 'something', then you have the choice to either go around the left end or the right end

I will demonstrate this strategy for a classic puzzle that is shown in picture 16. At the end of a long stick there is a rope attached, which is tangled into a wooden block with three holes. The objective is to free the stick from the block.

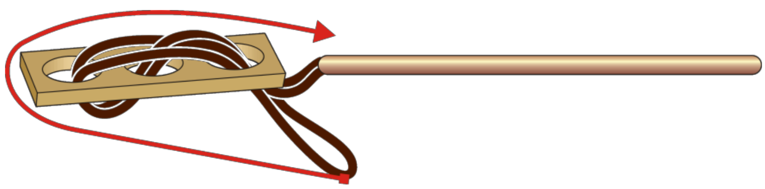
picture 16: Free the stick from the block with the three holes

For sure, the first thing to do is to grab the end of the rope, pull it through the right hole and try to move it around the right end of the stick (see picture 17). But, unfortunately, with this puzzle the rope is too short to successfully do this move. So, how can it be solved?



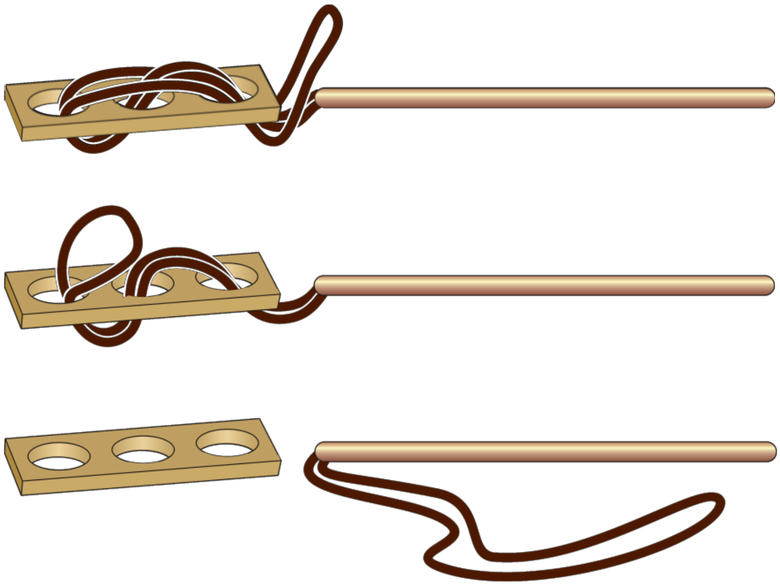
picture 17: The rope is too short to do this move!

Well, the solution is simple: if the rope cannot be moved around the 'right end' (and here, the stick is treated as the 'right end') then try the 'left end' (and here, the block with the holes is treated as the 'left end'). See picture 18:



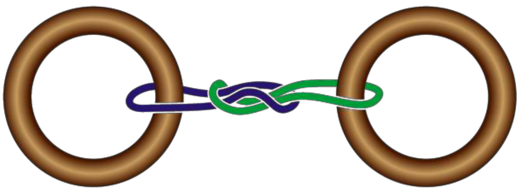
picture 18: Use the 'left end' of this puzzle to go to the intended position

After having done this move, you simply can remove the rope from the wooden block as shown in picture 19.

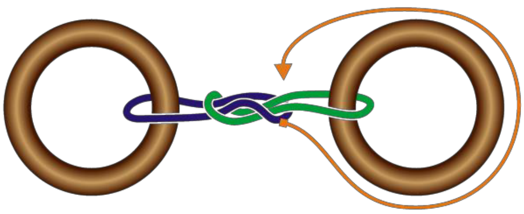


picture 19: last steps to remove the rope

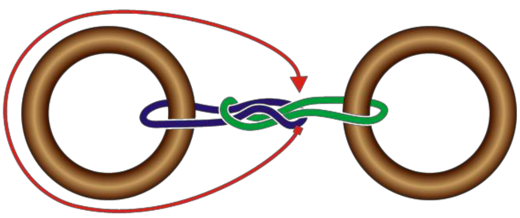
Here is another puzzle where this strategy can be applied (including the solution):



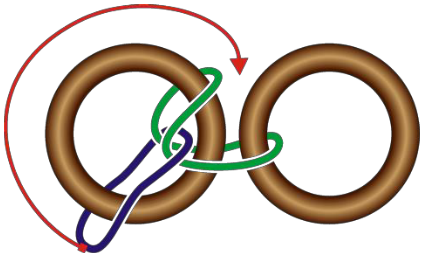
Objective: Separate the two rings with their ropes. Note that the loops are too small – i.e. a wooden ring cannot pass through a loop.



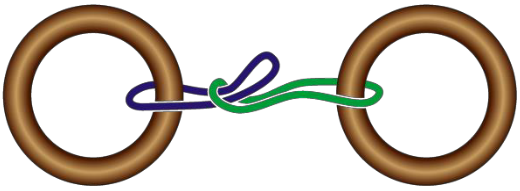
This move is what you might want to do at first glance. But as the loop is too short/small this move cannot be done!



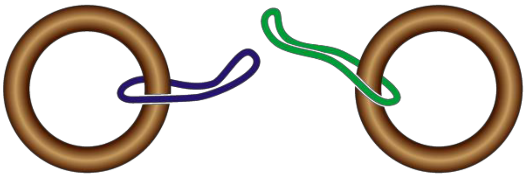
Going around the "left end" is the correct move.



Here, the critical move, in slow motion.

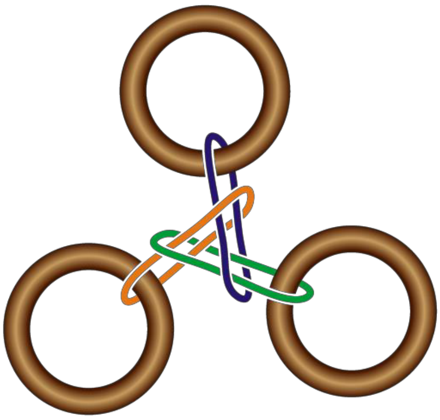


Nearly solved.



Solved.

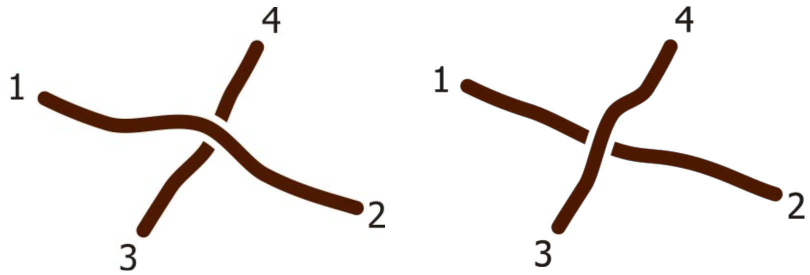
If you want to practice this strategy with another example, then use three of those ring-modules instead of only two (see picture 20). The solution now requires strategies 1, 2, and 3. So it might already get quite confusing!



picture 20: Separate the three ring-modules

Strategy 4: A crossing of 2 ropes leads to a maximum of 4 ends

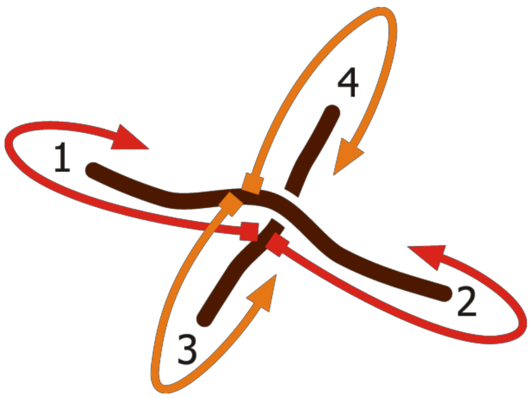
Strategy 2 dealt with either choosing the left or the right end for going around an obstacle. If this obstacle itself is a rope, then this strategy applies to the other rope as well. This means that we have the following situation:



picture 21: left: starting position with rope 1-2 is on top of rope 3-4.
goal: end position with rope 1-2 is underneath of rope 3-4

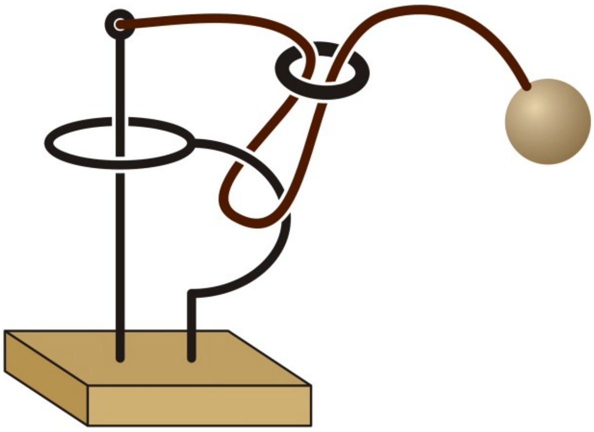
Here, rope 1-2 is lying on top of rope 3-4. If we want to pass rope 1-2 through rope 3-4, then it will end up like the right image of picture 21. But this means that in total there are four possible ends that we might want to check to see if this move is possible or not:

- 1st option: use rope 1-2 and move around the end 3
- 2nd option: use rope 1-2 and move around the end 4
- 3rd option: use rope 3-4 and move around the end 1
- 4th option: use rope 3-4 and move around the end 2



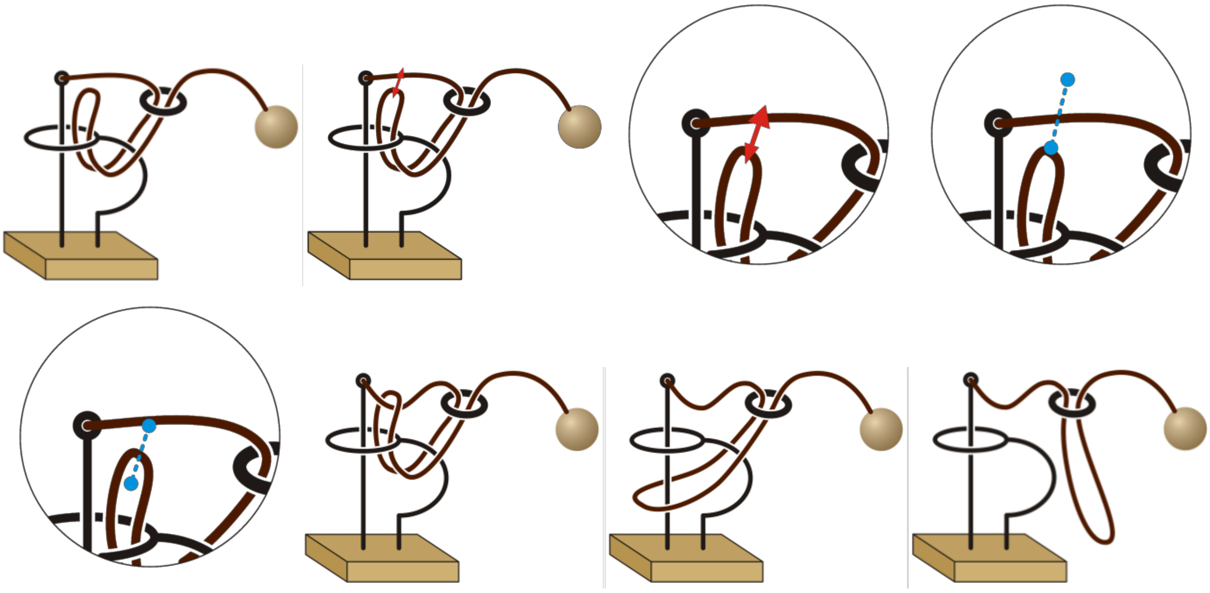
picture 22: left: starting position with rope 1-2 is on top of rope 3-4.
goal: end position with rope 1-2 is underneath of rope 3-4

If you want to recap, we already had this situation with the puzzle shown in picture 10. As you see, this strategy is not completely new, but I want to emphasize it as an individual strategy, because there might be situations where it might be “not obvious” at all. Do you want to try this new strategy on a sample puzzle? OK, here, you get one:



picture 23: objective: remove the small thick metal ring on the top right from the whole puzzle

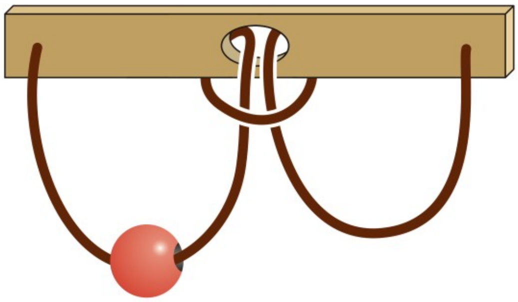
And here are some sample pictures that show the most critical steps (without further explanation):



picture 24: sample drawings for the most critical steps

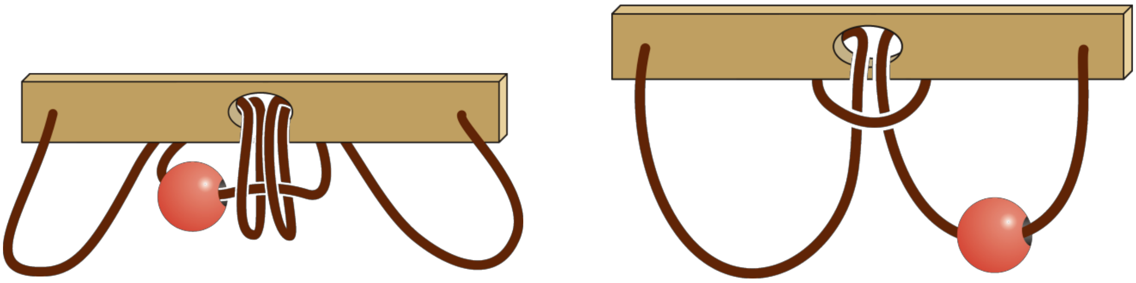
Strategy 5: Follow the rope

To demonstrate the strategy “***follow the rope***” let’s have a look at this puzzle:



picture 25: sample drawings for the most critical steps

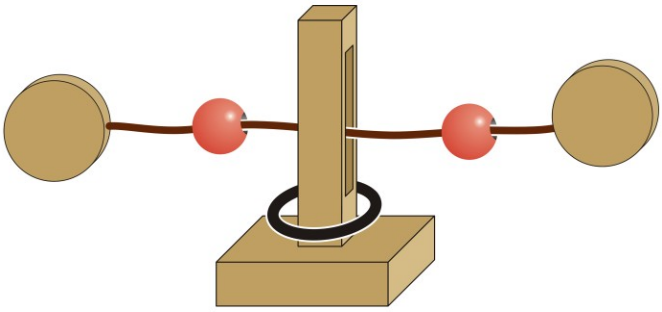
The objective is to move the red bead from the left loop to the right loop. As there is only one piece of rope involved the strategy is simple: ***just follow the rope*** with the bead to the right until you will end up at the intended final position. If you protest and note that the hole in the plank is too small for the ball to pass by, then I agree. But it is not necessary to move the ball through the hole. Instead, pull anything you want from the back of the hole through the hole! But remember, never slide the bead back on the rope to where you came from. Always continue moving the bead toward the right end of the rope! Picture 26 shows an intermediate step of the solution as well as the final position.



picture 26: intermediate step and final position

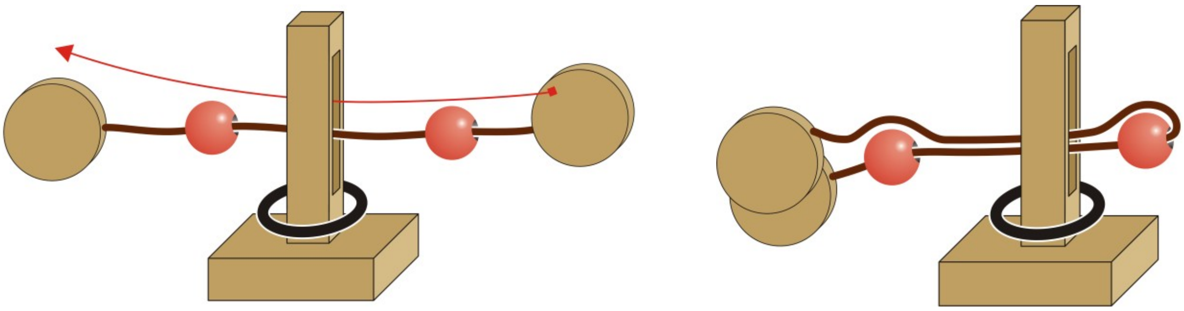
Strategy 6: Trick: Eliminate a disc at the end

You have already learned a lot of strategies. But there is one more to come. Let's have a look at the following puzzle:



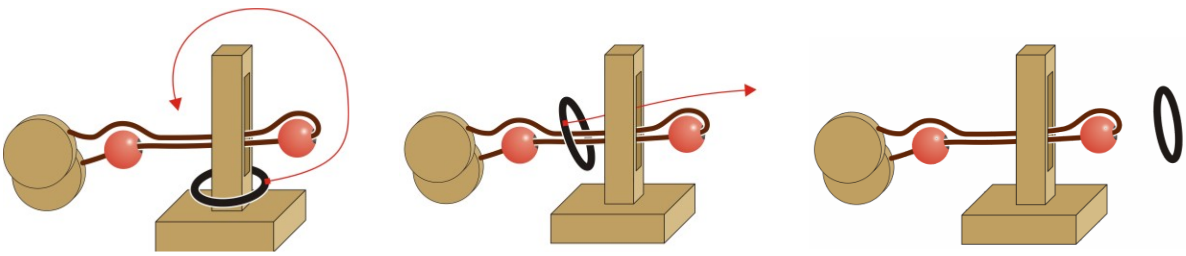
picture 27: starting position. Objective: remove the ring.

The objective of this puzzle is to remove the ring from the rest of the puzzle. But how can it be done as both ends of the rope are 'blocked' by a disk that cannot be passed by the ring? Again, the solution is simple: Move one of the discs (e.g. the right one) along its rope and place it next to the other disc (see picture 28).



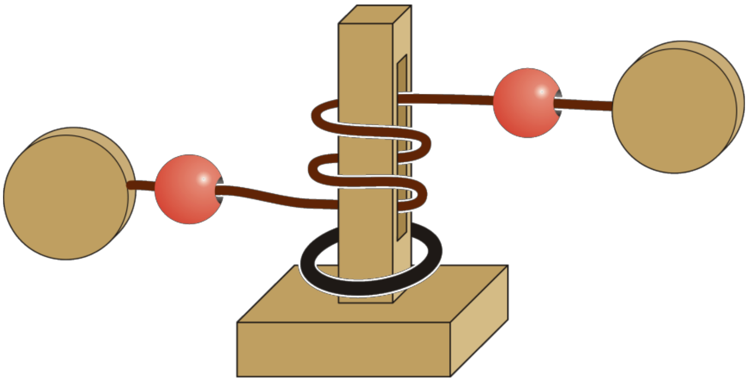
picture 28: Eliminate the right disc by moving it to the left side.

Looking at this new arrangement, we can interpret the double rope in the middle as being only "one thick rope". So, what we did was ***eliminating the disc at the right end***! Now it should be clear how to remove the ring. If not, then the next pictures show the solution.



picture 29: next steps to remove the ring

To practice this strategy of “eliminating a disc” you can try with the next puzzle. Give it a try, you now have all the knowledge you need to solve it.



picture 30: objective: remove the ring