Rope-Placing Method for Table-Top Knotting And Its Application to Clove Hitch

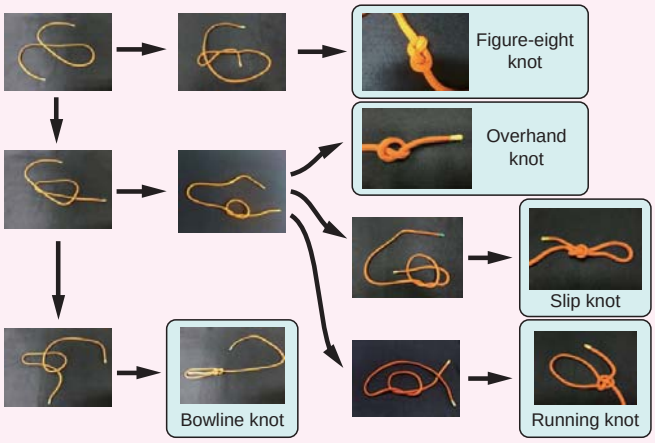
Masaru Takizawa Shunsuke Kudoh and Takashi Suehiro (UEC Tokyo)

Introduction

Now, robots are expected in various scenes (e.g. daily life supporting, rescure activity).
And there are many deformable objects such as rope clothes, paper and so on.
However it is difficult for robots to manipulate these deformable objects.

➪ **Manipulation of deformable objects is an important topic in robot-related research.**

In previous works, various knots can be derived from combinacion of skills on a table[1].



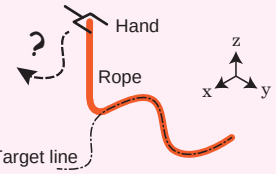
However, it is necessary to teach robot motions **through trial and error**.

When a situation change
- Make loop size bigger
- Change position of the knot

It is necessary to replot the movements through trial and error.

~ Goal ~

Target shape of the rope → Robot movement



[1] R. Katano, T. Gomi, T. Suehiro, S. Kudoh and T. Tomizawa ``Realization of Five Types of Tabletop Knotting with Dual-Arm Robot,'' Journal of the Robotics Society of Japan, 33(7), pp.505--513, 2015, in Japanese

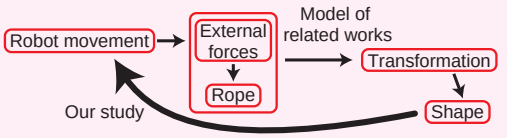
Proposed method

To place a rope in a target shape, a rope is placed on the target line little by little.

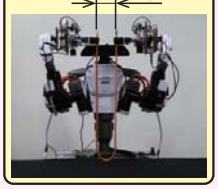
➪ The positional relationship between the hand and the touchdown point is needed.

➪ The shape of the rope in the air has to be considered.

➪ We propose a rope model which can be **used in limited situation** and derive hand trajectories from the model. In addition, **required parameter is easily identified**.



Measure only HERE!



When both ends of a rope are grasped and the distance between the hands is reduced, there is a position which the rope hangs vertically.

The distance between each vertical line is measured, and half of the distance is used as the parameter d.

The point where the height is the minimum is defined as the touchdown point.

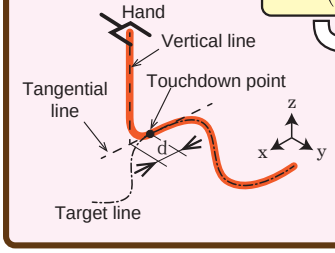
Hand trajectory is generated with keeping the shape of the curved section constant.
- On a vertical line passing through a point that maintains a distance d from the touchdown point to the tangential direction.
- Lower the hand position to the same length at witch the rope is placed on the table.

Target line

$$\mathbf{f}(s) = \begin{pmatrix} f_x(s) \\ f_y(s) \\ \text{const.} \end{pmatrix}$$

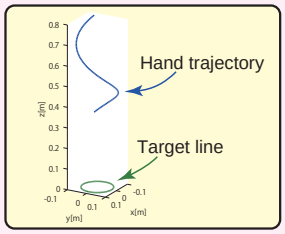
Hand Trajectory

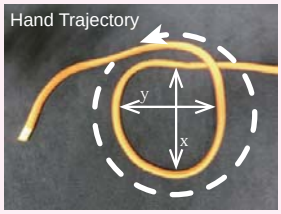
$$\mathbf{g}(s) = \begin{pmatrix} f_x(s) + \dfrac{d \cdot \frac{df_x}{ds}(s)}{\sqrt{\left(\frac{df_x}{ds}(s)\right)^2 + \left(\frac{df_y}{ds}(s)\right)^2}} \\ f_y(s) + \dfrac{d \cdot \frac{df_y}{ds}(s)}{\sqrt{\left(\frac{df_x}{ds}(s)\right)^2 + \left(\frac{df_y}{ds}(s)\right)^2}} \\ g_z(0) - \int_0^s \sqrt{\left(\frac{df_x}{dt}(t)\right)^2 + \left(\frac{df_y}{dt}(t)\right)^2}\, dt \end{pmatrix}$$



Experiment

To evaluate the our method, we formed circular loops (radii: R) and measured size of loops.





R=d ➪

2R[mm]	X ave.[mm]	Y ave.[mm]	X STD[mm]	Y STD[mm]	Success
150	151.0	161.5	9.1	9.7	10/10
120	120.5	139.0	7.6	11.7	10/10
90	102.7	105.0	10.0	19.8	9/10
60	97.5	92.5	3.8	10.0	8/10
30	Failure	Failure	Failure	Failure	0/10

When d is greater than or equal to R: when diameters are 150mm and 120mm;
- The mean size of x direction is almost the same as the size of target line.
- That of the y direction is bigger than the size of the target line.

When the loop size of target line become smaller and smaller;
- The size of loops which were made became going constant
- The success rate is decreased.

The experiments shows that if the target line is sufficiently gradual, we can control the shape of the rope placed on the tabletop.

➪ **It is possible for the robot to tie knots on a tabletop by using visual information.**

Application to clove hitch

We tied the clove hitch using the following three patterns.

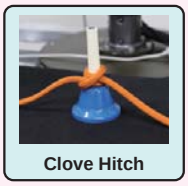
Pattern A
Radii of loops : 70mm
Start position of hands: Same height

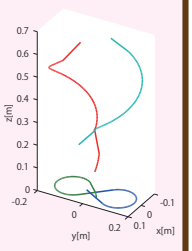
Change the position of the knot
Keep the size of the loop

Pattern B
Radii of loops : 70mm
Start position of hands:
Right hand is higher than 60mm

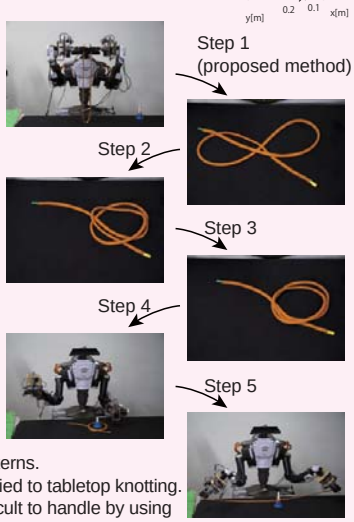
Change the size of loops
Keep the position of the knot

Pattern C
Radii of loops : 60mm
Start position of hands: Same height





	A	B	C
1	○	○	○
2	○	Step 4	Step 3
3	○	○	Step 4
4	Step 3	○	Step 2
5	Step 3	○	○



We were able to tie a clove hitch in all of the patterns.
The experiments shows the method can be applied to tabletop knotting.
And, it can be applied in a situation which is difficult to handle by using a simple coordinate transformation and a scaling of a hand trajectory.

Conclusion

In order to place a rope in target shape, we proposed a rope-shaping model and a method for deriving hand trajectories from the rope model in a simple manner.

Experiments showed that if the target line is sufficiently gradual, it is possible to control the shape of the rope.

The proposed method was used to tie a clove hitch. At the start stage of the clove hitch, two loops were created in a specified shape, and then the clove hitch was tied successfully.

The method can be applied in a situation which it is difficult to handle by using a simple coordinate transformation and a scaling of a hand trajectory.

It is need to make trajectories while removing the torsion in the future.