Visual 3D registration with flexible kinematic prior

Our aim is to extract the n-deflector configuration as well as the surface topology of the arm from the image of an RGB-D camera even with partial occlusion.

For this study different model for the arm description will be assessed first then they’ll be used as prior for the implementation of 3D registration.

## Evaluation criterion

# Robotic arm modelling

To make a prior based registration we need to model the arm deformation to limit the possible configuration. This as already been done with rigid skeleton as prior for human body or hand registration. They used the rigid skeleton to deform the 3D model and then compare the result to a visual input. This method as the advantages to limit the number of configuration parameter (limited number of nodes) and to limit the possible state of those parameter (parameter linked by kinematic model) possibly reducing again the number of parameters.

Here we want to adapt this method to represent a soft robotic arm. The model needs to have the following qualities:

-Limit the number of parameters to describe the configuration (discretisation)

-Constrain the parameter together (Kinematic prior)

-Smoothly reconstruct the deformation along the whole length of the arm (at least G1 continuity)

We can see that we have two different prior, the prior on the configuration parameter and the prior on the interpolated point.

In the case of a rigid skeleton the configuration prior is a fixed distance between point reducing the parameter to angle of rotation and the interpolation prior is to consider straight line interpolation. Additionally, prior limiting the angles of rotation can be used.

Add analysis on the errors of this model for our case

To account for a flexible arm both prior needs to be modified

## Global parameterization

The arm will be divided in section of equal length by points , each point will be defined by its position vector and its orientation represented as the rotation from the global frame of reference to the local orientation frame by a unitary quaternion

Later discuss the possibility of varying section length

The first point is fixed to the global reference frame

Each point can also be defined in the frame of reference of the point

And also

This notation , will be more convenient for the construction of the prior.

Then the shape of the arm is constructed using a function

## Rigid skeleton

Classic rigid skeleton kinematic prior with C2 spline interpolation

This model gives a kinematic prior

It’s a strong prior, decreasing the coordinate parameter by 1

## Piecewise constant curvature (PCC) description

Each section is defined as an arc. The end point is completely defined in 3D by two angles and .

The interpolation on a section is defined by

L

This model gives a kinematic prior

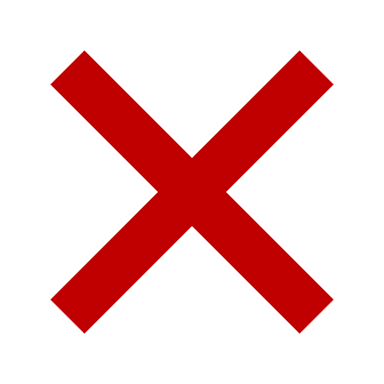
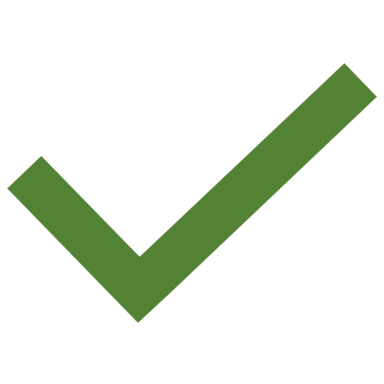
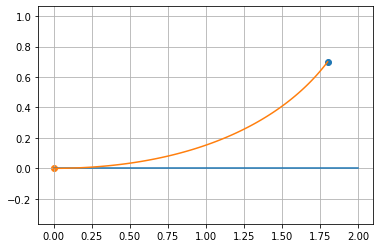
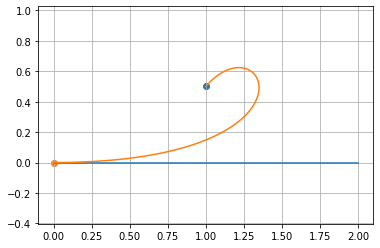
It’s a strong prior, decreasing the coordinate parameter by 1, additionally there is no degree of freedom on the orientation at end point

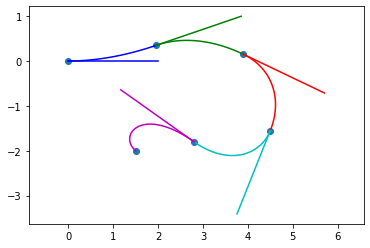
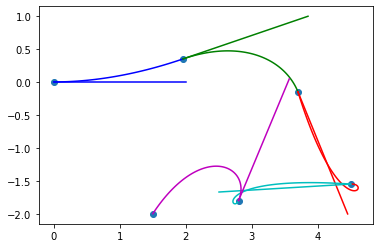
## Cubic pythagorean hodograph curve (PH curve) 2D conceptualization

Pythagorean hodograph curves have defined length. We will use this property to construct curves of fixed length L to model a section of the arm deforming. Additionally, we want the curve to be at the initial point. This method of construction gives two possible solution one exhibiting looping behaviour we will exclude those solution

This model gives a kinematic prior < L

A prior limiting the rotation of the orientation (hypothesis: the section is short thus can’t deform a lot)





Considering the interpolation between and for a length L and a tangent at defined by a complex number. We put , c being on the real line.

The following demonstration are taken from \*ref and we further detail some calculation for coding and prepare for later expansion to 3D cases

### -Definition of PH curves

In our case (cubic) and thus

### -Rectifying polygon

is the rectifying polygon of is length is L

To have tangency at

can be defined as a linear Bezier function from P using

For a non-looping behaviour we want all sign to be of same sign \*ref

From \*ref

If then

Solution outside are discarded

We can add a prior on the orientation at end point

## Degenerated 3D cubic pythagorean hodograph curve (PH curve)

Given the same constraint, , and the problem lies on a single plane. We can solve the problem as in 2D if we translate the 3D problem onto the right plane.

First, we apply a translation by

Then we find the normal vector of the plane

And compute the rotation that gives

# Prior based 3D registration