Supplementary Material: Joint Schematics for “Interactive Modeling of Mechanical Objects”

Francisca Gil Ureta, Chelsea Tymms, and Denis Zorin

New York University

1. Introduction

This supplement describes the parametric models for all joints used in our paper. We group the parameters into three sets:

- **Direct parameters.** Parameters whose values are calculated using our option-based system.
- **Indirect parameters.** Parameters whose values are derived from the direct parameters.
- **User-defined parameters.** Parameters set by the user through our interface.

To prevent fusion during printing, we separate different parts of the geometry by a distance c (clearance). This parameter, which is common across all joint types, depends on the printer and is therefore provided by the user.

2. Hinge

A hinge implements a one-dimensional rotation kinematics defined by an axis of rotation (a line in space given by a direction r_a and position p) and the minimal and maximal rotation angles about the axis.

As a prototype, we use the most common mechanical design, a “barrel hinge,” which is a sectional barrel secured by a pin (Figure 1). The barrel is composed of n pipe-shaped sections, called knuckles, that provide the rotational axis of the hinge. Each section is attached to only one part of the kinematic pair: even sections are attached to part A while odd sections are attached to part B. Along the length of the barrel, knuckles are separated from each other by the clearance distance c.

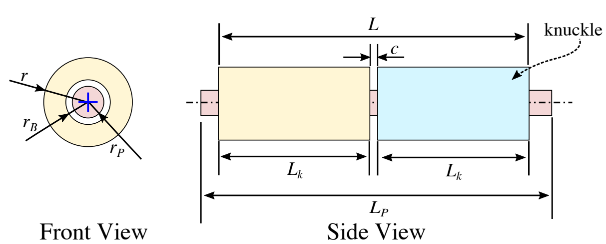

Figure 1: *Geometric parameters of the hinge joint.*

The rotation of the hinge is limited using interlocking notches in the knuckles (Figure 2). By default, our system creates a hinge with no limits, and the user must set the forward and backward angles (θ_1 and θ_0) using our interface. The length of the notches, l_k, is derived from the length of the knuckles (Table 2), but can be overridden by the user.

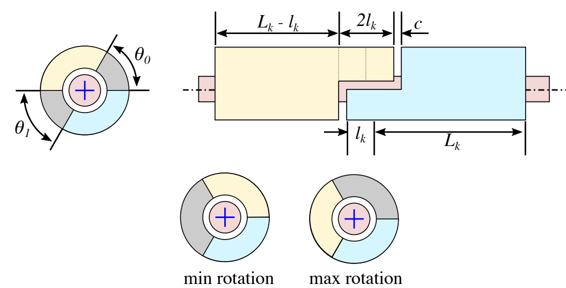

Figure 2: *Rotation limits of the hinge joint.*

Direct Parameters		
r	barrel external radius	
L	hinge total length	
Indirect parameters		
L_P	pin length	$L_P = L + 2c$
r_P	pin radius	$r_P = 0.2r$
r_B	barrel internal radius	$r_B = r_P + c$
n	number of knuckles	$n = \lceil L/(2r) \rceil$
L_k	length of each knuckle	$L_k = (L - c(n-1))/n$
l_k	length of rotation constraints	$l_k = 0.1L_k$
User-specified parameters		
θ_0	minimum angle of rotation	
θ_1	maximum angle of rotation	

Table 1: *Description of geometric parameters of the hinge joint.*

3. Sphere

A spherical joint allows an arbitrary rotation about a single point, the joint center, within specified bounds.

We use a common type of joint consisting of a spherical socket, which is directly attached to part A, and a ball with a pin, which is attached to part B. The ball and socket are separated from each other using the clearance distance c. The socket thickness d is set by default as two times the clearance but can be overridden by the user.

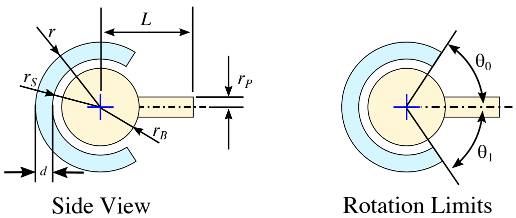

Figure 3: *Geometric parameters of the ball-and-socket joint.*

Direct Parameters		
r	socket external radius	
L	pin length	
d	socket thickness	default $d = 2c$
Indirect parameters		
r_B	ball radius	$r_1 = r - t$
r_S	socket internal radius	$r_0 = r_1 + c$
r_P	pin radius	$r_p = 0.1r$
User specified parameters		
θ_0	minimum angle of rotation	
θ_1	maximum angle of rotation	

Table 2: *Description of geometric parameters of the ball-and-socket joint.*

4. Slider

The slider allows for a single translational degree of freedom along a common line. Since many different cross-sections can allow this type of motion, slider joints can have many different geometries.

Our basic model for a slider is a "rail" slider similar to the type used in furniture. This model consists of two interlocked parts, the rail and the slider. The slider, shown in yellow in Figure 4, has a T-shape that prevents its translation along other axes. The rail is a hollow box whose thickness d is set by default as twice the clearance. The length of the rail, L, defines the translational limits of the slider. Its value is set directly by our system and, similar to the rotational constraints for the hinge and sphere, can be manually overridden by the user.

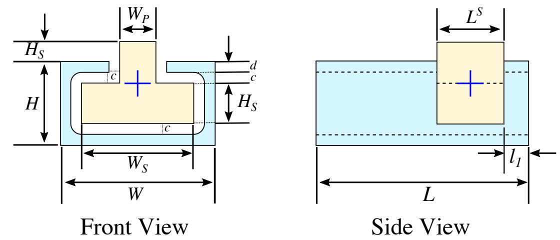

Figure 4: *Geometric parameters of the slider joint.*

Direct Parameters		
W	rail width	
L	rail length	
L_s	slider length	
H	rail height	
H_s	slider height	
d	rail thickness	default $d = 2c$
l_1	initial translation	
Indirect parameters		
W_p	pin width	$W_P = 0.33 * W$
W_s	slider width	$W_S = W - 2(c + d)$
H_s	slider height	$H_S = H - 2(c + d)$

Table 3: *Description of geometric parameters of the slider joint.*