

R-R Chain Design in Modified Yu's Coordinates

[-] Insert Library Functions

```
> with(dualvectors):  
Share Library: dualvectors  
Author: Perez,Alba.  
Description: Performs dual vectors and numbers operations.  
> with(quaternion):  
Share Library: quaternion  
Author: Perez,Alba.  
Description: Performs quaternion operations.  
> with(linalg):  
Warning, new definition for norm  
Warning, new definition for trace
```

[-] Insert data a,b,c,kappa (No numeric values yet)

```
> a:='a'; b:='b'; c:='c'; kappa:='kappa';  
a := a  
b := b  
c := c  
κ := κ
```

[-] Yu's Coordinates for a Bennett Linkage. Expression of G,W

```
> Apoint:=vector(3, [a*cos(kappa/2), a*sin(kappa/2), -c/2]);  
Apoint :=  $\begin{bmatrix} a \cos\left(\frac{1}{2} \kappa\right) \\ a \sin\left(\frac{1}{2} \kappa\right) \\ -\frac{1}{2} c \end{bmatrix}$   
> Bpoint:=vector(3, [b*cos(kappa/2), -b*sin(kappa/2), c/2]);  
Bpoint :=  $\begin{bmatrix} b \cos\left(\frac{1}{2} \kappa\right) \\ -b \sin\left(\frac{1}{2} \kappa\right) \\ \frac{1}{2} c \end{bmatrix}$   
> Cpoint:=vector(3, [-b*cos(kappa/2), b*sin(kappa/2), c/2]);  
Cpoint :=  $\begin{bmatrix} -b \cos\left(\frac{1}{2} \kappa\right) \\ b \sin\left(\frac{1}{2} \kappa\right) \\ \frac{1}{2} c \end{bmatrix}$   
> Dpoint:=vector(3, [-a*cos(kappa/2), -a*sin(kappa/2), -c/2]);  
Dpoint :=  $\begin{bmatrix} -a \cos\left(\frac{1}{2} \kappa\right) \\ -a \sin\left(\frac{1}{2} \kappa\right) \\ -\frac{1}{2} c \end{bmatrix}$   
> AC:=evalm(Cpoint-Apoint); AB:=evalm(Bpoint-Apoint);  
AC :=  $\begin{bmatrix} -b \cos\left(\frac{1}{2} \kappa\right) - a \cos\left(\frac{1}{2} \kappa\right) \\ b \sin\left(\frac{1}{2} \kappa\right) - a \sin\left(\frac{1}{2} \kappa\right) \\ c \end{bmatrix}$   
AB :=  $\begin{bmatrix} b \cos\left(\frac{1}{2} \kappa\right) - a \cos\left(\frac{1}{2} \kappa\right) \\ -b \sin\left(\frac{1}{2} \kappa\right) - a \sin\left(\frac{1}{2} \kappa\right) \\ c \end{bmatrix}$   
> BA:=evalm(-AB);BD:=evalm(Dpoint-Bpoint);  
BA :=  $\begin{bmatrix} -b \cos\left(\frac{1}{2} \kappa\right) + a \cos\left(\frac{1}{2} \kappa\right) \\ b \sin\left(\frac{1}{2} \kappa\right) + a \sin\left(\frac{1}{2} \kappa\right) \\ -c \end{bmatrix}$   
BD :=  $\begin{bmatrix} -b \cos\left(\frac{1}{2} \kappa\right) - a \cos\left(\frac{1}{2} \kappa\right) \\ b \sin\left(\frac{1}{2} \kappa\right) - a \sin\left(\frac{1}{2} \kappa\right) \\ -c \end{bmatrix}$   
> CA:=evalm(-AC);CD:=evalm(Dpoint-Cpoint);  
CA :=  $\begin{bmatrix} b \cos\left(\frac{1}{2} \kappa\right) + a \cos\left(\frac{1}{2} \kappa\right) \\ -b \sin\left(\frac{1}{2} \kappa\right) + a \sin\left(\frac{1}{2} \kappa\right) \\ -c \end{bmatrix}$   
CD :=  $\begin{bmatrix} b \cos\left(\frac{1}{2} \kappa\right) - a \cos\left(\frac{1}{2} \kappa\right) \\ -b \sin\left(\frac{1}{2} \kappa\right) - a \sin\left(\frac{1}{2} \kappa\right) \\ -c \end{bmatrix}$   
> DB:=evalm(-BD); DC:=evalm(-CD);
```

$$DB := \left[b \cos\left(\frac{1}{2} \kappa\right) + a \cos\left(\frac{1}{2} \kappa\right), -b \sin\left(\frac{1}{2} \kappa\right) + a \sin\left(\frac{1}{2} \kappa\right), c \right]$$

$$DC := \left[-b \cos\left(\frac{1}{2} \kappa\right) + a \cos\left(\frac{1}{2} \kappa\right), b \sin\left(\frac{1}{2} \kappa\right) + a \sin\left(\frac{1}{2} \kappa\right), c \right]$$

```
[ >
[ >
```

G and W:

```
[ >
[ Compute Gline (fixed axis A)
[ >
[ > epsilon:='epsilon';
[                                     ε := ε
[ > Gtemp:=simplify(crossprod(AC,AB));
[                                     Gtemp := [ 2 c b sin(1/2 κ), 2 c b cos(1/2 κ), 4 b cos(1/2 κ) a sin(1/2 κ) ]
[ > Gmag:=simplify(sqrt(dotprod(Gtemp, Gtemp, 'orthogonal')));
[                                     Gmag := 2 √[-b²(-c² - 4 cos(1/2 κ)² a² + 4 cos(1/2 κ)⁴ a²)]
[ > Gdir:=evalm(Gtemp);
[                                     Gdir := [ 2 c b sin(1/2 κ), 2 c b cos(1/2 κ), 4 b cos(1/2 κ) a sin(1/2 κ) ]
[ > Gmom:=simplify(crossprod(Apoint, Gdir));
[                                     Gmom := [ 4 a² b cos(1/2 κ) - 4 a² b cos(1/2 κ)³ + c² b cos(1/2 κ), -c² b sin(1/2 κ) - 4 a² cos(1/2 κ)² b sin(1/2 κ),
[                                     4 a cos(1/2 κ)² c b - 2 a c b ]
[ > Gscrewep:=evalm(Gdir+epsilon*Gmom);
[                                     Gscrewep := [ 2 c b sin(1/2 κ) + ε ( 4 a² b cos(1/2 κ) - 4 a² b cos(1/2 κ)³ + c² b cos(1/2 κ) ),
[                                     2 c b cos(1/2 κ) + ε ( -c² b sin(1/2 κ) - 4 a² cos(1/2 κ)² b sin(1/2 κ) ),
[                                     4 b cos(1/2 κ) a sin(1/2 κ) + ε ( 4 a cos(1/2 κ)² c b - 2 a c b ) ]
[ > Gscrew:=concat(Gdir, Gmom);
[                                     Gscrew := [ 2 c b sin(1/2 κ)          4 a² b cos(1/2 κ) - 4 a² b cos(1/2 κ)³ + c² b cos(1/2 κ) ]
[                                     2 c b cos(1/2 κ)          -c² b sin(1/2 κ) - 4 a² cos(1/2 κ)² b sin(1/2 κ) ]
[                                     4 b cos(1/2 κ) a sin(1/2 κ)          4 a cos(1/2 κ)² c b - 2 a c b ]
[ > Gline:=concat(Gdir/Gmag, Gmom/Gmag);
[ Gline :=
```

$$\left[\begin{array}{l} \frac{c b \sin\left(\frac{1}{2} \kappa\right)}{\sqrt{-b^2 \left(-c^2 - 4 \cos\left(\frac{1}{2} \kappa\right)^2 a^2 + 4 \cos\left(\frac{1}{2} \kappa\right)^4 a^2\right)}}, \frac{1}{2} \frac{4 a^2 b \cos\left(\frac{1}{2} \kappa\right) - 4 a^2 b \cos\left(\frac{1}{2} \kappa\right)^3 + c^2 b \cos\left(\frac{1}{2} \kappa\right)}{\sqrt{-b^2 \left(-c^2 - 4 \cos\left(\frac{1}{2} \kappa\right)^2 a^2 + 4 \cos\left(\frac{1}{2} \kappa\right)^4 a^2\right)}} \\ \frac{c b \cos\left(\frac{1}{2} \kappa\right)}{\sqrt{-b^2 \left(-c^2 - 4 \cos\left(\frac{1}{2} \kappa\right)^2 a^2 + 4 \cos\left(\frac{1}{2} \kappa\right)^4 a^2\right)}}, \frac{1}{2} \frac{-c^2 b \sin\left(\frac{1}{2} \kappa\right) - 4 a^2 \cos\left(\frac{1}{2} \kappa\right)^2 b \sin\left(\frac{1}{2} \kappa\right)}{\sqrt{-b^2 \left(-c^2 - 4 \cos\left(\frac{1}{2} \kappa\right)^2 a^2 + 4 \cos\left(\frac{1}{2} \kappa\right)^4 a^2\right)}} \\ \frac{2 b \cos\left(\frac{1}{2} \kappa\right) a \sin\left(\frac{1}{2} \kappa\right)}{\sqrt{-b^2 \left(-c^2 - 4 \cos\left(\frac{1}{2} \kappa\right)^2 a^2 + 4 \cos\left(\frac{1}{2} \kappa\right)^4 a^2\right)}}, \frac{1}{2} \frac{4 a \cos\left(\frac{1}{2} \kappa\right)^2 c b - 2 a c b}{\sqrt{-b^2 \left(-c^2 - 4 \cos\left(\frac{1}{2} \kappa\right)^2 a^2 + 4 \cos\left(\frac{1}{2} \kappa\right)^4 a^2\right)}} \end{array} \right]$$

Compute Wline (moving axis B)

> **Wtemp:=simplify(crossprod(BA, BD));**

$$Wtemp := \left[-2 c a \sin\left(\frac{1}{2} \kappa\right), 2 c a \cos\left(\frac{1}{2} \kappa\right), 4 b \cos\left(\frac{1}{2} \kappa\right) a \sin\left(\frac{1}{2} \kappa\right) \right]$$

> **Wmag:=simplify(sqrt(dotprod(Wtemp, Wtemp, 'orthogonal')));**

$$Wmag := 2 \sqrt{-a^2 \left(-c^2 - 4 b^2 \cos\left(\frac{1}{2} \kappa\right)^2 + 4 b^2 \cos\left(\frac{1}{2} \kappa\right)^4\right)}$$

> **Wdir:=evalm(Wtemp);**

$$Wdir := \left[-2 c a \sin\left(\frac{1}{2} \kappa\right), 2 c a \cos\left(\frac{1}{2} \kappa\right), 4 b \cos\left(\frac{1}{2} \kappa\right) a \sin\left(\frac{1}{2} \kappa\right) \right]$$

> **Wmom:=simplify(crossprod(Bpoint, Wdir));**

$$Wmom := \left[-4 b^2 \cos\left(\frac{1}{2} \kappa\right) a + 4 b^2 \cos\left(\frac{1}{2} \kappa\right)^3 a - c^2 a \cos\left(\frac{1}{2} \kappa\right), \right. \\ \left. -c^2 a \sin\left(\frac{1}{2} \kappa\right) - 4 b^2 \cos\left(\frac{1}{2} \kappa\right)^2 a \sin\left(\frac{1}{2} \kappa\right), 4 a \cos\left(\frac{1}{2} \kappa\right)^2 c b - 2 a c b \right]$$

> **Wscrewep:=evalm(Wdir+epsilon*Wmom);**

$$Wscrewep := \left[-2 c a \sin\left(\frac{1}{2} \kappa\right) + \epsilon \left(-4 b^2 \cos\left(\frac{1}{2} \kappa\right) a + 4 b^2 \cos\left(\frac{1}{2} \kappa\right)^3 a - c^2 a \cos\left(\frac{1}{2} \kappa\right)\right), \right. \\ \left. 2 c a \cos\left(\frac{1}{2} \kappa\right) + \epsilon \left(-c^2 a \sin\left(\frac{1}{2} \kappa\right) - 4 b^2 \cos\left(\frac{1}{2} \kappa\right)^2 a \sin\left(\frac{1}{2} \kappa\right)\right), \right. \\ \left. 4 b \cos\left(\frac{1}{2} \kappa\right) a \sin\left(\frac{1}{2} \kappa\right) + \epsilon \left(4 a \cos\left(\frac{1}{2} \kappa\right)^2 c b - 2 a c b\right) \right]$$

Wscrew:=concat(Wdir,Wmom);

$$Wscrew := \left[\begin{array}{l} -2 c a \sin\left(\frac{1}{2} \kappa\right) \quad -4 b^2 \cos\left(\frac{1}{2} \kappa\right) a + 4 b^2 \cos\left(\frac{1}{2} \kappa\right)^3 a - c^2 a \cos\left(\frac{1}{2} \kappa\right) \\ 2 c a \cos\left(\frac{1}{2} \kappa\right) \quad -c^2 a \sin\left(\frac{1}{2} \kappa\right) - 4 b^2 \cos\left(\frac{1}{2} \kappa\right)^2 a \sin\left(\frac{1}{2} \kappa\right) \\ 4 b \cos\left(\frac{1}{2} \kappa\right) a \sin\left(\frac{1}{2} \kappa\right) \quad 4 a \cos\left(\frac{1}{2} \kappa\right)^2 c b - 2 a c b \end{array} \right]$$

> **Wline:=concat(Wdir/Wmag,Wmom/Wmag);**

Wline :=

$$\left[\frac{c a \sin\left(\frac{1}{2} \kappa\right)}{\sqrt{-a^2 \left(-c^2 - 4 b^2 \cos\left(\frac{1}{2} \kappa\right)^2 + 4 b^2 \cos\left(\frac{1}{2} \kappa\right)^4\right)}}, \right.$$

$$\left[\begin{array}{l} \frac{1}{2} \frac{-4 b^2 \cos\left(\frac{1}{2} \kappa\right) a + 4 b^2 \cos\left(\frac{1}{2} \kappa\right)^3 a - c^2 a \cos\left(\frac{1}{2} \kappa\right)}{\sqrt{-a^2 \left(-c^2 - 4 b^2 \cos\left(\frac{1}{2} \kappa\right)^2 + 4 b^2 \cos\left(\frac{1}{2} \kappa\right)^4\right)}} \\ \left[\begin{array}{l} \frac{c a \cos\left(\frac{1}{2} \kappa\right)}{\sqrt{-a^2 \left(-c^2 - 4 b^2 \cos\left(\frac{1}{2} \kappa\right)^2 + 4 b^2 \cos\left(\frac{1}{2} \kappa\right)^4\right)}}, \frac{1}{2} \frac{-c^2 a \sin\left(\frac{1}{2} \kappa\right) - 4 b^2 \cos\left(\frac{1}{2} \kappa\right)^2 a \sin\left(\frac{1}{2} \kappa\right)}{\sqrt{-a^2 \left(-c^2 - 4 b^2 \cos\left(\frac{1}{2} \kappa\right)^2 + 4 b^2 \cos\left(\frac{1}{2} \kappa\right)^4\right)}} \right] \\ \left[\begin{array}{l} \frac{2 b \cos\left(\frac{1}{2} \kappa\right) a \sin\left(\frac{1}{2} \kappa\right)}{\sqrt{-a^2 \left(-c^2 - 4 b^2 \cos\left(\frac{1}{2} \kappa\right)^2 + 4 b^2 \cos\left(\frac{1}{2} \kappa\right)^4\right)}}, \frac{1}{2} \frac{4 a \cos\left(\frac{1}{2} \kappa\right)^2 c b - 2 a c b}{\sqrt{-a^2 \left(-c^2 - 4 b^2 \cos\left(\frac{1}{2} \kappa\right)^2 + 4 b^2 \cos\left(\frac{1}{2} \kappa\right)^4\right)}} \right] \end{array} \right]$$

— H and V:

[Compute Hline (fixed axis C)

> **Htemp:=simplify(crossprod(CD,CA));**

$$Htemp := \left[2 c a \sin\left(\frac{1}{2} \kappa\right), -2 c a \cos\left(\frac{1}{2} \kappa\right), 4 b \cos\left(\frac{1}{2} \kappa\right) a \sin\left(\frac{1}{2} \kappa\right) \right]$$

> **Hmag:=simplify(sqrt(dotprod(Htemp, Htemp, 'orthogonal')));**

$$Hmag := 2 \sqrt{-a^2 \left(-c^2 - 4 b^2 \cos\left(\frac{1}{2} \kappa\right)^2 + 4 b^2 \cos\left(\frac{1}{2} \kappa\right)^4\right)}$$

> **Hdir:=evalm(Htemp);**

$$Hdir := \left[2 c a \sin\left(\frac{1}{2} \kappa\right), -2 c a \cos\left(\frac{1}{2} \kappa\right), 4 b \cos\left(\frac{1}{2} \kappa\right) a \sin\left(\frac{1}{2} \kappa\right) \right]$$

> **Hmom:=simplify(crossprod(Cpoint, Hdir));**

$$Hmom := \left[\begin{array}{l} 4 b^2 \cos\left(\frac{1}{2} \kappa\right) a - 4 b^2 \cos\left(\frac{1}{2} \kappa\right)^3 a + c^2 a \cos\left(\frac{1}{2} \kappa\right), c^2 a \sin\left(\frac{1}{2} \kappa\right) + 4 b^2 \cos\left(\frac{1}{2} \kappa\right)^2 a \sin\left(\frac{1}{2} \kappa\right) \\ 4 a \cos\left(\frac{1}{2} \kappa\right)^2 c b - 2 a c b \end{array} \right]$$

> **Hscrewep:=evalm(Hdir+epsilon*Hmom);**

$$Hscrewep := \left[\begin{array}{l} 2 c a \sin\left(\frac{1}{2} \kappa\right) + \epsilon \left(4 b^2 \cos\left(\frac{1}{2} \kappa\right) a - 4 b^2 \cos\left(\frac{1}{2} \kappa\right)^3 a + c^2 a \cos\left(\frac{1}{2} \kappa\right) \right) \\ -2 c a \cos\left(\frac{1}{2} \kappa\right) + \epsilon \left(c^2 a \sin\left(\frac{1}{2} \kappa\right) + 4 b^2 \cos\left(\frac{1}{2} \kappa\right)^2 a \sin\left(\frac{1}{2} \kappa\right) \right) \\ 4 b \cos\left(\frac{1}{2} \kappa\right) a \sin\left(\frac{1}{2} \kappa\right) + \epsilon \left(4 a \cos\left(\frac{1}{2} \kappa\right)^2 c b - 2 a c b \right) \end{array} \right]$$

> **Hscrew:=concat(Hdir, Hmom);**

$$Hscrew := \left[\begin{array}{ll} 2 c a \sin\left(\frac{1}{2} \kappa\right) & 4 b^2 \cos\left(\frac{1}{2} \kappa\right) a - 4 b^2 \cos\left(\frac{1}{2} \kappa\right)^3 a + c^2 a \cos\left(\frac{1}{2} \kappa\right) \\ -2 c a \cos\left(\frac{1}{2} \kappa\right) & c^2 a \sin\left(\frac{1}{2} \kappa\right) + 4 b^2 \cos\left(\frac{1}{2} \kappa\right)^2 a \sin\left(\frac{1}{2} \kappa\right) \\ 4 b \cos\left(\frac{1}{2} \kappa\right) a \sin\left(\frac{1}{2} \kappa\right) & 4 a \cos\left(\frac{1}{2} \kappa\right)^2 c b - 2 a c b \end{array} \right]$$

> **Hline:=concat(Hdir/Hmag, Hmom/Hmag);**

Hline :=

$$\left[\frac{c a \sin\left(\frac{1}{2} \kappa\right)}{\sqrt{-a^2 \left(-c^2 - 4 b^2 \cos\left(\frac{1}{2} \kappa\right)^2 + 4 b^2 \cos\left(\frac{1}{2} \kappa\right)^4\right)}}, \frac{1}{2} \frac{4 b^2 \cos\left(\frac{1}{2} \kappa\right) a - 4 b^2 \cos\left(\frac{1}{2} \kappa\right)^3 a + c^2 a \cos\left(\frac{1}{2} \kappa\right)}{\sqrt{-a^2 \left(-c^2 - 4 b^2 \cos\left(\frac{1}{2} \kappa\right)^2 + 4 b^2 \cos\left(\frac{1}{2} \kappa\right)^4\right)}} \right]$$

$$\left[\frac{c a \cos\left(\frac{1}{2} \kappa\right)}{\sqrt{-a^2 \left(-c^2 - 4 b^2 \cos\left(\frac{1}{2} \kappa\right)^2 + 4 b^2 \cos\left(\frac{1}{2} \kappa\right)^4\right)}}, \frac{1}{2} \frac{c^2 a \sin\left(\frac{1}{2} \kappa\right) + 4 b^2 \cos\left(\frac{1}{2} \kappa\right)^2 a \sin\left(\frac{1}{2} \kappa\right)}{\sqrt{-a^2 \left(-c^2 - 4 b^2 \cos\left(\frac{1}{2} \kappa\right)^2 + 4 b^2 \cos\left(\frac{1}{2} \kappa\right)^4\right)}} \right]$$

$$\left[\frac{b \cos\left(\frac{1}{2} \kappa\right) a \sin\left(\frac{1}{2} \kappa\right)}{\sqrt{-a^2 \left(-c^2 - 4 b^2 \cos\left(\frac{1}{2} \kappa\right)^2 + 4 b^2 \cos\left(\frac{1}{2} \kappa\right)^4\right)}}, \frac{1}{2} \frac{4 a \cos\left(\frac{1}{2} \kappa\right)^2 c b - 2 a c b}{\sqrt{-a^2 \left(-c^2 - 4 b^2 \cos\left(\frac{1}{2} \kappa\right)^2 + 4 b^2 \cos\left(\frac{1}{2} \kappa\right)^4\right)}} \right]$$

Compute Vline (moving axis D)

> **Vtemp:=simplify(crossprod(DB, DC));**

$$Vtemp := \left[-2 c b \sin\left(\frac{1}{2} \kappa\right), -2 c b \cos\left(\frac{1}{2} \kappa\right), 4 b \cos\left(\frac{1}{2} \kappa\right) a \sin\left(\frac{1}{2} \kappa\right) \right]$$

> **Vmag:=simplify(sqrt(dotprod(Vtemp, Vtemp, 'orthogonal')));**

$$Vmag := 2 \sqrt{-b^2 \left(-c^2 - 4 \cos\left(\frac{1}{2} \kappa\right)^2 a^2 + 4 \cos\left(\frac{1}{2} \kappa\right)^4 a^2\right)}$$

> **Vdir:=evalm(Vtemp);**

$$Vdir := \left[-2 c b \sin\left(\frac{1}{2} \kappa\right), -2 c b \cos\left(\frac{1}{2} \kappa\right), 4 b \cos\left(\frac{1}{2} \kappa\right) a \sin\left(\frac{1}{2} \kappa\right) \right]$$

> **Vmom:=simplify(crossprod(Dpoint, Vdir));**

$$Vmom := \left[-4 a^2 b \cos\left(\frac{1}{2} \kappa\right) + 4 a^2 b \cos\left(\frac{1}{2} \kappa\right)^3 - c^2 b \cos\left(\frac{1}{2} \kappa\right), c^2 b \sin\left(\frac{1}{2} \kappa\right) + 4 a^2 \cos\left(\frac{1}{2} \kappa\right)^2 b \sin\left(\frac{1}{2} \kappa\right), \right. \\ \left. 4 a \cos\left(\frac{1}{2} \kappa\right)^2 c b - 2 a c b \right]$$

> **Vscrewep:=evalm(Vdir+epsilon*Vmom);**

$$Vscrewep := \left[-2 c b \sin\left(\frac{1}{2} \kappa\right) + \epsilon \left(-4 a^2 b \cos\left(\frac{1}{2} \kappa\right) + 4 a^2 b \cos\left(\frac{1}{2} \kappa\right)^3 - c^2 b \cos\left(\frac{1}{2} \kappa\right) \right), \right. \\ \left. -2 c b \cos\left(\frac{1}{2} \kappa\right) + \epsilon \left(c^2 b \sin\left(\frac{1}{2} \kappa\right) + 4 a^2 \cos\left(\frac{1}{2} \kappa\right)^2 b \sin\left(\frac{1}{2} \kappa\right) \right), \right. \\ \left. 4 b \cos\left(\frac{1}{2} \kappa\right) a \sin\left(\frac{1}{2} \kappa\right) + \epsilon \left(4 a \cos\left(\frac{1}{2} \kappa\right)^2 c b - 2 a c b \right) \right]$$

> **Vscrew:=concat(Vdir, Vmom);**

$$Vscrew := \left[\begin{array}{cc} -2 c b \sin\left(\frac{1}{2} \kappa\right) & -4 a^2 b \cos\left(\frac{1}{2} \kappa\right) + 4 a^2 b \cos\left(\frac{1}{2} \kappa\right)^3 - c^2 b \cos\left(\frac{1}{2} \kappa\right) \\ -2 c b \cos\left(\frac{1}{2} \kappa\right) & c^2 b \sin\left(\frac{1}{2} \kappa\right) + 4 a^2 \cos\left(\frac{1}{2} \kappa\right)^2 b \sin\left(\frac{1}{2} \kappa\right) \\ 4 b \cos\left(\frac{1}{2} \kappa\right) a \sin\left(\frac{1}{2} \kappa\right) & 4 a \cos\left(\frac{1}{2} \kappa\right)^2 c b - 2 a c b \end{array} \right]$$

> **Vline:=concat(Vdir/Vmag, Vmom/Vmag);**

Vline :=

$$\left[\frac{c b \sin\left(\frac{1}{2} \kappa\right)}{\sqrt{-b^2 \left(-c^2 - 4 \cos\left(\frac{1}{2} \kappa\right)^2 a^2 + 4 \cos\left(\frac{1}{2} \kappa\right)^4 a^2\right)}}, \right. \\ \left. \frac{1}{2} \frac{-4 a^2 b \cos\left(\frac{1}{2} \kappa\right) + 4 a^2 b \cos\left(\frac{1}{2} \kappa\right)^3 - c^2 b \cos\left(\frac{1}{2} \kappa\right)}{\sqrt{-b^2 \left(-c^2 - 4 \cos\left(\frac{1}{2} \kappa\right)^2 a^2 + 4 \cos\left(\frac{1}{2} \kappa\right)^4 a^2\right)}} \right]$$

$$\left[\begin{array}{l} \frac{c b \cos\left(\frac{1}{2} \kappa\right)}{\sqrt{-b^2 \left(-c^2 - 4 \cos\left(\frac{1}{2} \kappa\right)^2 a^2 + 4 \cos\left(\frac{1}{2} \kappa\right)^4 a^2\right)}}, \frac{1}{2} \frac{c^2 b \sin\left(\frac{1}{2} \kappa\right) + 4 a^2 \cos\left(\frac{1}{2} \kappa\right)^2 b \sin\left(\frac{1}{2} \kappa\right)}{\sqrt{-b^2 \left(-c^2 - 4 \cos\left(\frac{1}{2} \kappa\right)^2 a^2 + 4 \cos\left(\frac{1}{2} \kappa\right)^4 a^2\right)}} \\ \frac{2 b \cos\left(\frac{1}{2} \kappa\right) a \sin\left(\frac{1}{2} \kappa\right)}{\sqrt{-b^2 \left(-c^2 - 4 \cos\left(\frac{1}{2} \kappa\right)^2 a^2 + 4 \cos\left(\frac{1}{2} \kappa\right)^4 a^2\right)}}, \frac{1}{2} \frac{4 a \cos\left(\frac{1}{2} \kappa\right)^2 c b - 2 a c b}{\sqrt{-b^2 \left(-c^2 - 4 \cos\left(\frac{1}{2} \kappa\right)^2 a^2 + 4 \cos\left(\frac{1}{2} \kappa\right)^4 a^2\right)}} \end{array} \right]$$

[-] Insert screws S12, S13 (No numeric values yet)

[-] Define Screws A=S12 and B=S13

```

> delta1:='delta1'; d1:='d1';delta2:='delta2'; d2:='d2';
      delta1 := delta1
      d1 := d1
      delta2 := delta2
      d2 := d2
> Aline:=matrix(3,2, [cos(delta1),-d1*sin(delta1),
sin(delta1),d1*cos(delta1),0,0]);
      Aline := [cos(delta1)  -d1 sin(delta1)
sin(delta1)   d1 cos(delta1)
0             0]
> Adir:=col(Aline,1);
      Adir := [cos(delta1), sin(delta1), 0]
> Bline:=matrix(3,2, [cos(delta2),-d2*sin(delta2),
sin(delta2),d2*cos(delta2),0,0]);
      Bline := [cos(delta2)  -d2 sin(delta2)
sin(delta2)   d2 cos(delta2)
0             0]
> Bdir:=col(Bline,1);
      Bdir := [cos(delta2), sin(delta2), 0]
> psi:='psi';y:='y';
      psi := psi
      y := y
> Amag:=sin(psi[1]/2); Apitch:=(y[1]/2)*cos(psi[1]/2)/sin(psi[1]/2);
Bmag:=sin(psi[2]/2);Bpitch:=(y[2]/2)*cos(psi[2]/2)/sin(psi[2]/2);
      Amag := sin(1/2 psi1)
      Apitch := 1/2 y1 cos(1/2 psi1) / sin(1/2 psi1)
      Bmag := sin(1/2 psi2)
      Bpitch := 1/2 y2 cos(1/2 psi2) / sin(1/2 psi2)
> Ascrew:=concat(Amag*col(Aline,1),
Amag*col(Aline,2)+Amag*Apitch*col(Aline,1));

```

$$A_{screw} := \begin{bmatrix} \sin\left(\frac{1}{2}\psi_1\right)\cos(\delta_1) & -\sin\left(\frac{1}{2}\psi_1\right)d_1\sin(\delta_1) + \frac{1}{2}y_1\cos\left(\frac{1}{2}\psi_1\right)\cos(\delta_1) \\ \sin\left(\frac{1}{2}\psi_1\right)\sin(\delta_1) & \sin\left(\frac{1}{2}\psi_1\right)d_1\cos(\delta_1) + \frac{1}{2}y_1\cos\left(\frac{1}{2}\psi_1\right)\sin(\delta_1) \\ 0 & 0 \end{bmatrix}$$

```
> B_screw:=concat(Bmag*col(Bline,1),
Bmag*col(Bline,2)+Bmag*Bpitch*col(Bline,1));
```

$$B_{screw} := \begin{bmatrix} \sin\left(\frac{1}{2}\psi_2\right)\cos(\delta_2) & -\sin\left(\frac{1}{2}\psi_2\right)d_2\sin(\delta_2) + \frac{1}{2}y_2\cos\left(\frac{1}{2}\psi_2\right)\cos(\delta_2) \\ \sin\left(\frac{1}{2}\psi_2\right)\sin(\delta_2) & \sin\left(\frac{1}{2}\psi_2\right)d_2\cos(\delta_2) + \frac{1}{2}y_2\cos\left(\frac{1}{2}\psi_2\right)\sin(\delta_2) \\ 0 & 0 \end{bmatrix}$$

```
>
```

- Generate constraints

The direction constraint for S12:

```
> num:=simplify(dotprod(Gdir,crossprod(col(Aline,1),Wdir),orthogonal));
```

$$\begin{aligned} num := & 8 c b^2 \sin(\delta_1) \cos\left(\frac{1}{2}\kappa\right) a - 8 c b^2 \sin(\delta_1) \cos\left(\frac{1}{2}\kappa\right)^3 a - 8 c b^2 \cos\left(\frac{1}{2}\kappa\right)^2 \cos(\delta_1) a \sin\left(\frac{1}{2}\kappa\right) \\ & + 8 b \cos\left(\frac{1}{2}\kappa\right)^2 a^2 \sin\left(\frac{1}{2}\kappa\right) \cos(\delta_1) c + 8 b \cos\left(\frac{1}{2}\kappa\right) a^2 \sin(\delta_1) c - 8 b \cos\left(\frac{1}{2}\kappa\right)^3 a^2 \sin(\delta_1) c \end{aligned}$$

```
> den:=simplify(dotprod(crossprod(Gdir,col(Aline,1)),crossprod(col(Aline,1),Wdir),orthogonal));
```

$$den := -16 b^2 \cos\left(\frac{1}{2}\kappa\right)^2 a^2 + 16 b^2 \cos\left(\frac{1}{2}\kappa\right)^4 a^2 + 4 c^2 b a - 4 c^2 b a \cos\left(\frac{1}{2}\kappa\right)^2 - 4 c^2 b a \cos(\delta_1)^2$$

```
> algeq1:=tan(theta12/2)+num/den;
```

$$\begin{aligned} algeq1 := & \tan\left(\frac{1}{2}\theta_{12}\right) + \left(8 c b^2 \sin(\delta_1) \cos\left(\frac{1}{2}\kappa\right) a - 8 c b^2 \sin(\delta_1) \cos\left(\frac{1}{2}\kappa\right)^3 a \right. \\ & - 8 c b^2 \cos\left(\frac{1}{2}\kappa\right)^2 \cos(\delta_1) a \sin\left(\frac{1}{2}\kappa\right) + 8 b \cos\left(\frac{1}{2}\kappa\right)^2 a^2 \sin\left(\frac{1}{2}\kappa\right) \cos(\delta_1) c + 8 b \cos\left(\frac{1}{2}\kappa\right) a^2 \sin(\delta_1) c \\ & \left. - 8 b \cos\left(\frac{1}{2}\kappa\right)^3 a^2 \sin(\delta_1) c \right) / \left(\right. \\ & \left. -16 b^2 \cos\left(\frac{1}{2}\kappa\right)^2 a^2 + 16 b^2 \cos\left(\frac{1}{2}\kappa\right)^4 a^2 + 4 c^2 b a - 4 c^2 b a \cos\left(\frac{1}{2}\kappa\right)^2 - 4 c^2 b a \cos(\delta_1)^2 \right) \end{aligned}$$

The direction constraint for S13

```
> num:=simplify(dotprod(Gdir,crossprod(col(Bline,1),Wdir),orthogonal));
```

$$\begin{aligned} num := & 8 c b^2 \sin(\delta_2) \cos\left(\frac{1}{2}\kappa\right) a - 8 c b^2 \sin(\delta_2) \cos\left(\frac{1}{2}\kappa\right)^3 a - 8 c b^2 \cos\left(\frac{1}{2}\kappa\right)^2 \cos(\delta_2) a \sin\left(\frac{1}{2}\kappa\right) \\ & + 8 b \cos\left(\frac{1}{2}\kappa\right)^2 a^2 \sin\left(\frac{1}{2}\kappa\right) \cos(\delta_2) c + 8 b \cos\left(\frac{1}{2}\kappa\right) a^2 \sin(\delta_2) c - 8 b \cos\left(\frac{1}{2}\kappa\right)^3 a^2 \sin(\delta_2) c \end{aligned}$$

```
> den:=simplify(dotprod(crossprod(Gdir,col(Bline,1)),crossprod(col(Bline,1),Wdir),orthogonal));
```

$$den := -16 b^2 \cos\left(\frac{1}{2}\kappa\right)^2 a^2 + 16 b^2 \cos\left(\frac{1}{2}\kappa\right)^4 a^2 + 4 c^2 b a - 4 c^2 b a \cos\left(\frac{1}{2}\kappa\right)^2 - 4 c^2 b a \cos(\delta_2)^2$$

```
> algeq2:=tan(theta13/2)+num/den;
```

$$\begin{aligned} algeq2 := & \tan\left(\frac{1}{2}\theta_{13}\right) + \left(8 c b^2 \sin(\delta_2) \cos\left(\frac{1}{2}\kappa\right) a - 8 c b^2 \sin(\delta_2) \cos\left(\frac{1}{2}\kappa\right)^3 a \right. \\ & - 8 c b^2 \cos\left(\frac{1}{2}\kappa\right)^2 \cos(\delta_2) a \sin\left(\frac{1}{2}\kappa\right) + 8 b \cos\left(\frac{1}{2}\kappa\right)^2 a^2 \sin\left(\frac{1}{2}\kappa\right) \cos(\delta_2) c + 8 b \cos\left(\frac{1}{2}\kappa\right) a^2 \sin(\delta_2) c \\ & \left. - 8 b \cos\left(\frac{1}{2}\kappa\right)^3 a^2 \sin(\delta_2) c \right) / \left(\right. \\ & \left. -16 b^2 \cos\left(\frac{1}{2}\kappa\right)^2 a^2 + 16 b^2 \cos\left(\frac{1}{2}\kappa\right)^4 a^2 + 4 c^2 b a - 4 c^2 b a \cos\left(\frac{1}{2}\kappa\right)^2 - 4 c^2 b a \cos(\delta_2)^2 \right) \end{aligned}$$

$$\frac{-8 b \cos\left(\frac{1}{2} \kappa\right)^3 a^2 \sin(\delta 2) c}{-16 b^2 \cos\left(\frac{1}{2} \kappa\right)^2 a^2 + 16 b^2 \cos\left(\frac{1}{2} \kappa\right)^4 a^2 + 4 c^2 b a - 4 c^2 b a \cos\left(\frac{1}{2} \kappa\right)^2 - 4 c^2 b a \cos(\delta 2)^2}$$

The position constraint for S12

```
> algeq3:=t12/2-dotprod(col(Aline,1),evalm(Apoint-Bpoint),orthogonal);
algeq3 := 1/2 t12 - cos(δ1) (-b cos(1/2 κ) + a cos(1/2 κ)) - sin(δ1) (b sin(1/2 κ) + a sin(1/2 κ))
```

The position constraint for S13

```
> algeq4:=t13/2-dotprod(col(Bline,1),evalm(Apoint-Bpoint),orthogonal);
algeq4 := 1/2 t13 - cos(δ2) (-b cos(1/2 κ) + a cos(1/2 κ)) - sin(δ2) (b sin(1/2 κ) + a sin(1/2 κ))
```

+ Solve (symbolic)

- Numeric values for the axes S12, S13. Numeric solution

- Numeric values

- Values in Tsai-Roth

```
> #Solutions
> rothw1:=vector(3,[0.3649,0.4520,0.8140]);
rothw1 := [.3649, .4520, .8140]
> rothwp1:=vector(3,[-0.9388,0.7580,0.7793]);
rothwp1 := [-.9388, .7580, .7793]
> Rothw1:=concat(rothw1,crossprod(rothwp1,rothw1));
Rothw1 := [ .3649   .26476840
            .4520   1.04854977
            .8140  -0.70093180 ]
> rothw2:=vector(3,[-0.5960,0.3593,-0.7181]);
rothw2 := [-.5960, .3593, -.7181]
> rothwp2:=vector(3,[0.8460,1.4034,-0.3793]);
rothwp2 := [.8460, 1.4034, -.3793]
> Rothw2:=concat(rothw2,crossprod(rothwp2,rothw2));
Rothw2 := [ -.5960  -0.87149905
            .3593   .83357540
            -.7181  1.14039420 ]
> rothg1:=vector(3,[0.5960,0.3593,0.7181]);
rothg1 := [.5960, .3593, .7181]
> rothwg1:=vector(3,[-0.8460,1.4034,0.3793]);
rothwg1 := [-.8460, 1.4034, .3793]
> Rothg1:=concat(rothg1,crossprod(rothwg1,rothg1));
Rothg1 := [ .5960   .87149905
            .3593   .83357540
            .7181  -1.14039420 ]
> rothg2:=vector(3,[-0.3649,0.4520,-0.8140]);
rothg2 := [-.3649, .4520, -.8140]
> rothwg2:=vector(3,[0.9388,0.7580,-0.7793]);
rothwg2 := [.9388, .7580, -.7793]
> Rothg2:=concat(rothg2,crossprod(rothwg2,rothg2));
```



```

Rothg2 :=  $\begin{bmatrix} -0.3649 & -0.26476840 \\ 0.4520 & 1.04854977 \\ -0.8140 & 0.70093180 \end{bmatrix}$ 
[ > #Initial screws
[ > rS12:=matrix(3,2,[0,0,0,0,1,0]);

$$rS12 := \begin{bmatrix} 0 & 0 \\ 0 & 0 \\ 1 & 0 \end{bmatrix}$$

[ > rS13:=evalf(concat(vector(3,[sin(30*Pi/180),0,cos(30*Pi/180)]),crossprod(vector(3,[0,1,0]),vector(3,[sin(30*Pi/180),0,cos(30*Pi/180)]))));

$$rS13 := \begin{bmatrix} 0.5000000000 & 0.8660254040 \\ 0 & 0 \\ 0.8660254040 & -0.5000000000 \end{bmatrix}$$

[ > rrot12:=evalf(40*Pi/180);
 $rrot12 := 0.6981317008$ 
[ > rrot13:=evalf(70*Pi/180);
 $rrot13 := 1.221730477$ 
[ > rtrans12:=0.8;
 $rtrans12 := 0.8$ 
[ > rtrans13:=0.6;
 $rtrans13 := 0.6$ 

```

Find principal axes (A, sigma, zoffset, pitches)

```

[ > distangle:=screwdot(rS12,rS13);
 $distangle := [0.8660254040, -0.5000000000]$ 
[ > rdist:=-distangle[2]/sqrt(1-distangle[1]^2);
 $rdist := 1.000000001$ 
[ > rangle:=arctan(-distangle[2]/rdist,distangle[1]);
 $rangle := 0.5235987751$ 
[ > evalf(rangle*180/Pi);
 $29.99999996$ 
[ > rpitch12:=(rtrans12/2)/(tan(rrot12/2));
 $rpitch12 := 1.098990968$ 
[ > rpitch13:=(rtrans13/2)/(tan(rrot13/2));
 $rpitch13 := 0.4284444017$ 
[ > rZoffset:=(1/2)*(rdist-(rpitch13-rpitch12)*cos(rangle)/sin(rangle));
 $rZoffset := 1.080710362$ 
[ > rAradius:=sqrt(rdist^2+(rpitch13-rpitch12)^2)/(2*sin(rangle));
 $rAradius := 1.204006936$ 
[ > rsigma:=arctan((rdist*sin(rangle)-(rpitch13-rpitch12)*cos(rangle))/2,((rpitch13-rpitch12)*sin(rangle)+rdist*cos(rangle))/2);
 $rsigma := 1.114282655$ 
[ > #the principal axes are at half the distance and in the
maximum/minimum pitch.
[ > rhx:=rpitch12+rAradius*cos(rsigma)-rAradius;
 $rhx := 0.425736154$ 
[ > rhy:=rpitch12+rAradius*cos(rsigma)+rAradius;
 $rhy := 2.833750026$ 
[ > rzx:=rAradius*sin(rsigma);
 $rzx := 1.080710362$ 
[ > #rzx must be equal to rZoffset, and it is.
[ > #The principal axes are located at a distance rzx and rotated rsigma/2
from the original reference axes, that are s12 and the perpendicular
between s12 and s13.
[ Identify who is HX and who is HY
[ > angletoX:=1/2*(arccos((-rhx+rpitch12+rAradius*cos(rsigma))/rAradius)+r
sigma);
 $angletoX := 0.5571413275$ 

```

```

[ > evalf(angletOX*180/Pi);
                                     31.92184667
[ > evalf(rsigma*90/Pi);
                                     31.92184667
[ This proves HX is located at sigma/2 positive from S12
[ > angletOY:=1/2*(arccos((-rhy+rpitchl2+rAradius*cos(rsigma))/rAradius)+r
  sigma);
                                     angletOY := 2.127937655
[ > evalf(angletOY*180/Pi);
                                     121.9218467
[ And HY at sigma/2+90
[ >
[ >

```

Write transformation A, from original axes to principal axes.

```

[ > #Transformation matrix
[ > Mtrans:=matrix(4,4,[sin(rsigma/2),0,cos(rsigma/2),0,cos(rsigma/2),0,-s
  in(rsigma/2),0,0,1,0,-rzx,0,0,1]);
                                     Mtrans :=
                                     [
                                     .5287620059  0  .8487701344  0
                                     .8487701344  0  -.5287620059  0
                                     0  1  0  -1.080710362
                                     0  0  0  1
                                     ]
[ > #####
  # SCREWTRANS
  #####
  # Routine to transform coordinates for screws.
  # Given the transformation matrix, multiplies by the dual vector
  #####
  #
  screwtrans:=proc(M,S)
  local S2,d,A,w,v,wa,va,ans;
  S2:=format(S);
  w:=col(S2,1);
  v:=col(S2,2);
  A:=submatrix(M,1..3,1..3);
  d:=vector(3,[M[1,4],M[2,4],M[3,4]]);
  wa:=evalm(A &* w);
  va:=evalm(crossprod(d,evalm(A &* w))+A &* v);
  ans:=concat(wa,va);
  eval(ans)
  end:
  #
[ > Z:=matrix(3,2,[0,0,0,0,1,0]); X:=matrix(3,2,[1,0,0,0,0,0]);
                                     Z :=
                                     [
                                     0  0
                                     0  0
                                     1  0
                                     ]
                                     X :=
                                     [
                                     1  0
                                     0  0
                                     0  0
                                     ]
[ > rcheck:=evalm(duvemult(Z,vector(2,[cos(rsigma/2),-rZoffset*sin(rsigma/
  2)]))+duvemult(X,vector(2,[sin(rsigma/2),rZoffset*cos(rsigma/2)])));
                                     rcheck :=
                                     [
                                     .5287620059  .9172746792
                                     0  0
                                     .8487701344  -.5714385788
                                     ]
[ > screwtrans(Mtrans,rcheck);
                                     [
                                     .9999999999  0
                                     0  0
                                     0  0
                                     ]
[ > rcheck2:=evalm(duvemult(Z,vector(2,[cos((rsigma+Pi)/2),-rZoffset*sin((
  rsigma+Pi)/2)]))+duvemult(X,vector(2,[sin((rsigma+Pi)/2),rZoffset*cos(
  (rsigma+Pi)/2)])));

```



```

> values2:=subs(d1=de1,d2=de2,delta1=deltaone*Pi/180,delta2=deltatwo*Pi/180
,t12=0.8,t13=0.6,theta12=40*Pi/180,theta13=70*Pi/180,algeq2);
values2 := tan(7/36 pi) + (8 c b^2 sin(-.01067692592 pi) cos(1/2 kappa) a
- 8 c b^2 sin(-.01067692592 pi) cos(1/2 kappa) a - 8 c b^2 cos(1/2 kappa)^2 cos(-.01067692592 pi) a sin(1/2 kappa)
+ 8 b cos(1/2 kappa)^2 a^2 sin(1/2 kappa) cos(-.01067692592 pi) c + 8 b cos(1/2 kappa)^2 a^2 sin(-.01067692592 pi) c
- 8 b cos(1/2 kappa)^3 a^2 sin(-.01067692592 pi) c) / (
-16 b^2 cos(1/2 kappa)^2 a^2 + 16 b^2 cos(1/2 kappa)^4 a^2 + 4 c^2 b a - 4 c^2 b a cos(1/2 kappa)^2 - 4 c^2 b a cos(-.01067692592 pi)^2
)
> values3:=subs(d1=de1,d2=de2,delta1=deltaone*Pi/180,delta2=deltatwo*Pi/180
,t12=0.8,t13=0.6,theta12=40*Pi/180,theta13=70*Pi/180,algeq3);
values3 := .4000000000 - cos(-.1773435926 pi) (-b cos(1/2 kappa) + a cos(1/2 kappa))
- sin(-.1773435926 pi) (b sin(1/2 kappa) + a sin(1/2 kappa))
> values4:=subs(d1=de1,d2=de2,delta1=deltaone*Pi/180,delta2=deltatwo*Pi/180
,t12=0.8,t13=0.6,theta12=40*Pi/180,theta13=70*Pi/180,algeq4);
values4 := .3000000000 - cos(-.01067692592 pi) (-b cos(1/2 kappa) + a cos(1/2 kappa))
- sin(-.01067692592 pi) (b sin(1/2 kappa) + a sin(1/2 kappa))
> fsolve({values1,values2,values3,values4},{a,b,c,kappa});
{b = .9271547677, c = .6453985164, kappa = 3.412931041, a = -1.220134870}
These two sets of solutions are obtained changing the sign of t1i/2 and theta1i/2. They correspond to both pair of dyads of the mechanism
With pitch equal to disp over tan
> afinal:=-1.220134870;bfinal:=.9271547677;cfinal:=.6453985164;kappafinal:=3.412931041;
afinal := -1.220134870
bfinal := .9271547677
cfinal := .6453985164
kappafinal := 3.412931041
> Gnumer:=evalf(subs(a=afinal,b=bfinal,c=cfinal,kappa=kappafinal,axiscrew(Gscrew)));
Gnumer := [ .8838278702 - .5853506912
-1.206493541 - .3598007854
.4519867580 1.048569486 ]
> Wnumer:=evalf(subs(a=afinal,b=bfinal,c=cfinal,kappa=kappafinal,axiscrew(Wscrew)));
Wnumer := [ .9246409849 - .3708108723
.1262206607 .3434393781
.3593151722 .8335795652 ]
> ploty1:=lineplot3(axiscrew(Gnumer),axiscrew(Wnumer));
Share Library: dualvectors
Author: Perez,Alba.
Description: Performs dual vectors and numbers operations.
ploty1 := PLOT3D(CURVES(
[[-1.602628369, -9676243958, -1.226672776], [1.932683111, -1.450221812, .5812742565]]),
CURVES([[1.723881146, -.6661938616, 1.041329602], [-1.974682794, -1.171076504, -.3959310868]])

```

```

, CURVES(
  [[-1254008243, -9186351830, 3226992576], [.1650273710, -1.208923104, -3226992595]],
  LINESSTYLE(3)), AXESSTYLE(FRAME))
> ploty2:=lineplot3(rps12,rps13);
Share Library: dualvectors
Author: Perez,Alba.
Description: Performs dual vectors and numbers operations.
ploty2 := PLOT3D(CURVES(
  [[1.697540269, -1.057524012, -1.080710362], [-1.697540269, 1.057524012, -1.080710362]]),
  CURVES(
  [[-1.998875003, .0670725252, -.08071036198], [1.998875003, -.0670725252, -.08071036198]]),
  CURVES([[0, 0, -.08071036198], [0, 0, -1.080710362]], LINESSTYLE(3)), AXESSTYLE(FRAME))
> display1:=display(ploty2,thickness=2);
display1 := PLOT3D(CURVES(
  [[1.697540269, -1.057524012, -1.080710362], [-1.697540269, 1.057524012, -1.080710362]]),
  CURVES(
  [[-1.998875003, .0670725252, -.08071036198], [1.998875003, -.0670725252, -.08071036198]]),
  CURVES([[0, 0, -.08071036198], [0, 0, -1.080710362]], LINESSTYLE(3)), THICKNESS(2),
  AXESSTYLE(FRAME))
> ploty3:=lineplot3(axiscrew(screwtrans(Mtrans,Rothg1)),axiscrew(screwtrans
(Mtrans,Rothw1)));
Share Library: dualvectors
Author: Perez,Alba.
Description: Performs dual vectors and numbers operations.
ploty3 := PLOT3D(CURVES(
  [[-1.974395247, -1.170905826, -.3957988870], [1.724217509, -.6662487904, 1.041415413]]),
  CURVES([[1.932953961, -1.450311897, .5814025948], [-1.602330685, -.9675402486, -1.226550390]]),
  , CURVES(
  [[.1653116379, -1.208926073, -.3225738974], [-.1250888687, -.9185773084, .3228082630]],
  LINESSTYLE(3)), AXESSTYLE(FRAME))
> ploty4:=lineplot3(axiscrew(screwtrans(Mtrans,Rothg2)),axiscrew(screwtrans
(Mtrans,Rothw2)));
Share Library: dualvectors
Author: Perez,Alba.
Description: Performs dual vectors and numbers operations.
ploty4 := PLOT3D(
  CURVES([[1.932953961, -1.450311897, .5814025948], [1.602330685, .9675402486, -1.226550390]]),
  CURVES([[1.724217509, .6662487904, 1.041415413], [1.974395247, 1.170905826, -.3957988870]]),
  CURVES([[1.250888687, .9185773084, .3228082630], [-.1653116379, 1.208926073, -.3225738974]],
  LINESSTYLE(3)), AXESSTYLE(FRAME))
> display(ploty3,ploty4,display1,ploty1);

```

