Design of a gear-based spherical mechanism

Institut de Robòtica
i Informàtica Industrial

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Abstract

The objective of this internship was the development of a cross spherical gear controlled by three monopoles and thus three motors, in order to be able to direct a robotic arm for example in any direction. Based on the previous research of my tutor Frederico Thomas, I was able to design the parts of the system on SolidWorks, to print them in 3D, to make the necessary calculations for the control of the system, and to perform simulations on Matlab.

Keywords

Solid Works, 3D printing, control, kinematics.

Résumé

L'objectif de ce stage était le développement d'un engrenage sphérique contrôlé par trois monopoles et donc trois moteurs, dans le but de pouvoir diriger un bras robotisé par exemple dans n'importe quelle direction. En m'appuyant sur les recherches préalables de mon tuteur Frederico Thomas, j'ai pu effectuer le design des pièces du système sur SolidWorks, leur impression 3D, les calculs necéssaires au contrôle du système, et des simulations sur Matlab.

Mots clés

Solid Works, impression 3D, contrôle, cinématique.

Special thanks

I would first like to thank IRI for hosting me during this internship, and especially my tutor Frederico Thomas who followed and helped me throughout the development of this project. I would also like to thank my Robotics teachers at ENSTA Bretagne, whose teachings allowed me to carry out the task I was given.

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Introduction

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Presentation of the laboratory

This internship was carried out as part of my second year of engineering school at ENSTA Bretagne. It is an engineering assistant internship that I did at the IRI (Institut de Robòtica i Informàtica Industrial) in Barcelona and that took place from May 9th to August 26th 2023. The IRI is a joint research centre of the Spanish National Research Council (CSIC: Concejo Superior de Investigaciones Científicas) and the Polytechnic University of Catalonia (UPC: l'Universitat Politècnica de Catalunya). The institute, founded in 1995, is a key player in the Spanish robotics and automation scenes, and a valued participant in a large number of international collaborations. I did my internship in the "Kinematics and robot design" laboratory, composed of 6 researchers. My tutor was Frederico Thomas, who entrusted me with the development of one of his projects.

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Presentation of the subject

The object of the research is a robotic system consisting of a sphere gear and three monopolies to control it. The work from which this project is inspired and on which it is largely based is the ABENICS[1][2] project developed by Yamataga University in Japan.

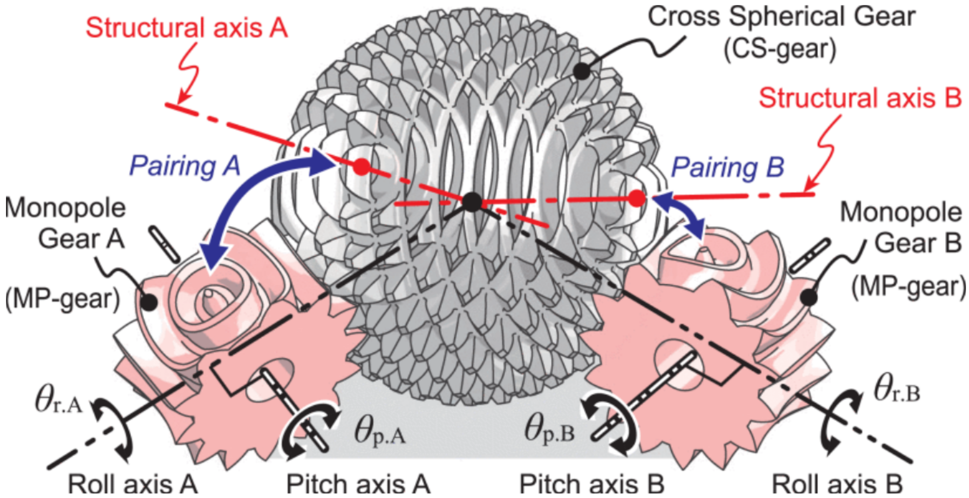


FIGURE 1 – Shéma du mécanisme ABENICS [1]

This work presents a three-degree-of-freedom spherical gear system driven by two monopole gears, each monopole driving two of the three degrees of rotation of the sphere. This system allows for high torque transmission and reliable positioning without an orientation sensor, which is why it is particularly interesting. However, this system is over-controlled because it requires four motors to control three degrees of freedom. My tutor had the idea of optimising this system by using three monopoles to steer the sphere, each with a single controlled degree of freedom, thus reducing the number of motors required to three.

My role was to design the parts of this system, and to continue the kinematic calculations of it, in order to be able to code the control of the sphere.

1 Part design

The design and printing of all the parts of this system took up about half of my internship. The tool at my disposal was Solid Works, which I had already learned to use in my first year of school, but in a rather superficial way. So I had the opportunity to deepen my skills in the field.

1.1 The cross spherical gear

To create this sphere, I first took the 2D profile of a gear and created a part by rotating this profile around one of its axes of symmetry. After having created two parts in this way, but with different axes (Ox and Oy for example) there was only to combine them to obtain the final sphere. This is created in such a way that a monopole with an Ox or Oy axis can follow any movement of the sphere.

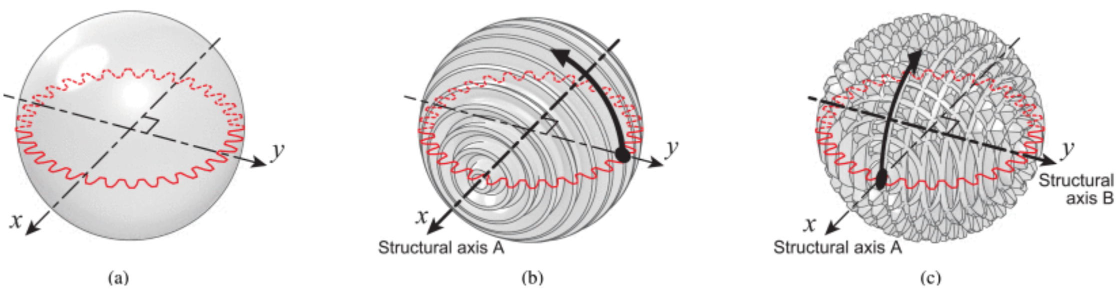


FIGURE 2 – Principle of creating the cross spherical gear [1]

1.2 The monopole

The purpose of a monopole with an Ox axis is to be able to rotate around the sphere like a gear but from any side. By making a cut on the sphere and the monopoly, we obtain the 2D profile of two gears, as long as this cut is made according to a plane containing the Ox axis.

The monopole is therefore created from a cylinder whose exterior is curved to match the shape of the sphere. Its central outer diameter is half the diameter of the sphere. This curved cylinder is then rolled around a spherical gear (not a cross one, see step 1 of the creation of the cross spherical gear) so that it takes the impression of its teeth.

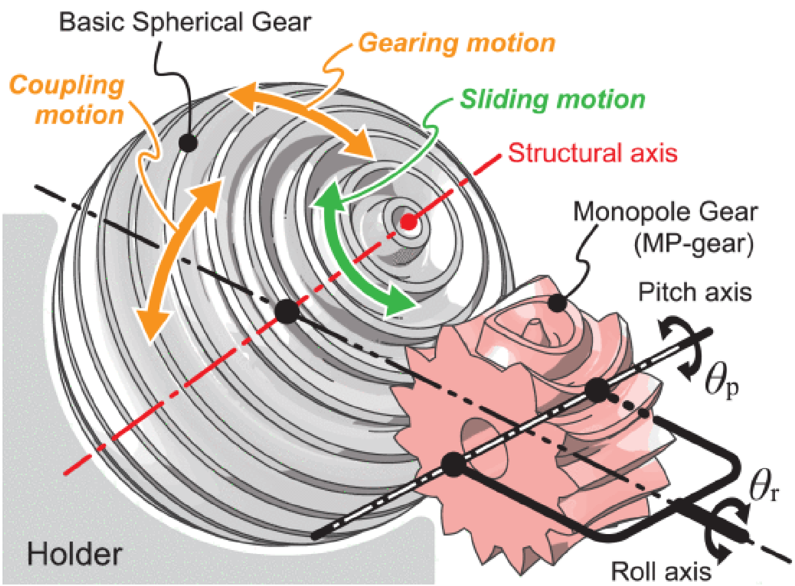


FIGURE 3 – Principle of creating the monopole [1]

The middle of the monopole thus has the exact profile of the gear that corresponds to that used to create the sphere (4), but the rest of the monopole has a rather original shape due to the spherical shape of the gear that faces it.

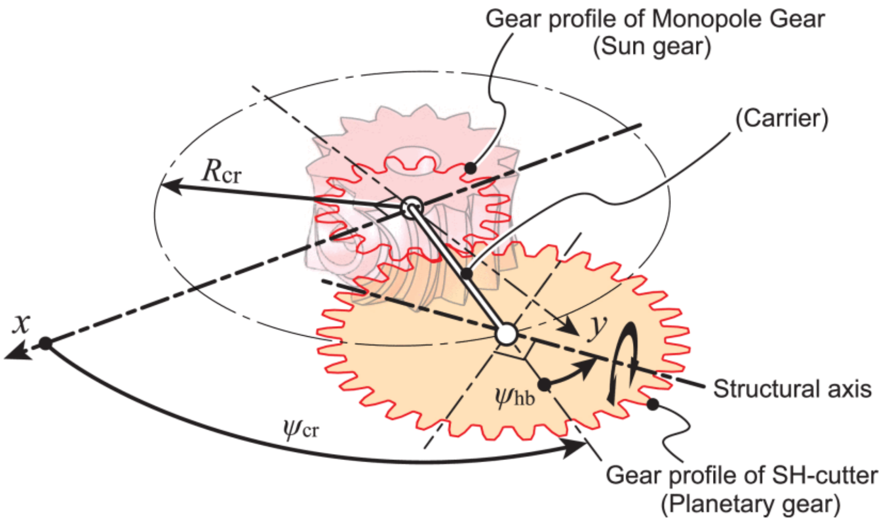


FIGURE 4 – Middle cut of the sphere and the monopole [1]

The monopole took quite a long time to create as a "dynamic" print is not possible in SolidWorks, so it had to be created in several steps and the results had to be fine-tuned for a perfect match with the sphere. The result was achieved on the second try, as the first 3D print showed some imperfections that prevented a perfect match between the sphere and the monopole.

1.3 The support

Once these main parts were validated, I had to create a support for them. Having no example or indication for this support I started with a simple structure, which I modified as I went along according to the new constraints I was thinking about (ease of assembly, resistance, location of the motors etc...) I then printed all these parts in 3D as I went along to check their compatibility.

I also had to choose the external mounting parts such as bearings, screws, nuts, springs etc..

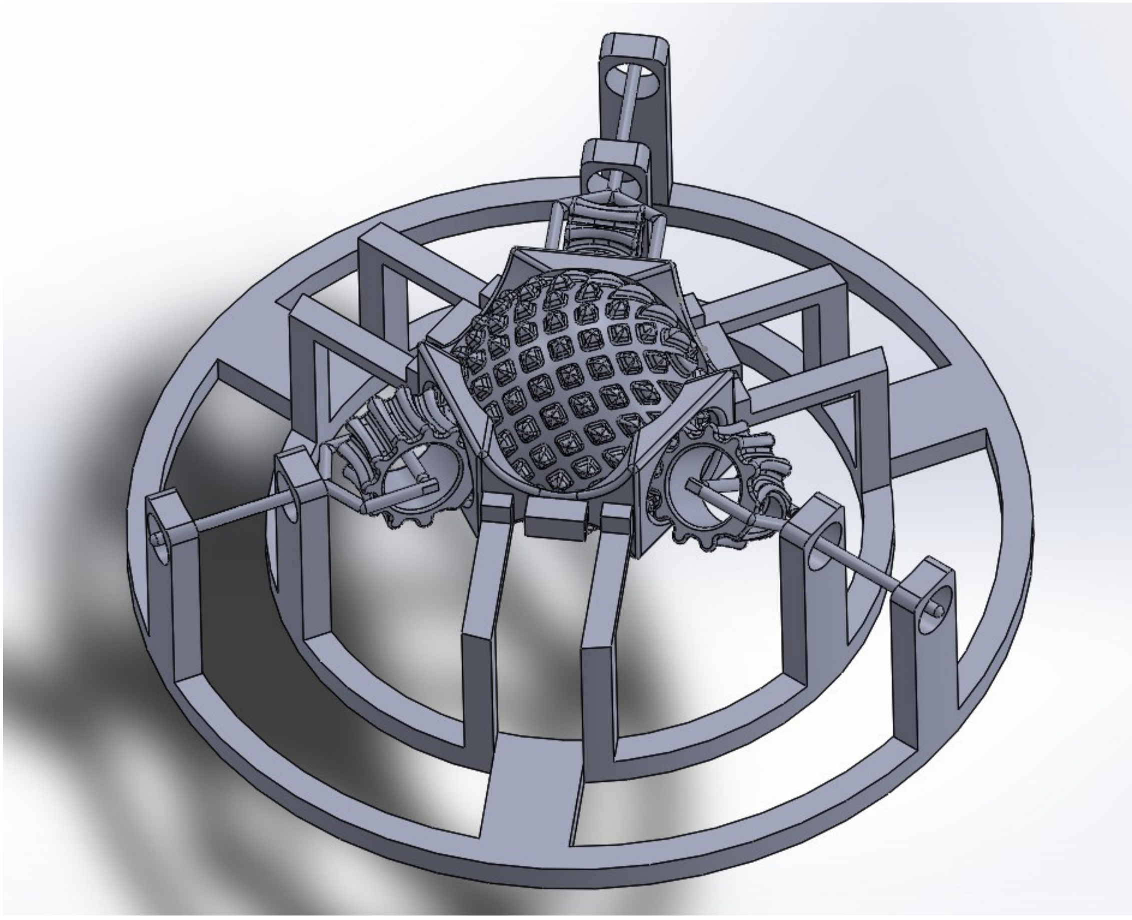


Figure 5 – Overall structure design on SolidWorks

1.4 3D results

The photo below (6) shows the 3D prints of the final versions of the cross spherical gear and one of the monopoles.

Figure 6 – The 3D printed sphere and monopole

The sphere support was printed in three times because its size did not allow me to print it in one go. The following photo (7) shows the three parts of the holder assembled. In the assembly, the screw and the nut are separated by a spring, which allows to adapt the diameter of the support to that of the sphere.

Figure 7 – Assembled sphere support

The following piece corresponds to a third of the final structure, which was printed like this for the same reasons as the previous one. One can distinguish the two arms on the sides which allow to support the sphere support (7) and the two central supports equipped with ball bearings in which will be inserted the arms of the monopoles controlling their angles θ_i, as shown on the image (**??**).

FIGURE 8 – Structure (1/3)

2 Calculations

2.1 Kinematics

The aim of the calculations carried out was to be able to express the rotation of the sphere as a function of the three angles θ_i of the monopoles that are controlled. The sphere has radius r, and its motion is determined by its rotation matrix R. It has 4 poles located at (r,0,0), (-r,0,0), (0,r,0) and (0,-r,0). A monopole is of radius r/2 and can mate with the x or y axis of the sphere. Due to the symmetry of the sphere, it can be noted that the monopole can mate with both poles of the same axis. The motion of the monopole i (i=1,2,3) is defined by the angle θ_i which is controlled and the angle ϕ_i which is left free. The initial positions of the monopoles are defined by :

$$D_1 = T(\frac{r}{2}, 0, 0)R_x(\pi)R_z(\frac{\pi}{2}) \quad (1)$$

$$D_2 = R_z(\frac{2\pi}{3})D_1 \quad (2)$$

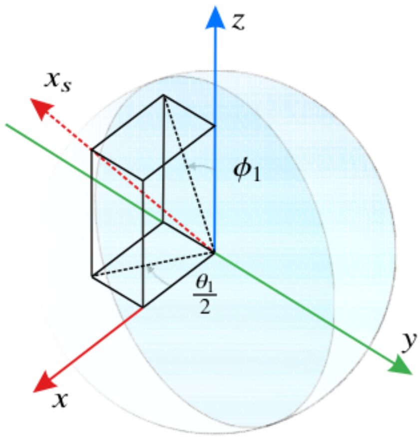
$$D_3 = R_z(\frac{-2\pi}{3})D_1 \quad (3)$$

It will be noticed that the initial positions of monopoles 2 and 3 do not correspond to positions where these monopoles match with the sphere. However this does not matter because this position serves as a reference and does not have to be realised in any case, it was chosen thus for the sake of ease of calculation. The position of the monopole i with respect to the reference frame is thus:

$$M_i = D_i R_x(\phi_i) R_z(\theta_i) \tag{4}$$

The formulas can be deduced from this scheme:

$$\begin{aligned} \phi_1 &= \operatorname{atan2}(r_{21}, r_{31}) \\ \theta_1 &= 2\arccos(r_{11}) \end{aligned} \tag{5}$$



Because of the invariance of the sphere by $\frac{\pi}{2}$ rotation about the z-axis we can obtain the angles of the monopoles 2 and 3 by replacing R with the following formulas:

$$R_2 = R_z(-\frac{2\pi}{3}) R R_z(\frac{\pi}{2}) \tag{6}$$

$$R_3 = R_z(\frac{2\pi}{3}) R R_z(\frac{\pi}{2}) \tag{7}$$

witch gives:

$$\phi_2 = \operatorname{atan2}(-\frac{\sqrt{3}}{2} r_{12} - \frac{1}{2} r_{22}, r_{32}) \quad \text{and} \quad \theta_2 = 2\arccos(-\frac{1}{2} r_{12} + \frac{\sqrt{3}}{2} r_{22}) \tag{8}$$

$$\phi_3 = \operatorname{atan2}(\frac{1}{2} r_{12} - \frac{\sqrt{3}}{2} r_{22}, r_{32}) \quad \text{and} \quad \theta_3 = 2\arccos(-\frac{1}{2} r_{12} - \frac{\sqrt{3}}{2} r_{22}) \tag{9}$$

Inverting these equations we get:

$$r_{11} = \cos\frac{\theta_1}{2} \tag{10}$$
$$r_{21} = k_1 \text{sin}\phi_1 \tag{11}$$
$$r_{31} = k_1 \text{cos}\phi_1 \tag{12}$$
$$r_{12} = \frac{1}{\sqrt{3}}(k_3 sin\phi_3 - k_2 sin\phi_2) = -\cos\frac{\theta_2}{2} - \cos\frac{\theta_3}{2} \tag{13}$$
$$r_{22} = \frac{1}{\sqrt{3}}(\cos\frac{\theta_2}{2} - \cos\frac{\theta_3}{2}) = -k_2\sin\phi_2 - k_3\sin\phi 3 \tag{14}$$
$$r_{32} = k_2\cos\phi_2 = k_3\cos\phi_3 \tag{15}$$

By writing the rotation matrix as a function of the angles θ_i we obtain:

$$R = \begin{pmatrix} c_1 & -c_2 - c_3 & r_{13} \\ r_{21} & \frac{1}{\sqrt{3}}(c_2 - c_3) & r_{23} \\ r_{31} & r_{32} & r_{33} \end{pmatrix}$$

With $c_i = \cos\frac{\theta_i}{2}$

To express the whole rotation matrix in terms of the angles θ_i one could use the system of equations $det(R) = 1$ and $RR^T = I$ but it is simpler to go by the Euler angles.

A rotation matrix whose Euler angles are α_1, α_2 and α_3 according to XZY is expressed as follows:

$$R = R_x(\alpha_1)R_z(\alpha_2)R_y(\alpha_3) = \begin{pmatrix} C_2C_3 & -S_2 & C_2S_3 \\ S_1S_3 + C_1C_3S_2 & C_1C_2 & C_1S_2S_3 - C_3S_1 \\ C_3S_1S_2 - C_1S_3 & C_2S_1 & C_1C_3 + S_1S_2S_3 \end{pmatrix}$$

With $C_i = \cos\alpha_i$ et $S_i = \sin\alpha_i$

By identifying the following relations are easily found:

$$\alpha_1 = \text{atan2}\,(r_{32}, r_{22}) \qquad \alpha_2 = \arcsin\,(-r_{12}) \qquad \alpha_3 = \text{atan2}\,(r_{13}, r_{11}) \tag{16}$$

To obtain the coefficients r_{13} and r_{32} as a function of θ_i, we use the property of the rotation matrix $RR^T = I$, i.e. that the sum of the squared coefficients of each row or column is equal to 1.

$$c_1^2 + (c_2 + c_3)^2 + r_{13}^2 = 1 \qquad \Longleftrightarrow \qquad r_{13} = \sqrt{1 - c_1^2 - (c_2 + c_3)^2}$$

$$(c_2 + c_3)^2 + \frac{1}{3}(c_2 - c_3)^2 + r_{32}^2 = 1 \qquad \Longleftrightarrow \qquad r_{32} = \sqrt{1 - (c_2 + c_3)^2 - \frac{1}{3}(c_2 - c_3)^2}$$

Inserting these results into the equations (16), we obtain:

$$\begin{aligned} R = & R_x(\operatorname{atan2}(\sqrt{1 - (c_2 + c_3)^2 - \frac{1}{3}(c_2 - c_3)^2}, \frac{1}{\sqrt{3}}(c_2 - c_3))) \\ & R_z(\arcsin(c_2 + c_3)) \\ & R_y(\operatorname{atan2}(\sqrt{1 - c_1^2 - (c_2 + c_3)^2}, c_1)) \end{aligned} \tag{17}$$

We are therefore able to predict the movements of the sphere from the three angles θ_i of the monopoles. But we can notice that because of the square roots in the equation (17), there are four possible solutions of the rotation matrix for given angles θ_1, θ_2 and θ_3 given.

2.2 Singularities

Intuitively one can notice that when the pole of the monopole is in contact with a pole of the sphere, the angle ϕ_i is indeterminate. This corresponds to the positions of the sphere defined by the following rotation matrices:

$$R = R_x(\omega)R_z(n\pi), \qquad R = R_z(\frac{2\pi}{3} + n\pi)R_y(\omega) \qquad \text{et} \qquad R = R_z(-\frac{2\pi}{3} + n\pi)R_y(\omega)$$

with $n \in \mathbb{Z}$ et $\omega \in \mathbb{R}$.

These situations can also be found algebraically since they correspond to the cases where both elements of atan2 are simultaneously zero in the equations (5), (8) and (9). Moreover, there are some cases where there are no longer four solutions, but only one or two. This happens when the square roots are zero in the equation (17). We therefore propose to check the following equations:

$$(c_2 + c_2)^2 - \frac{1}{3}(c_3 - c_3)^2 \geq 1 \qquad \text{et} \qquad c_1^2 - (c_2 + c_3)^2 \geq 1 \tag{18}$$

2.3 Adaptation to three orthogonal axes

In the previous calculations we took the ABENICS sphere which had been created to work with two monopoles, so it has two pole axes, one along Ox and one along Oy. In our project we have adapted this configuration with one monopole matching the x-axis of the sphere and two monopoles matching the y-axis. However, it would be possible to create a pole axis of the sphere along z and thus have one monopole per axis. I have therefore easily redesigned the sphere in this way, and adapted the calculations of the third monopole so that it can follow this model.

To move from the x-axis to the y-axis we had used a rotation of $\frac{-\pi}{2}$ along the z-axis in the equation (7) . Here to pass from the x-axis to the z-axis we use a rotation of $\frac{-\pi}{2}$ along y. The equation thus becomes:

$$R = R_z(\frac{2\pi}{3}) R R_y(\frac{-\pi}{2}) \tag{19}$$

Proceeding in the same way as above we obtain the following angles for monopole 3:

$$\phi_3 = \operatorname{atan2}(\frac{\sqrt{3}}{2} r_{13} - \frac{1}{2} r_{23}, r_{33}) \quad \text{et} \quad \theta_3 = 2 \arccos(-\frac{1}{2} r_{13} - \frac{\sqrt{3}}{2} r_{23}) \tag{20}$$

2.4 Phi control

For practical reasons I wondered whether it would not be better to check the angle ϕ instead of the angle θ. I therefore tried to repeat all the previous calculations based on the knowledge of the ϕ_i angles. We will stay with the sphere model developed in part 4.1 with two pole axes Ox and Oy. The rotation matrix R written as a function of the angles ϕ_i gives:

$$R = \begin{pmatrix} r_{11} & \frac{1}{\sqrt{3}}(k_3 sin\phi_3 - k_2 sin\phi_2) & r_{13} \\ k_1 \sin\phi_1 & -k_2 \sin\phi_2 - k_3 \sin\phi_3 & r_{23} \\ k_1 \cos\phi_1 & k_2 \cos\phi_2 = k_3 \cos\phi_3 & r_{33} \end{pmatrix}$$

First, the expressions of the constants k_1, k_2 and k_3 must be obtained in order to continue the calculations. The equation (15) gives directly:

$$\boxed{k_3 = k_2 \frac{\cos(\phi_2)}{\cos(\phi_3)}}$$

Furthermore

$$\begin{aligned} r_{12}^2 + r_{22}^2 + r_{32}^2 = 1 \quad &\implies \quad k_2^2(A^2 + B^2 + C^2) = 1 \\ &\implies \quad \boxed{k_2 = \frac{1}{\pm\sqrt{A^2 + B^2 + C^2}}} \end{aligned}$$

With

$$\begin{aligned} A &= \frac{1}{\sqrt{3}}(\cos(\phi_2)\tan(\phi_3) - \sin(\phi_2)) \\ B &= -\sin(\phi_2) - \cos(\phi_2)\tan(\phi_3) \\ C &= \cos(\phi_2) \end{aligned}$$

Finally, the rotation matrix is orthogonal so:

$$\begin{aligned} < R[:,1], R[:,2] >= 0 \quad &\implies \quad r_{11}r_{12} + r_{21}r_{22} + r_{31}r_{32} = 0 \\ &\implies \quad \pm\sqrt{1 - k_1^2}A + k_1 \sin(\phi_1)B + k_1 \cos(\phi_1)C = 0 \\ &\implies \quad \boxed{k_1 = \pm\sqrt{\frac{A^2}{A^2 + (\sin\phi_1 B + \cos(\phi_1)C)}}} \end{aligned}$$

The equations (16) which express the Euler angles as a function of the coefficients of the matrix are still valid, this time we must find r_{11} and r_{13} as a function of the phi_i. Still thanks to the orthogonality of the matrix we have:

$$\begin{aligned} r_{11}^2 + r_{21}^2 + r_{31}^2 = 1 \quad &\iff \quad r_{11} = \sqrt{1 - k_1^2} \\ r_{11}^2 + r_{12}^2 + r_{13}^2 = 1 \quad &\iff \quad r_{13} = \sqrt{k_1^2 - \frac{1}{\sqrt{3}}(k_3 sin(\phi_3) - k_2 \sin(\phi_2))} \end{aligned}$$

By inserting these results into the Euler angle equations (16), we obtain the rotation matrix as a function of the angles ϕ_i:

$$\begin{aligned} R =& R_x(\operatorname{atan2}(k_2\cos(\phi_2), -k_2\sin(\phi_2) - k_3\sin(\phi_3))) \\ & R_z(\arcsin(-\frac{1}{\sqrt{3}}(k_3\sin(\phi_3) - k_2\sin(\phi_2)))) \\ & R_y(\operatorname{atan2}(\sqrt{k_1^2 - \frac{1}{\sqrt{3}}(k_3 sin(\phi_3) - k_2\sin(\phi_2))}, \sqrt{1 - k_1^2})) \end{aligned} \tag{21}$$

3 Simulation

To check the harmony between the designed parts and the accuracy of the calculations, I performed simulations in Matlab (the main code is provided in the Appendices). It uses the .stl files of the 3D parts and then makes them move according to the rotation matrices of the sphere and each of the monopoles. First the motions of the sphere are defined by any equation, and then the motion of each monopole is calculated according to that of the sphere using the equations developed in part 3.2.

To switch to the configuration with a three-axis sphere, it is sufficient to change the .stl model of the sphere, and to change the equation that gives the angles ϕ_3 and θ_3.

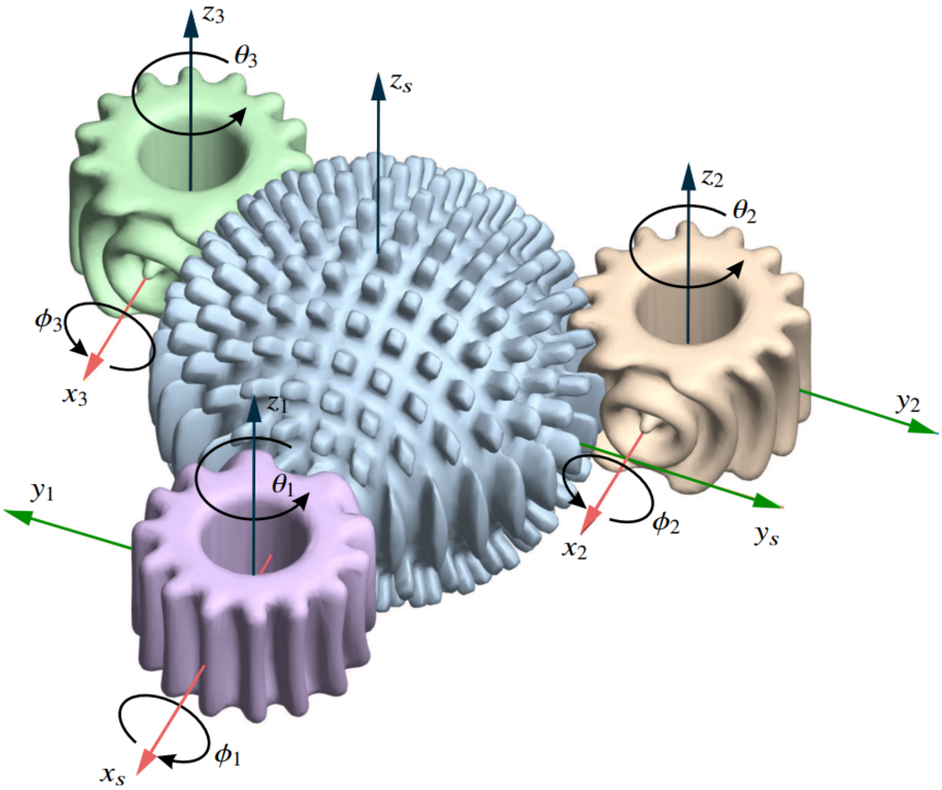


FIGURE 9 – Initial positions of the sphere and monopolies in a simulation

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Conclusion

To conclude, the model I developed during these four months of internship can be very useful in a large number of robotic and other systems, like the ABENICS project, but it is as expected less expensive in terms of hardware (especially motors) and is not over-controlled. Even if I could not go all the way, i.e. to the assembly and coding of the system, my work allowed the project to progress and to get closer to its concrete implementation.

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Bibliography

[1] Abe K., Tadakuma K., Tadakuma R. *"ABENICS: Active Ball Joint Mechanism With Three-DoF Based on Spherical Gear Meshings."* IEE Transactions on Robotics (vol 8, n 35, oct 2021)

[2] Yamagata Univ. *"ABENICS: Active Ball Joint Mechanism With Three-DoF Based on Spherical Gear Meshings."* Youtube (juin 2021)

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Appendices

```
close all;
clear all;

addpath Utils;

cog = stlread('Models/cog.stl');
core = stlread('Models/core.stl');

cog1 = reducepatch(cog, 0.05);
cog2 = cog1;
cog3 = cog1;

core = reducepatch(core, 0.05);

fh = figure();
fh.WindowState = 'maximized';

daspect([1 1 1]);
view([150 60]);

hold on;

H1=patch(core,'FaceColor',          [0.8 0.9 1.0], ...
          'EdgeColor',         'none',         ...
          'FaceLighting',      'gouraud',      ...
          'AmbientStrength', 0.15);

H2=patch(cog1,'FaceColor',          [0.9 0.8 1.0], ...
          'EdgeColor',         'none',         ...
          'FaceLighting',      'gouraud',      ...
          'AmbientStrength', 0.15);

H3=patch(cog2,'FaceColor',          [1.0 0.9 0.8], ...
          'EdgeColor',         'none',         ...
          'FaceLighting',      'gouraud',      ...
          'AmbientStrength', 0.15);

H4=patch(cog3,'FaceColor',          [0.8 1.0 0.8], ...
```

```
            'EdgeColor',        'none',         ...
            'FaceLighting',     'gouraud',      ...
            'AmbientStrength', 0.15);

axis padded;
ax = gca;
ax.Clipping = 'off';

axis off;
grid off;
set(ax,'color', 'w');
zoom(1.5);
camtarget([0 0 1500]);

RefCoreVert = H1.Vertices';
RefCoreVert = [RefCoreVert; ones(1, length(RefCoreVert))];
RefCog1Vert = H2.Vertices';
RefCog1Vert = [RefCog1Vert; ones(1, length(RefCog1Vert))];
RefCog2Vert = H3.Vertices';
RefCog2Vert = [RefCog2Vert; ones(1, length(RefCog2Vert))];
RefCog3Vert = H4.Vertices';
RefCog3Vert = [RefCog3Vert; ones(1, length(RefCog3Vert))];

camlight('headlight');
material('dull');

T1 = translate(4600,0,0)*trotz(pi)*trotx(pi/2);
T2 = trotz(2*pi/3)*T1;
T3 = trotz(-2*pi/3)*T1;

v = VideoWriter('animation2.avi');
open(v);

for i=1:2000

% Definition of the trajectory
 M = trotx(i*(pi/4)/100)*troty(i*(pi/3)/100)*trotz(i*(pi/8)/100);

 M2 = trotz(-2*pi/3)*M*trotz(pi/2);

 M3 = trotz(2*pi/3)*M*trotz(pi/2);

% Computation of the inverse kinematics
```

```
 roll1 = atan2(M(2,1),M(3,1));
 pitch1 = 2*acos(M(1,1));

 roll2 = atan2(M2(2,1),M2(3,1));
 pitch2 = 2*acos(M2(1,1));

 roll3 = atan2(M3(2,1),M3(3,1));
 pitch3 = 2*acos(M3(1,1));

% Animation
 NewCore = M*RefCoreVert;
 set(H1, 'Vertices', NewCore(1:3,:)');

 M = T1*trotx(roll1)*trotz(pitch1);
 NewCog1 = M*RefCog1Vert;
 set(H2, 'Vertices', NewCog1(1:3,:)');

 M = T2*trotx(roll2)*trotz(pitch2);
 NewCog2 = M*RefCog2Vert;
 set(H3, 'Vertices', NewCog2(1:3,:)');

 M = T3*trotx(roll3)*trotz(pitch3);
 NewCog3 = M*RefCog3Vert;
 set(H4, 'Vertices', NewCog3(1:3,:)');

 drawnow;

 frame = getframe(gcf);
 writeVideo(v,frame);

end
close(v);
```

RAPPORT D'EVALUATION
ASSESSMENT REPORT

Merci de retourner ce rapport par courrier ou par voie électronique en fin du stage à :
At the end of the internship, please return this report via mail or email to:

ENSTA Bretagne – *Bureau des stages - 2 rue François Verny - 29806 BREST cedex 9 – FRANCE*
☎ 00.33 (0) 2.98.34.87.70 / stages@ensta-bretagne.fr

I - ORGANISME / *HOST ORGANISATION*

NOM / *Name* Institut de Robótica i Informàtica Industrial (UPC-CSIC)

Adresse / *Address* Llorens Artigas 4, 08028 Barcelona, Spain

Tél / *Phone (including country and area code)* + 34 934 01 57 51

Nom du superviseur / *Name of internship supervisor* Federico Thomas

Fonction / *Function* Professor of Research of the Spanish Research Council

Adresse e-mail / *E-mail address* f.thomas@csic.es

Nom du stagiaire accueilli / *Name of intern* Ermance DECAUDAVEINE

II - EVALUATION / *ASSESSMENT*

Veuillez attribuer une note, en encerclant la lettre appropriée, pour chacune des caractéristiques suivantes. Cette note devra se situer entre **A (très bien)** et **F (très faible)**
Please attribute a mark from ***A (excellent)*** *to* ***F (very weak).***

MISSION / *TASK*

- La mission de départ a-t-elle été remplie ? A B C D E F
  Was the initial contract carried out to your satisfaction?

- Manquait-il au stagiaire des connaissances ? ☐ oui/*yes* ☒ non/*no*
  Was the intern lacking skills?

  Si oui, lesquelles ? / *If so, which skills?* __________

ESPRIT D'EQUIPE / *TEAM SPIRIT*

- Le stagiaire s'est-il bien intégré dans l'organisme d'accueil (disponible, sérieux, s'est adapté au travail en groupe) / *Did the intern easily integrate the host organisation? (flexible, conscientious, adapted to team work)*

  A B C D E F

Souhaitez-vous nous faire part d'observations ou suggestions ? / *If you wish to comment or make a suggestion, please do so here* The student very rapidly adapted to the the work. Since very first week she contributed to attain the goals of the project

COMPORTEMENT AU TRAVAIL / *BEHAVIOUR TOWARDS WORK*

Le comportement du stagiaire était-il conforme à vos attentes (Ponctuel, ordonné, respectueux, soucieux de participer et d'acquérir de nouvelles connaissances) ?
Did the intern live up to expectations? (Punctual, methodical, responsive to management instructions, attentive to quality, concerned with acquiring new skills)?

A B C D E F

Souhaitez-vous nous faire part d'observations ou suggestions ? / *If you wish to comment or make a suggestion, please do so here* She has been one of the best students we have received on this respect

INITIATIVE – AUTONOMIE / *INITIATIVE – AUTONOMY*

Le stagiaire s'est –il rapidement adapté à de nouvelles situations ? A B C D E F
(Proposition de solutions aux problèmes rencontrés, autonomie dans le travail, etc.)

Did the intern adapt well to new situations? A B C D E F
(eg. suggested solutions to problems encountered, demonstrated autonomy in his/her job, etc.)

Souhaitez-vous nous faire part d'observations ou suggestions ? / *If you wish to comment or make a suggestion, please do so here* A completely autonomous person.

CULTUREL – COMMUNICATION / *CULTURAL – COMMUNICATION*

Le stagiaire était-il ouvert, d'une manière générale, à la communication ? A B C D E F
Was the intern open to listening and expressing himself /herself?

Souhaitez-vous nous faire part d'observations ou suggestions ? / *If you wish to comment or make a suggestion, please do so here* Excellent communication. The limitations, if any, came from our side more than from hers.

OPINION GLOBALE / *OVERALL ASSESSMENT*

- La valeur technique du stagiaire était : A B C D E F
  Please evaluate the technical skills of the intern:

III - PARTENARIAT FUTUR / *FUTURE PARTNERSHIP*

- Etes-vous prêt à accueillir un autre stagiaire l'an prochain ?
  Would you be willing to host another intern next year? [X] oui/*yes* [ ] non/*no*

Fait à ______, le ______
In Barcelone, on September 26th, 2022

Signature Entreprise ______ Signature stagiaire
Company stamp ______ *Intern's signature*

Merci pour votre coopération
We thank you very much for your cooperation