Gripping robotic system composed by a pair of robots petit

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Abstract

In this development a gripping system is presented, it is built with 2 petit robots, a goal is to execute object grasps by using the couple of petit robots as robotic fingers. For the construction of each petit robot is taken as a basis, a design previously developed. MATLAB® has been used to get mathematical models of the direct kinematics of the finger. Graphical User Interface (GUI) is also programmed in MATLAB®. Main goal of this development is showing feasibility on one hand use of petit robots designed earlier and on the other hand, customizing GUI developed for single petit robot. To provide movement to joints, servomotors have been used. Considering that each petit robot is composed by combination of 4 degrees of freedom, one finger has four servomotors to actuate every one of them. Graphical user interface is built with all components needed to command all 8 servomotors of whole system.

Petit robot, gripping system, modeling, design, interface, simulation

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Introduction

Different developments, on the theme of petit robots, have been held in the Technological Institute of Nuevo Leon. The goal pursued is developing more complex robotic systems with a good relationship between versatility, mechanical complexity, cost and ease of use, among other related aspects.

This development is on a gripping system. It has been proposed to design a prototype that mimics the movements of grasping or grip with 2 fingers of the human hand. It is an interesting topic, to complement training in mechatronics, the project was held at the Technological Institute of Nuevo Leon in order to contribute further to the design of a robotic hand. The proposed system is a multi gripping robotic system. It has 4 servo motors in each finger, to achieve the movements of human fingers.

This prototype has been designed so that each petit robot has individual movements and movements together, which allows a variety of applications.

In this project, the study of direct and inverse kinematics has been made. The latter allows to know the trajectories of each robotic finger, which gives the possibility to perform simulation and command system.

The gripping system, consisting of two anthropomorphic fingers, which are commanded by the graphical user interface designed with the MATLAB® software. The use of robotic fingers predesigned enables the movement obtained is anthropomorphic, ie the petit robots, which form the gripping system, move like human fingers.

The aim of this paper is to show that you can get complex robotic systems from a petit robot designed previously.

Background

In (Jiménez Villalobos & Ramírez De La Cruz, 2005), the construction of a robotic arm three DOF (Degrees of Freedom) type PUMA (Programmable Universal Manipulator for Assembly) is presented.

Equations both direct kinematic model and the inverse kinematic model are presented. Using the Lagrange equations of motion, equations of the dynamic model are developed. In this robot architecture, a pair of joints with parallel axes is observed.

Immediately in the work developed in (Cimadevilla Lajud & Pérez Herrera, 2006), the reproduction of some limbs of human beings either for medical or industrial purposes, are mentioned. Spatially hand has become the subject of research, because it is important for everyday activities, robotic hands have been built, but until today has not been achieved imitate his skill.

In (Aguilar Acevedo & Ruiz González, 2011) the direct kinematic model is shown. The geometrical representation of the elements of the kinematic chain of the effector relative to a fixed reference system, using the methodology Denavit-Hartenberg of modified, is used. 4 GDL robot is modeled.

In the part of the inverse kinematics transform is critical specifications assigned to the robot movement in its operating space, in joint movements that allow such movement.

The inverse kinematics solution is reduced to a planar motion with 3 GDL, which has a redundant degrees of mobility with respect to the position of the end point of the robot, this because the final orientation is not considered.

Considering the existence of at least one element that specifies the orientation of the robot is possible to find a solution in closed form from a geometric analysis of the robot.

A project that involves the design, construction and control of a manipulator arm 4 degrees of freedom is described in (Cuevas Ramírez, Ramírez Vargas, & Cruz Hernández, 2012). The project is divided into three stages, the first is the design and mechanical construction of the robot manipulator, the second is the implementation and deployment of the control system and the third is for the adaptation of the manipulator arm to a mobile robot to have a robot exploration and security.

A description of the mechanical hand called MA-I (Artificial Intelligent Hand) as part of an integrated experimentation and testing strategies apprehension and object manipulation system is presented in (Suárez & Grosch, 2003). The basic configuration of the hand is 4 fingers with 4 degrees of freedom (DOF) each one of them.

First designs and construction of mini robots are presented in (Hernández Hernández, Garcia Andrade, Fernández Ramírez, & Cuan Duron, 2014; Hernández Hernández, Garcia Andrade, & Fernández Ramírez, 2014), then in (Fernández Ramírez, Cuan Duron, Garcia Andrade, & Urquizo Barraza, 2015) the petit robot for construct more complex robotics systems is introduced.

Kinematics

Forward kinematics

The direct kinematic model is the relationship that determines the vector **x** of operational coordinates corresponding to a given robot configuration **q**.

This model is expressed as:

$$x = f(q) \tag{1}$$

Petit robots Forward kinematics

In table 1, DH modified (Khalil, W.; Kleinfinger, 1986) parameters of the first petit robot are shown.

Eslabón	α_i(°)	d_i(cm)	θ_i(°)	r_i(cm)
1	0	0	θ_1	0
2	90	0	θ_2	0
3	0	3.6	θ_3	0
4	0	3.5	θ_4	0
5	0	1.5	0	0

Table 1 DH parameters for the first petit robot.

DH modified parameters of the second petit robot are shown in table 2.

Eslabón	α_i(°)	d_i(cm)	θ_i(°)	r_i(cm)
1	0	0	θ_1	0
2	90	0	θ_2	0
3	0	3.6	θ_3	0
4	0	3.5	θ_4	0
5	0	1.5	0	0

Table 2 DH parameters for the second petit robot.

These parameters of each link i, are substituted into the following formula:

$$^{i-1}T_i = \mathrm{Rot}(x, \square_i)\,\mathrm{Trans}(x, d_i)\,\mathrm{Rot}(z, \square_i)\,\mathrm{Trans}(z, r_i) = \begin{bmatrix} C\theta_i & -S\theta_i & 0 & d_i \\ C\alpha_i S\theta_i & C\alpha_i C\theta_i & -S\alpha_i & -r_i S\alpha_i \\ S\alpha_i S\theta_i & S\alpha_i C\theta_i & C\theta_i & r_i C\alpha_i \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{2}$$

Where S is the sine function and C the cosine function.

The prototype of the gripping system shown in Figure 1.

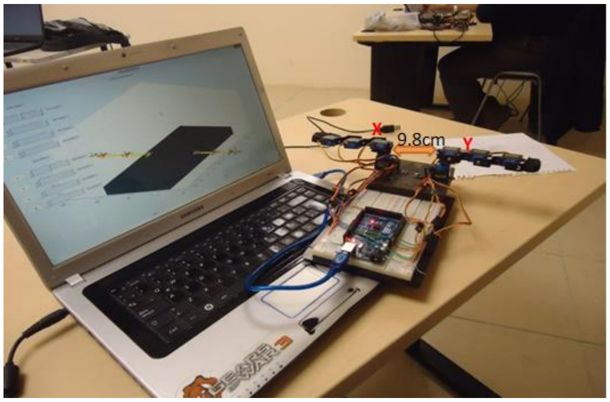

Figure 1 The gripping system.

Homogeneous transformation matrices in numerical form below:

For the first petit robot with $\theta_1 = \theta_2 = \theta_3 = \theta_4 = 0$, $d_3 = 3.6$ mm, $d_4 = 3.5$ mm and $d_5 = 1.5$ mm.

$$^{0}T_1 = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \quad \textbf{(3)}$$

$$^{1}T_2 = \begin{pmatrix} 0 & -1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \quad (4)$$

$$^{2}T_3 = \begin{pmatrix} 1 & 0 & 0 & 3.6 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \quad (5)$$

$$^{3}T_4 = \begin{pmatrix} 1 & 0 & 0 & 3.5 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \quad (6)$$

$$^{4}T_5 = \begin{pmatrix} 1 & 0 & 0 & 1.5 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \quad (7)$$

For the second petit robot with $\theta_1 = \theta_2 = \theta_3 = \theta_4 = 0$, $d_3 = 3.6$ mm, $d_4 = 3.5$ mm and $d_5 = 1.5$ mm son:

$$^{0}T_1 = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \quad (8)$$

$$^{1}T_2 = \begin{pmatrix} 0 & -1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \quad (9)$$

$$^{2}T_3 = \begin{pmatrix} 1 & 0 & 0 & 3.6 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \quad (10)$$

$$^{3}T_4 = \begin{pmatrix} 1 & 0 & 0 & 3.5 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \quad (11)$$

$$ {}^{4}T_{5} = \begin{pmatrix} 1 & 0 & 0 & 1.5 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \qquad (12) $$

Inverse kinematics

The inverse kinematic model allows for all possible solution configurations of a robot corresponding to a given effector location (operational coordinates). This model is usually called the closed form of the inverse kinematic model. There is not a general solution for this model:

$$ q = f^{-1}(x) \qquad (13) $$

For the solution of inverse kinematics problem, in this paper, a geometric approach is used. A fixed relationship of dependency or coupling between the third and fourth joint is supposed, as mentioned in (Cimadevilla Lajud & Pérez Herrera, 2006), the relationship that is used is as follows:

$$ \theta_4 = \left(\frac{2}{3}\right)\theta_3 \qquad (14) $$

Eq. 6 allows to reduce the problem of inverse kinematics to calculate intersections between two pairs of circumferences.

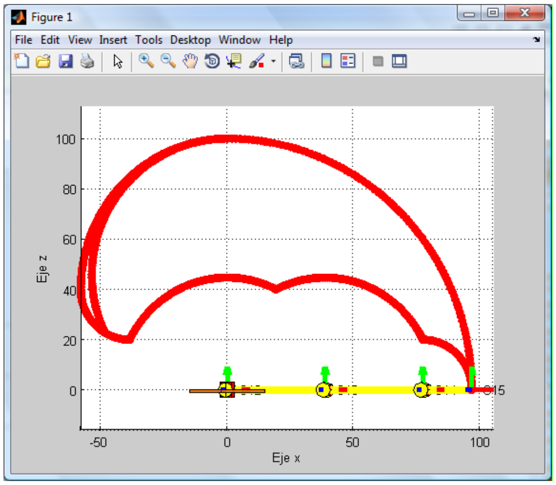

Figure 2 Petit robot´s workspace without the relationship.

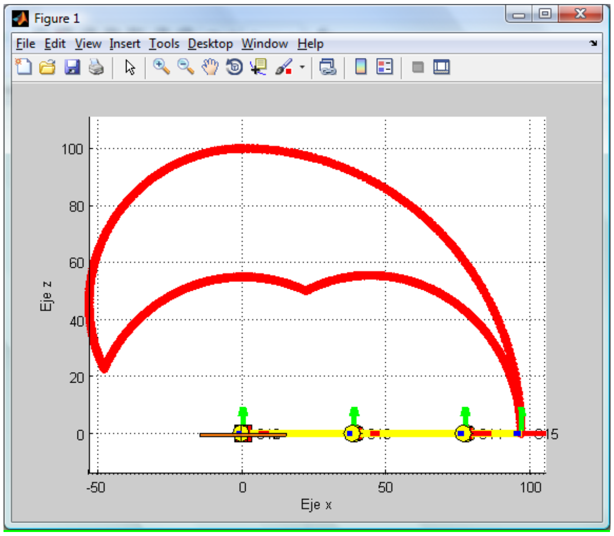

Figure 3 *Petit robot´s workspace with the relationship.*

In figures 2 and 3, x-z workspace projection allows to remark a reduction in the workspace due to Eq. (6).

Design and craftsmanship.

Petit robot geometry is generated using design 3D, in a computer aided design software, SolidWorks®. In Figure 4, all elements or components which are used to completely assemble the gripping system in SolidWorks® are shown.

In order to assemble each robot, aluminum phalanges are used, because this material is light and easy to be bent. The base which holds the system is made of acrylic.

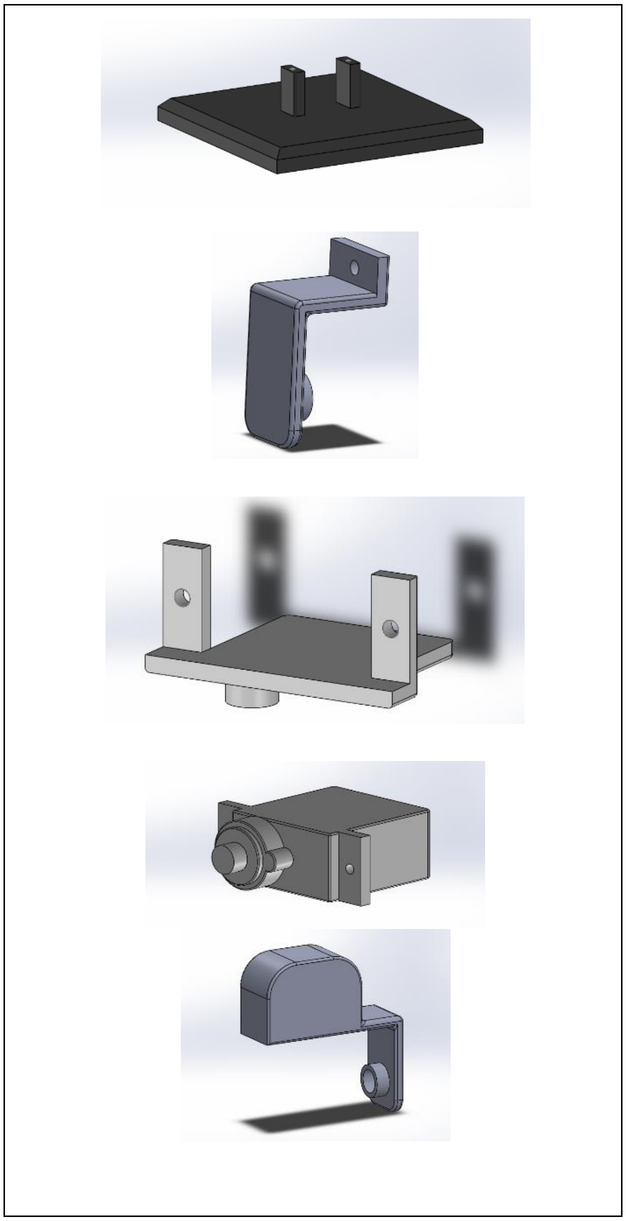

Figure 4 Gripping system components.

Once built each robotic finger, the gripping system has been assembled, and then in Figures 3 and 4, the system designed in some configurations is shown.

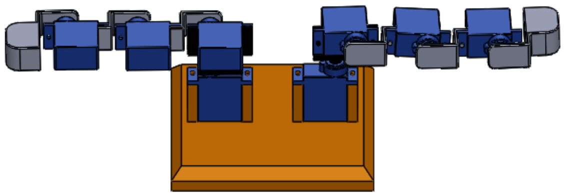

Figure 5 Home configuration **q** = [0º, 0º, 0º, 0º] for each petit robot.

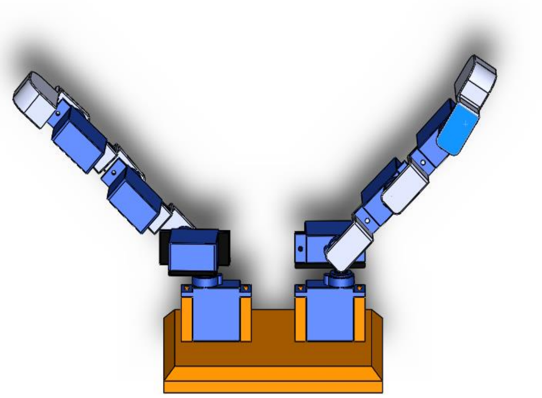

Figure 6 Configuration **q** = [0o, 45o, 0o, 0o] for each petit robot.

Graphical user interface (GUI)

MATLAB® has been used to code the graphical user interface. In order to represent phalanges and joints of the petit robot, lines and cylinders were used to represent them, respectively.

To interact with the interface, sliders are used, every one of them can change the value each robot joint variables. The value of each variable articulate can be seen in the corresponding edit box (Figure 5). Every time that user is interacting with this element, the forward or direct kinematic problem of the petit robot is resolved.

User can also interact with GUI via the edit boxes, in this case, first petit robot configuration and on second the position of the slider are updated. By the way, during this interaction, petit robot direct kinematics is solved.

In addition, the graphical user interface has edit boxes to display, numerically, the position of the end of the petit robot, using Cartesian coordinates.

The interface has buttons with the "+" and labels "-", which allow to solve the problem of inverse kinematics.

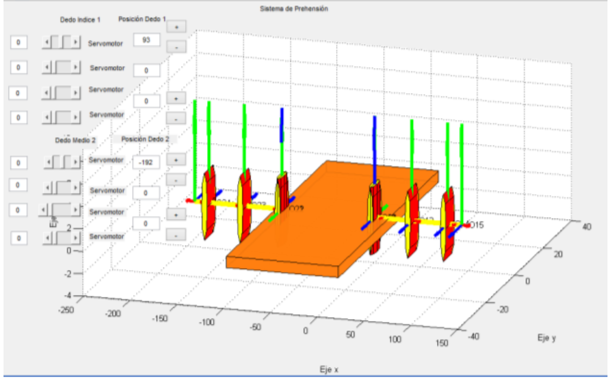

Figure 7 GUI gripping system with petit robots both in a **q** = [0º, 0º, 0º, 0º] configuration.

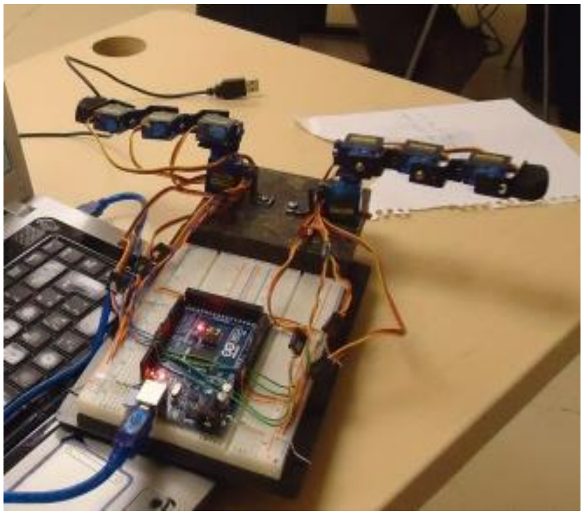

Figure 8 Gripping system with petit robots, configuration **q** = [0º, 0º, 0º, 0º] each of them.

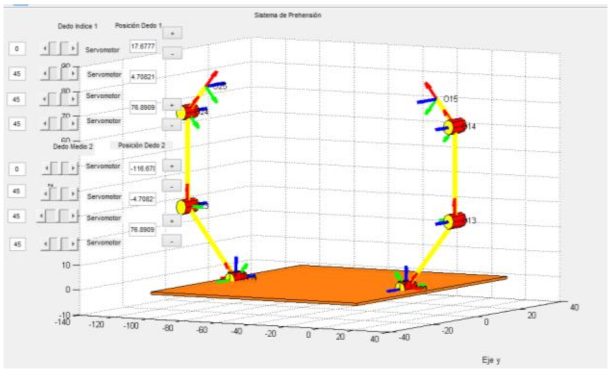

Figure 9 GUI gripping system with petit robots both in a **q** = [0º, 45º, 45º, 45º] configuration.

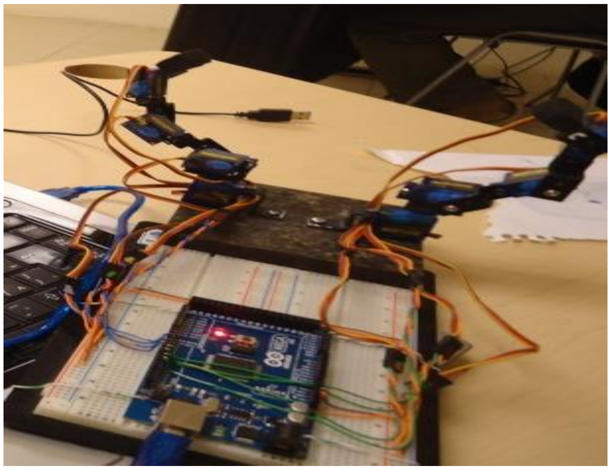

Figure 10 *Gripping system with petit robots, configuration* ***q*** *= [0º, 45º, 45º, 45º] each of them.*

The software implemented in Arduino Mega®, to control the petit robot through the graphical user interface developed in MATLAB®, is able to read all the time all the interface type in the serial port of the computer.

Code

Gripping system´s code implemented in Arduino Mega® is shown below.

```
#include <Servo.h>
Servo servo[8];
int pin[8]={
  2,3,4,5,
  6,7,8,9};
```

```
void setup(){
  //servo[0].attach(3);
  for (int i=0;i<8;i++){
    servo[i].attach(pin[i]);
  }
  Serial.begin(9600);
}
int grados;
void loop(){
 if (Serial.available()){
    for (int i=0;i<8;i++){
      grados = Serial.parseInt();
      if(grados>0 && grados < 180){
        servo[i].write(grados);
        delay(50);
      }
    }
  }
}
```

Algorithm

MATLAB® application´s pseudo code is presented to briefly illustrate the operation of the graphical user interface.

```
01 Start Application

02 Initial Configuration q = [0 0 0 0] each petit robot

03 Updating the petit robots and resolution of the forward kinematics

04 Opening the serial port

05 Writing the initial configuration on the serial port

06 Close the serial port

07 Waiting user interaction

08 If value change in articular variable (slider or edit box)
09 Then update petit robots and solving the forward kinematics

10 Open serial port

11 Writing current configuration on the serial port

12 Close the serial port

13 If you click on "+" or "-"

14 Then solving inverse kinematics

15 Checking the validity of the solution and update petit robots representation

16 Opening the serial port

17 Writing current settings to the serial port

18 Close the serial port
```

In the current stage of development, a system of open-loop control is used. This is because sensors are not implemented or some method to quantify the error. Without feedback, for now, another control system cannot be used. The block diagram for each engine is shown in Figure 9.

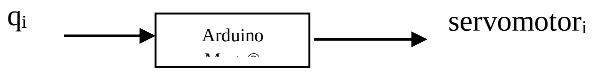

Figure 11 *Bl*ock diagram for each servomotor.

Results

A thesis, a system gripping prototype, and the graphical interface have been developed, as tangible results of this work.

The results allow us to move towards the development of more complex systems with petit robots and designing robots with different architectures.

Conclusions

A gripping system is designed and built at the Technological Institute of Nuevo Leon. A brief description of the objectives pursued in its design, the most relevant details of their mechanical structure, electrical and electronics, software developed for controlling the system are made.

This project is developed in the field of electronics and robotics, also integrating knowledge and expertise in programming Arduino Mega® and MATLAB®. The graphical user interface allows us to show the system simulation, in addition to observing real way, the solution of direct and inverse kinematics of each of the petit robots composing the system.

The goal of integrating a more complex system from the petit robots previously presented in (Fernández Ramírez et al., 2015) is fulfilled. The number of degrees of freedom manipulables is doubled and the graphical user interface is modified for this purpose. The petit robots gripping system move in anthropomorphic form.

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