12DOF Quadruped Spider Robot

catalogue

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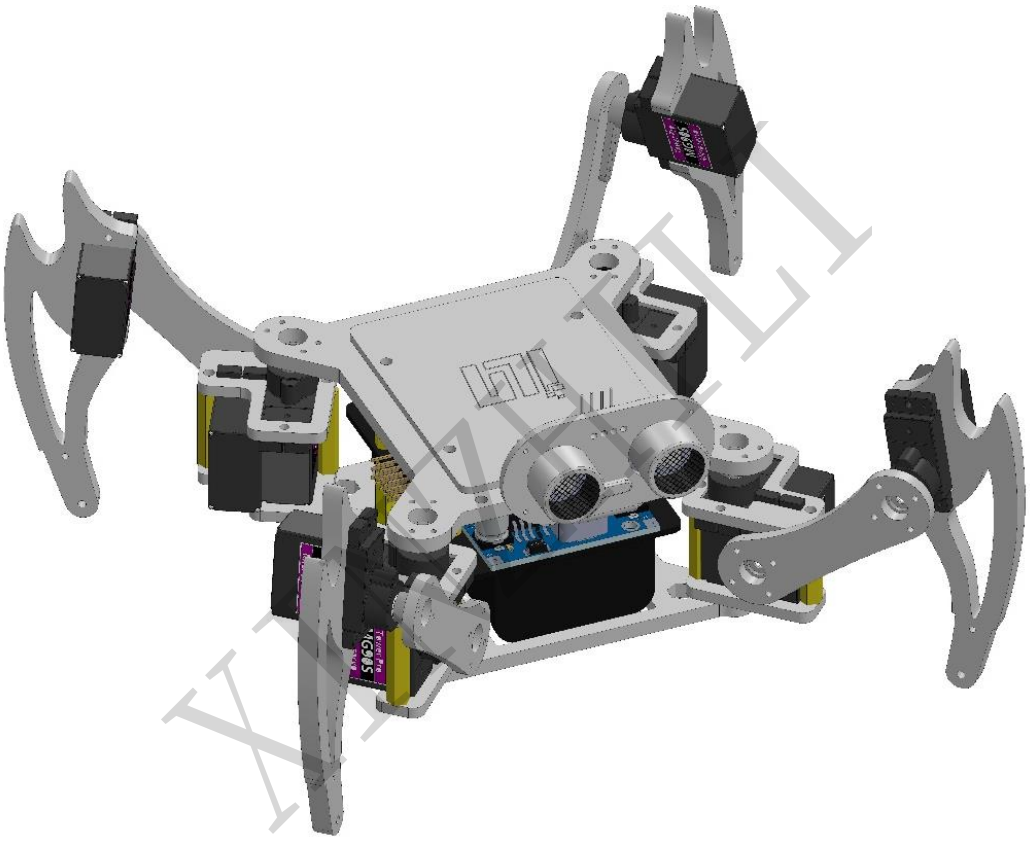


0 Statement

0.1 Use statement:

0.1.1 Please read this manual before use;
0.1.2 The product appearance in the picture is for reference, please refer to the actual product;
0.1.3 The company reserves the right to interpret this manual. In case of product updates or upgrades, there without notification, please refer to the actual product you purchased,

0.2 Warranty statement:

0.2.1 Please check the quality of the product carefully after receiving the product. we will not provide warranty once used.

0.3 Material statement

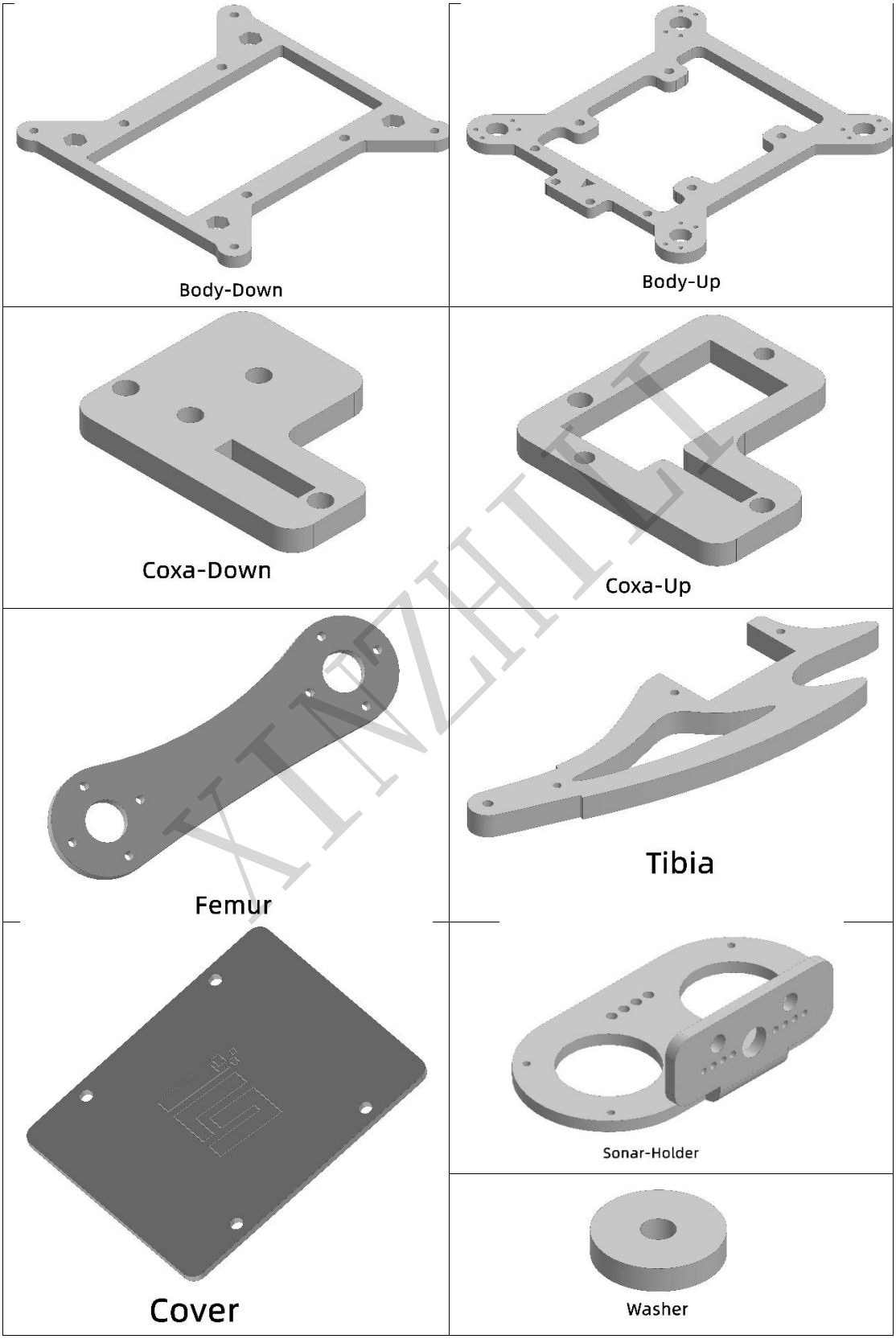
0.3.1 The copyright of this product material belongs to our company. “XINZHILI” is the brand and trademark, we will be held legally responsibility If copy or disseminate the matirial without authorization,

1 Kit list

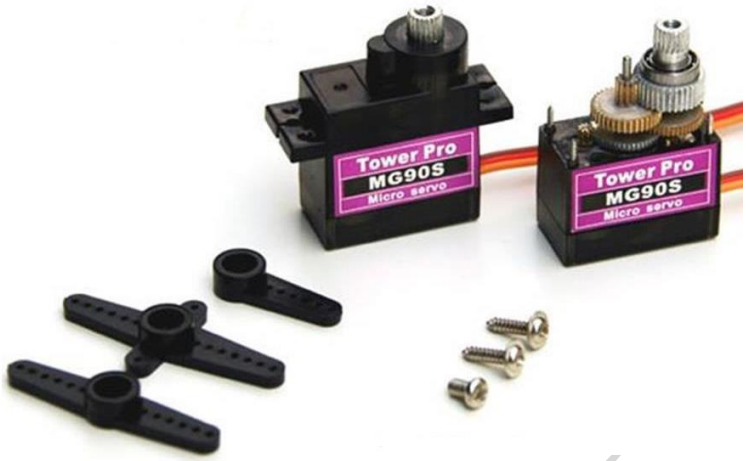
1.1. Accessories Collection

No	Name	Quantity
1	ESP32	1
2	Servo shield	1
3	MG90S servo	12
4	18650 battery (self provided)	2
5	MicroUSB cable	1
6	Acrylic	1
7	Ligature	some
8	Screwdriver	1
9	M2.5 * 6 screw	16
10	M2.5*23 screw	8
11	M2.5*20 single-pass-through copper pillar	4
12	M2.5*20 pass-through copper pillar	4
13	M2.5*10 screw	10
14	M1.7*6 screw	48
15	M2*10 screw	8
16	M2 nut	8
17	M1.7*5 screw	4
18	M2.5*14 screw	4
19	M2.5 lock nut	4
20	HC-SR04 Ultrasonic module	1
21	Ultrasonic module bracket	1

1.2 List of structural

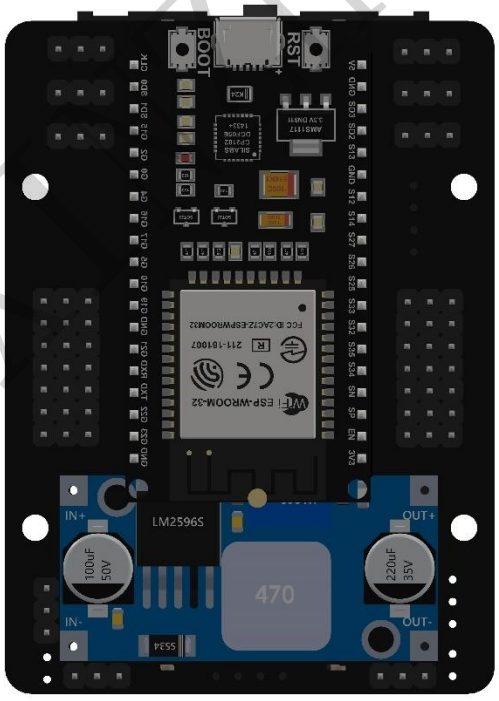


1.3.Servo



MG90S

1.3 Circuit description



The battery is in series mode. The positive pole of the battery is connected to the "+" character end next to the circuit board switch, and the negative pole of the battery is connected to the "-" character end next to the circuit board switch.

2. Assembly steps

Step 1. Test the servo

Before testing the servo motors, you need to set up a development environment on the computer. Please open the tutorials provided by us and enter "Lesson0 Setting Development Environment.pdf" under "03 Tutorial & Code → Arduino → Lesson 0 Setting Development Environment". Follow the instructions of the tutorial and complete the construction of the development environment.

After successfully completing the construction of the development environment, please open the tutorials and enter "Lesson1 Drives a Single Servo motors.pdf" under "03 Tutorial & Code → Arduino → Lesson1 Drives a Single Servo motors". Follow the instructions in the tutorial to complete the test of the servo motors.

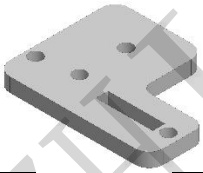
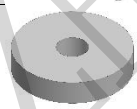
After completing Lesson1, open the tutorials, enter "03 Tutorial & Code → Arduino → Lesson2 Wifi Control → Quadbot-E-V1.4", double-click to open QuadBot-E-V1.4.ino, and download the program into the singlechip as the same with previous two Lessons.

Step 2. Prepare for assembly

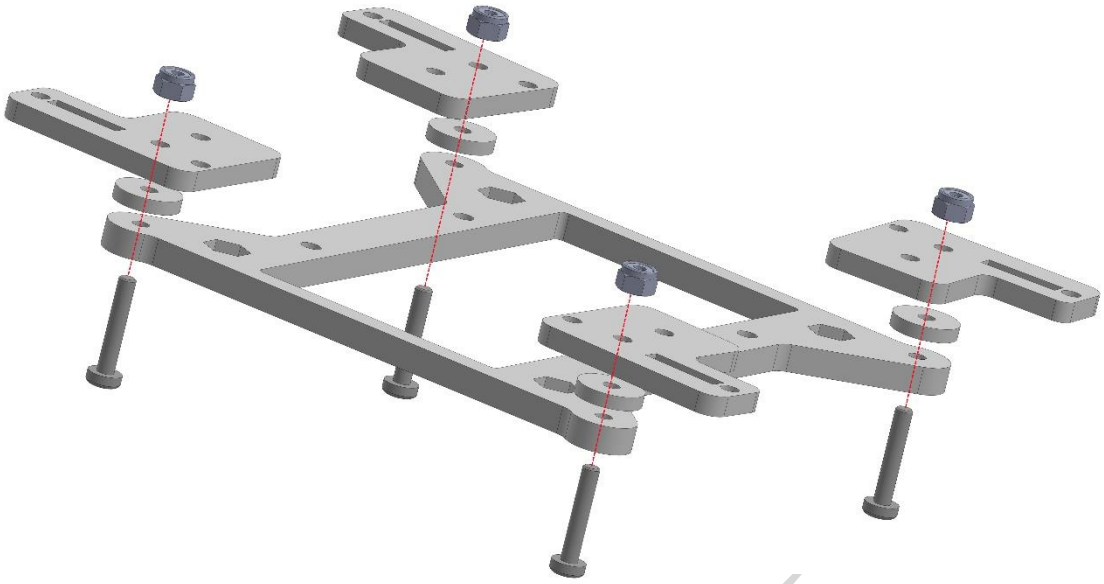
Tear off the protective paper stuck on the acrylic structure.

Step 3.Install Coxa-Down

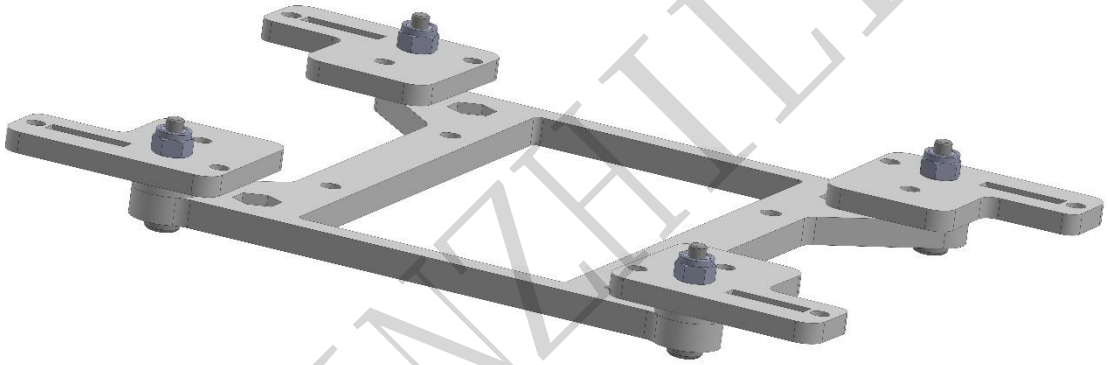
Accessories used:

Name	Picture	Quantity
Body-Down		1
Coxa-Down		4
washer		4
M2.5*14 screw		4
M2.5 lock nut		4

Use M2.5 * 14 screws to successively pass through Body-Down, washer and Coxa-Down, and fix them together with M2.5 locknut (note that the nut should not lock Coxa-Down, washer and Body-Down, and ensure that Coxa-Down can rotate easily!!!)

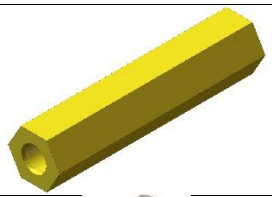


The effect after installation is shown in the following figure

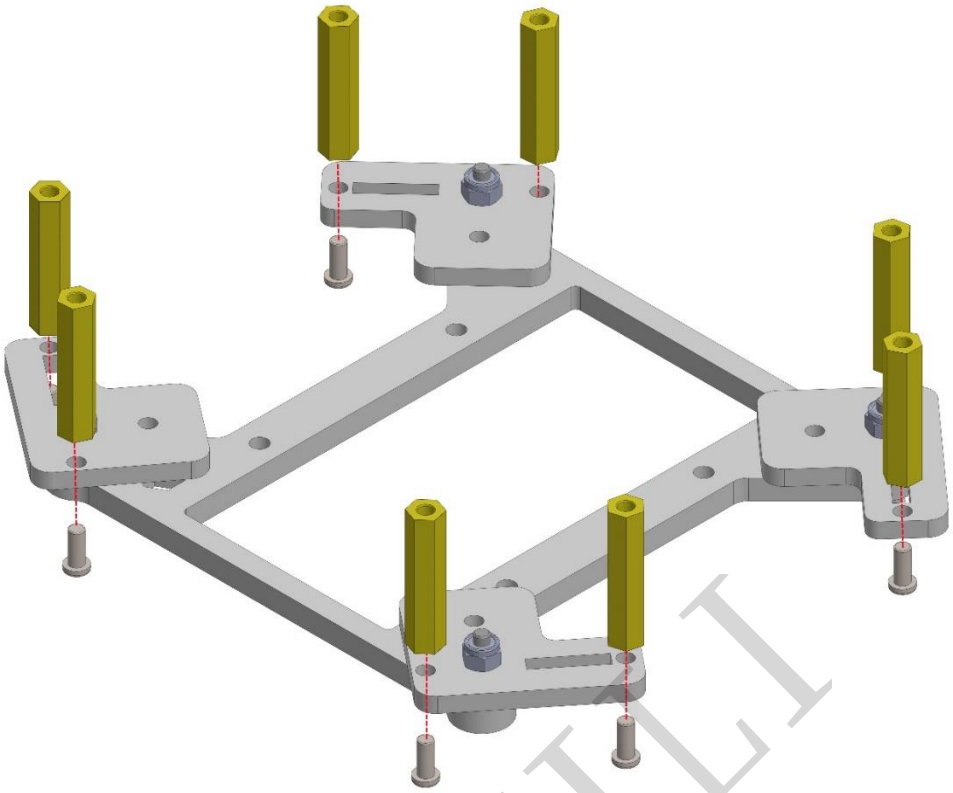


Step 4.Install hexagonal spacer

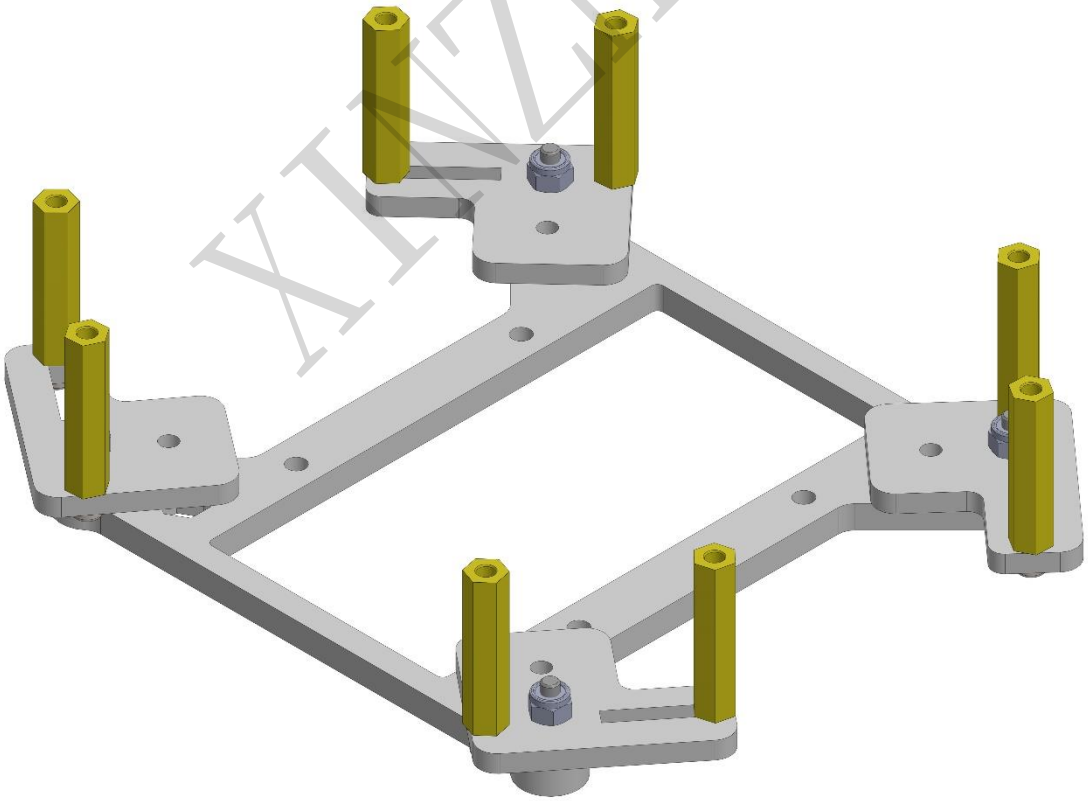
New accessories:

Name	Picture	Quantity
M2.5*23 hexagonal spacer		8
M2.5*6 screw		8

Fix 8 M2.5 * 23 hexagonal spacer on Coxa-Down with M2.5 * 6 screws

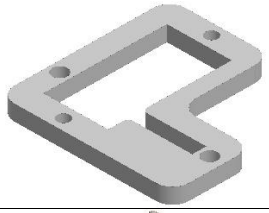


The effect after assembly is shown in the pictur below



Step 5. Install the servo on the Coxa-Up

New accessories:

Name	Picture	Quantity
MG90S servo		4
Coxa-Up		4
M2*10 screw		8
M2 nut		8

Fix the servo on Coxa-Up with M2 * 10 screws and M2 nuts (pay attention to the direction of servo), as shown in the figure below

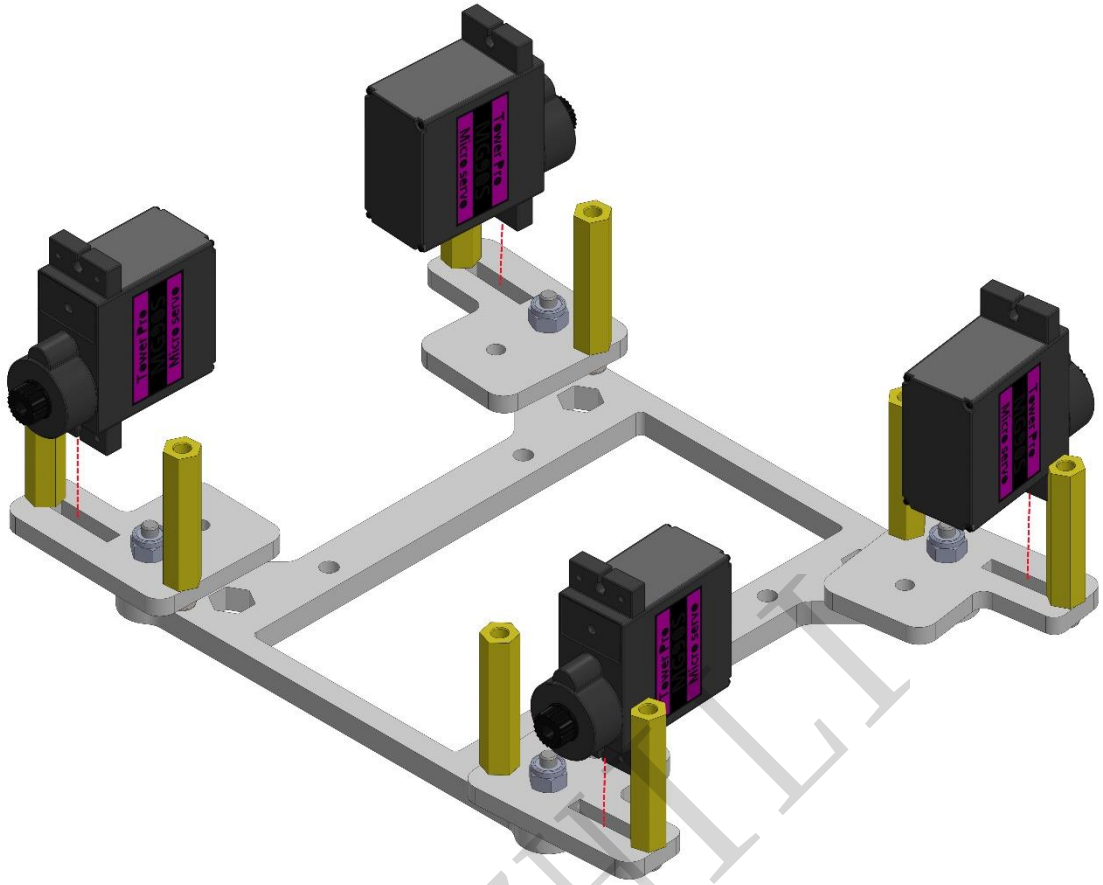
The effect after assembly is shown in the pictur below

Step 6.Install the servo on the Coxa-Down

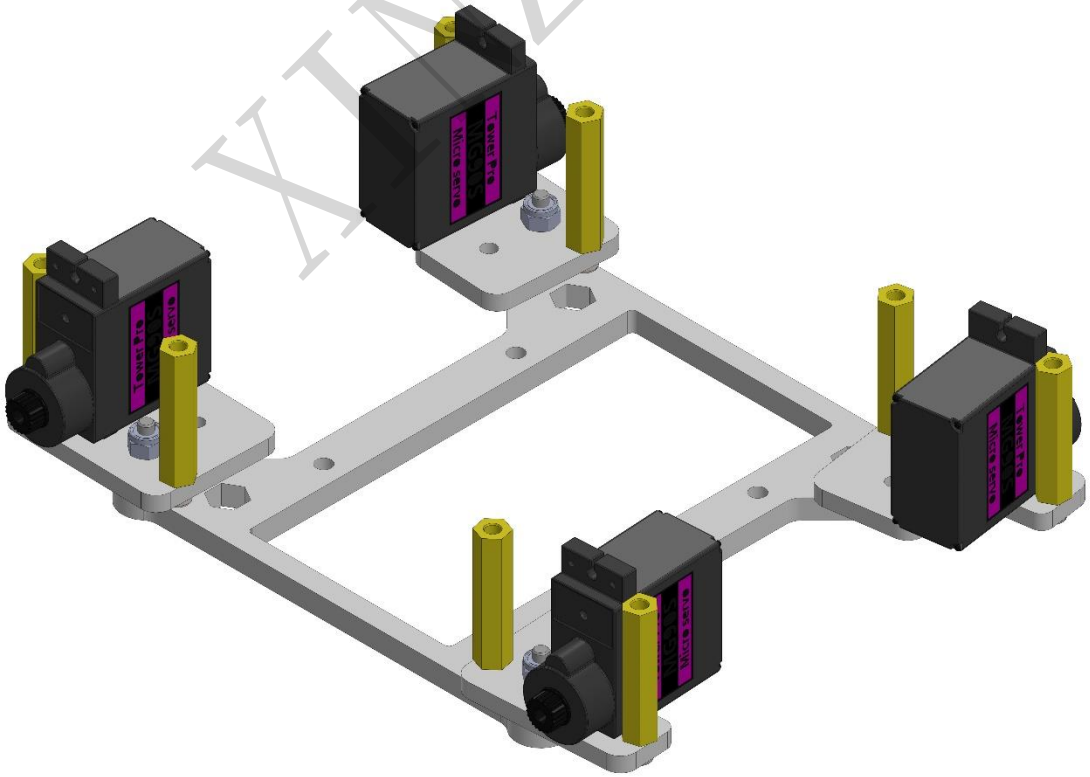
New accessories:

Name	Picture	Quantity
MG90S servo		4

Insert the 4 servos into the slots on the Coxa-Down (note that the rotation axis of the servos is below!!!!!)



The effect after assembly is shown in the pictur below

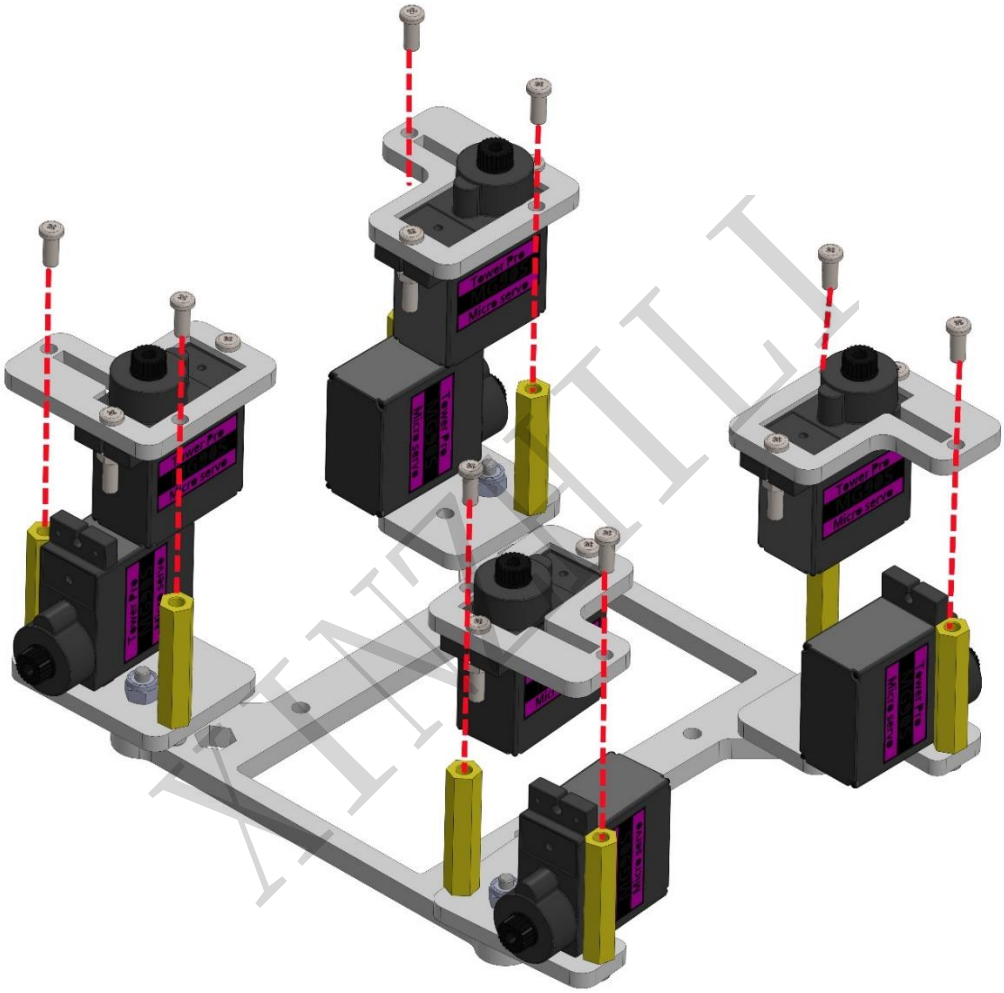


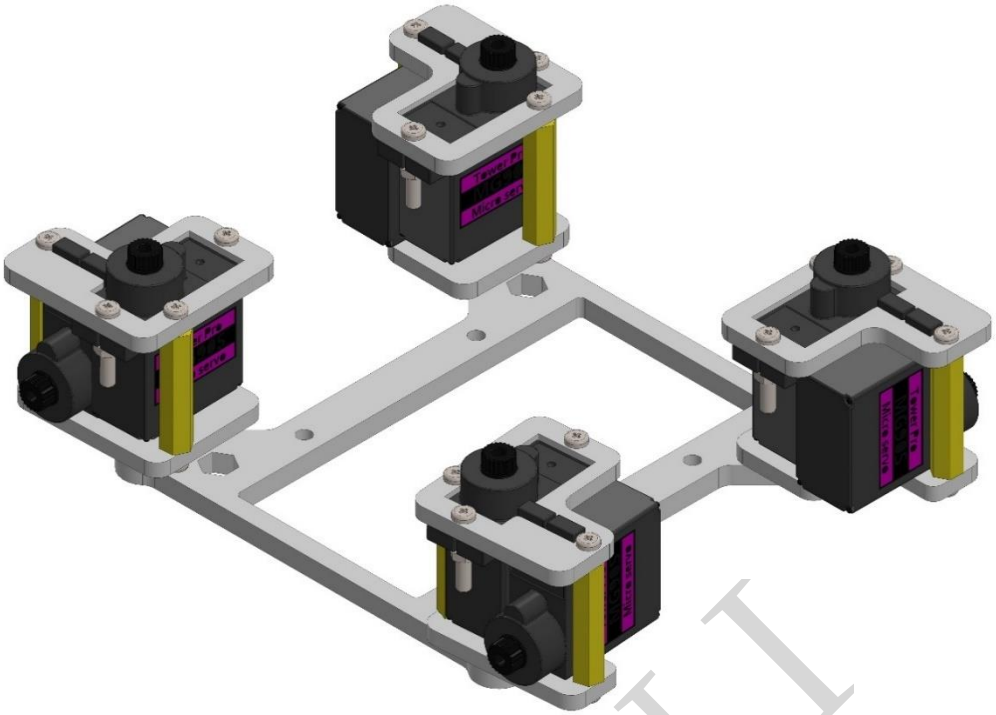
Step 7.Connecting Coxa-Up and Coxa-Down

New accessories:

Name	Picture	Quantity
M2.5*6 screw		8

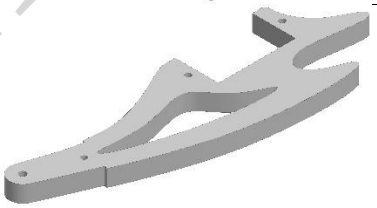
Use 8 M2.5 * 6 screws to connect the previously assembled Coxa-Up and servo assembly with Coxa-Down. See the figure below for details.



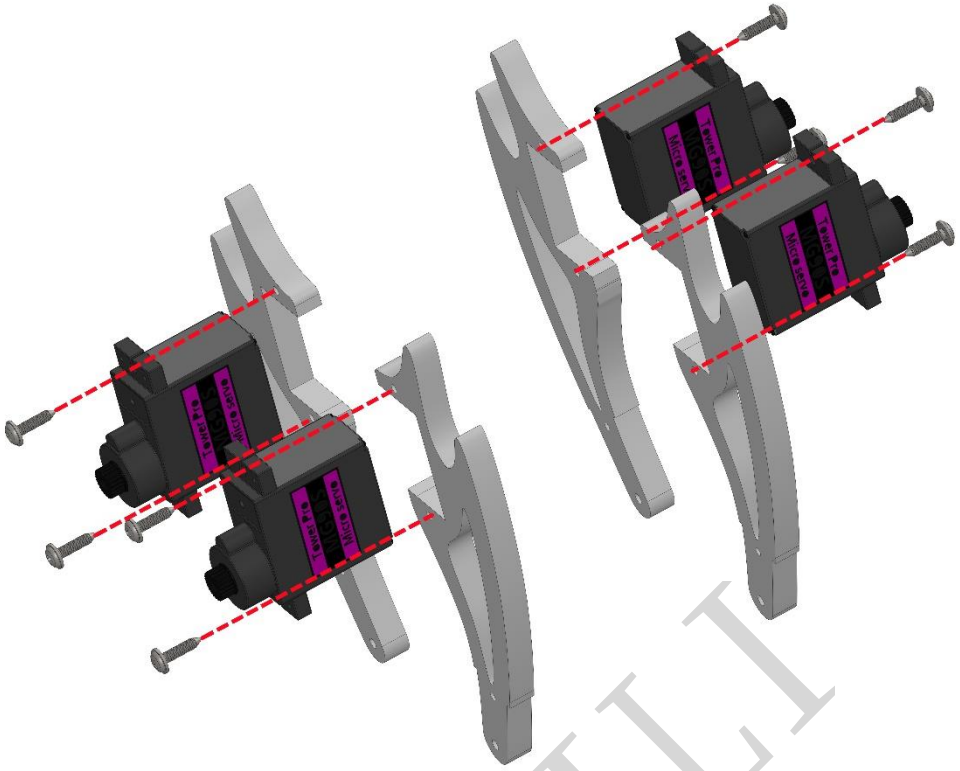


Step 8.Install the servo on Tibia

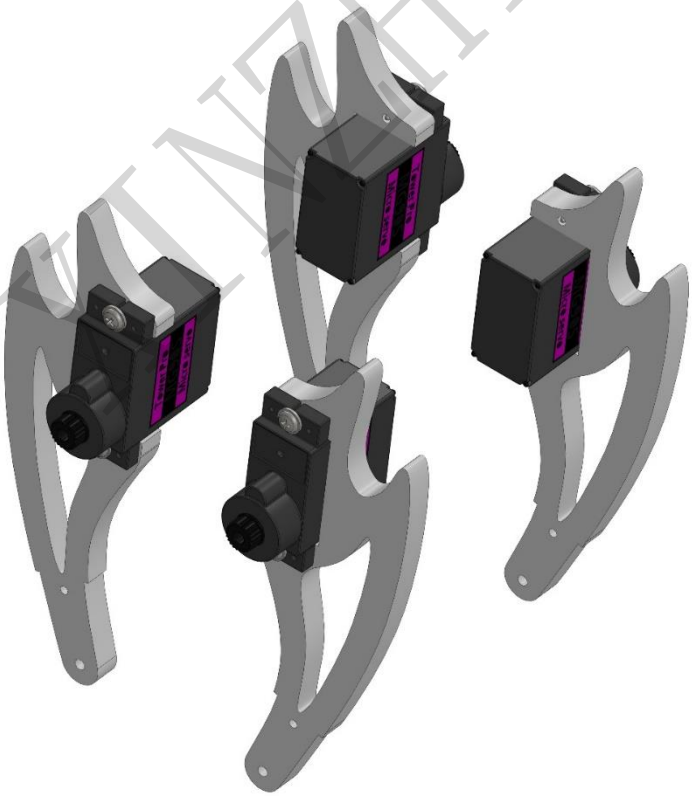
New accessories:

Name	Picture	Quantity
MG90S servo		4
Tibia		4
M1.9*7 screw(In the servo bag)		8

Take out eight M1.9 * 7 self tapping screws from the bag containing the servo, and fix the servo on Tibia.

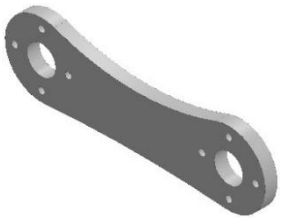


The effect after assembly is shown in the pictur below

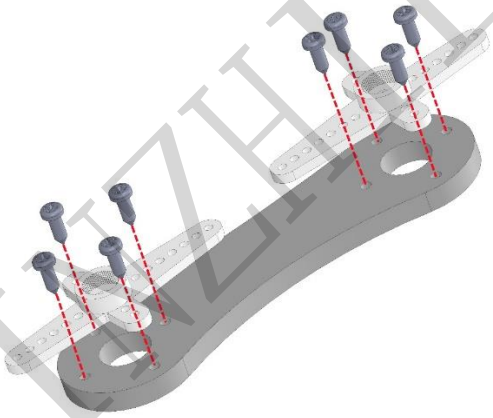


Step 9.Install servo arm on Femur

New accessories:

Name	Picture	Quantity
Femur		4
Servo arm		4
M1.7*6 self-tapping screw		8

Use M1.7 * 6 tapping screws to fix the servo arm on the four Femurs. The following figure is an example of one operation.

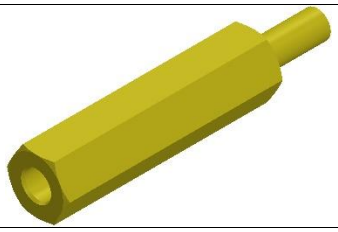


The effect after assembly is shown in the pictur below

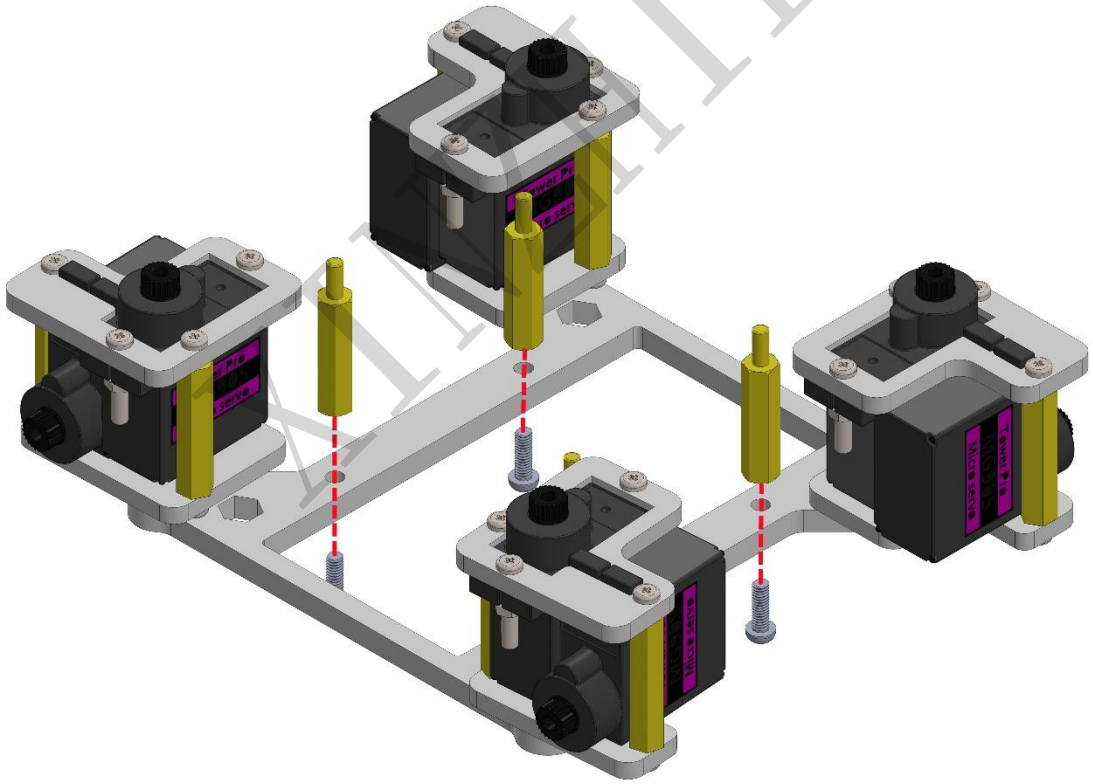
Similarly, install the servo arms on the remaining three Femurs.

Step 10.Inatall hexagonal spacer on Body-Down

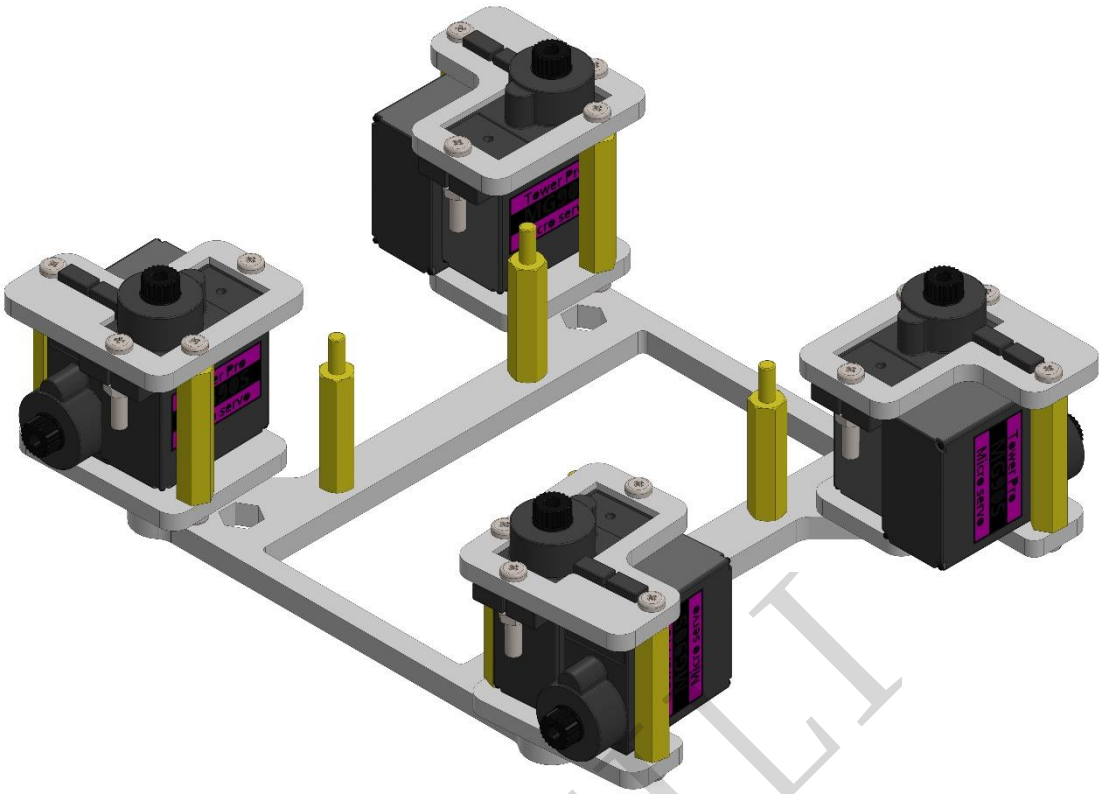
New accessories:

Name	Picture	Quantity
M2.5*20 half-pass-through hexagonal spacer		4
M2.5*10 screw		4

Install 4 M2.5*20 half-pass-through hexagonal spacer on BODY-DOWN with M2.5 * 10 screws, as shown in the figure below.

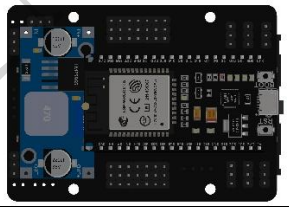
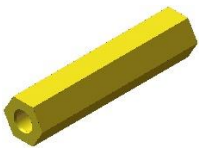


The effect after assembly is shown in the pictur below.

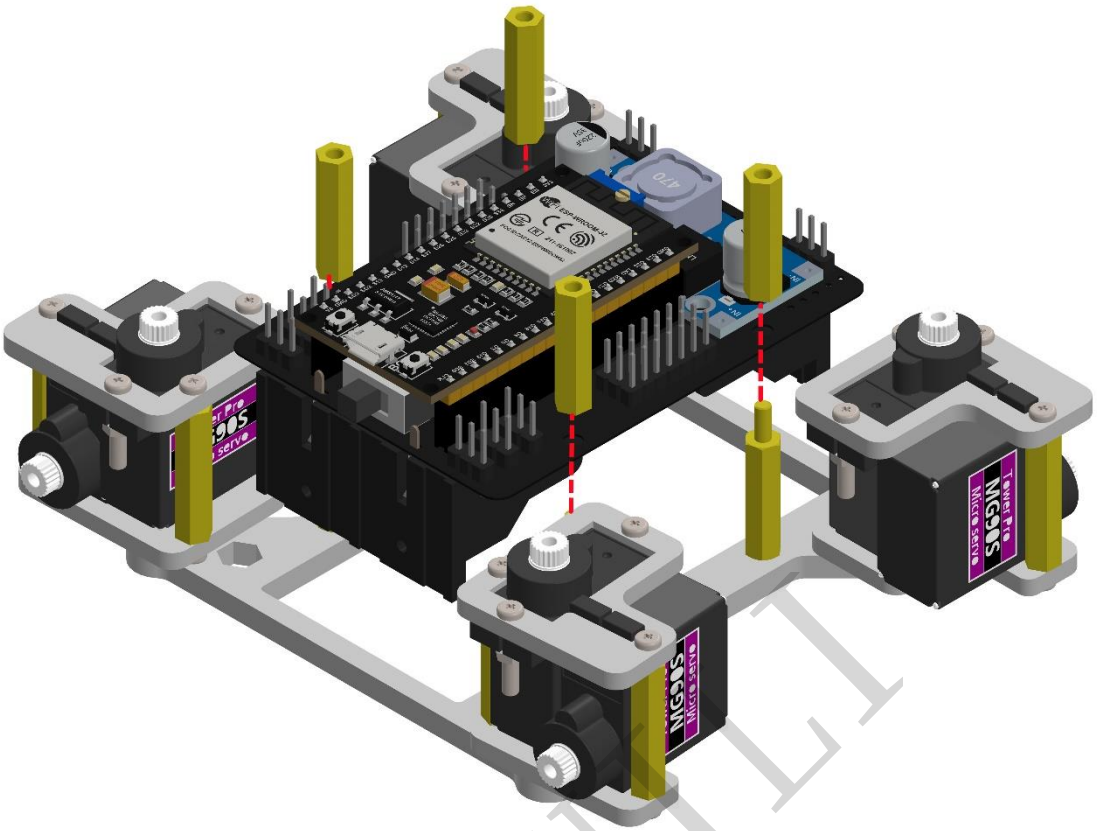


Step 11. Instal the circuit board

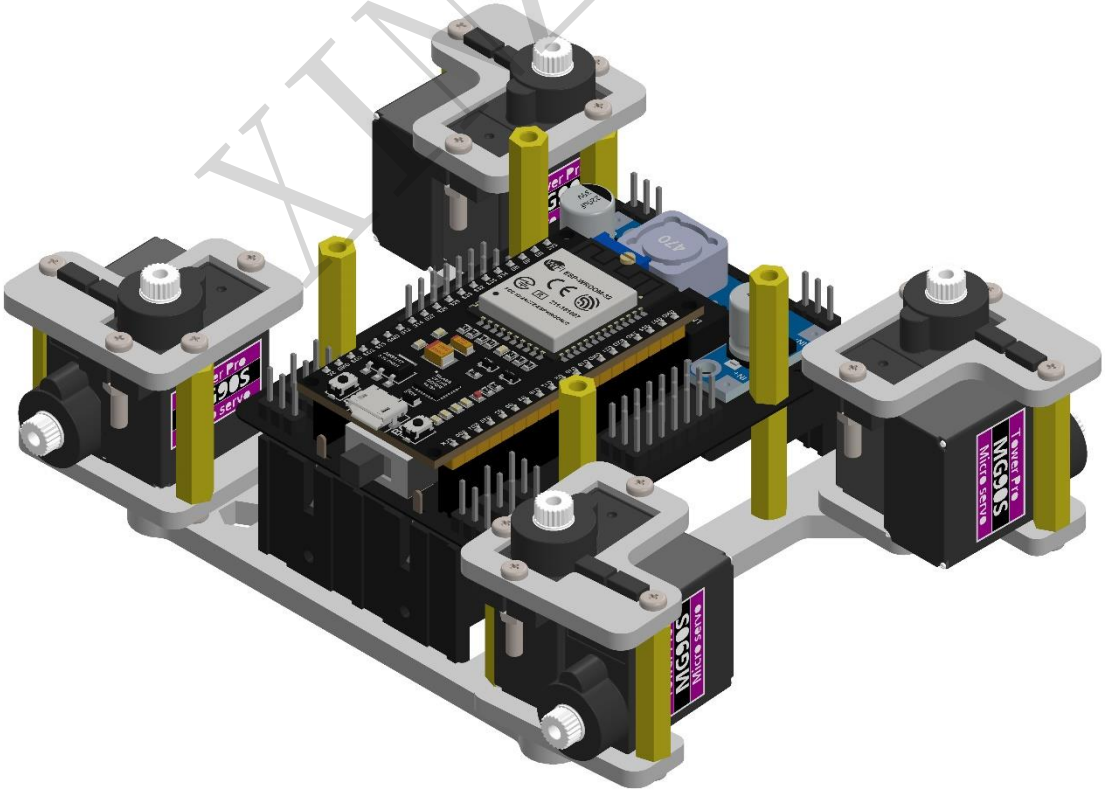
New accessories:

Name	Picture	Quantity
Servo shield + ESP32		1
M2.5*20 pass-through hexagonal spacer		4

Install the circuit board on the four half-pass-through hexagonal spacer below with four M2.5 * 21 pass-through hexagonal spacer.

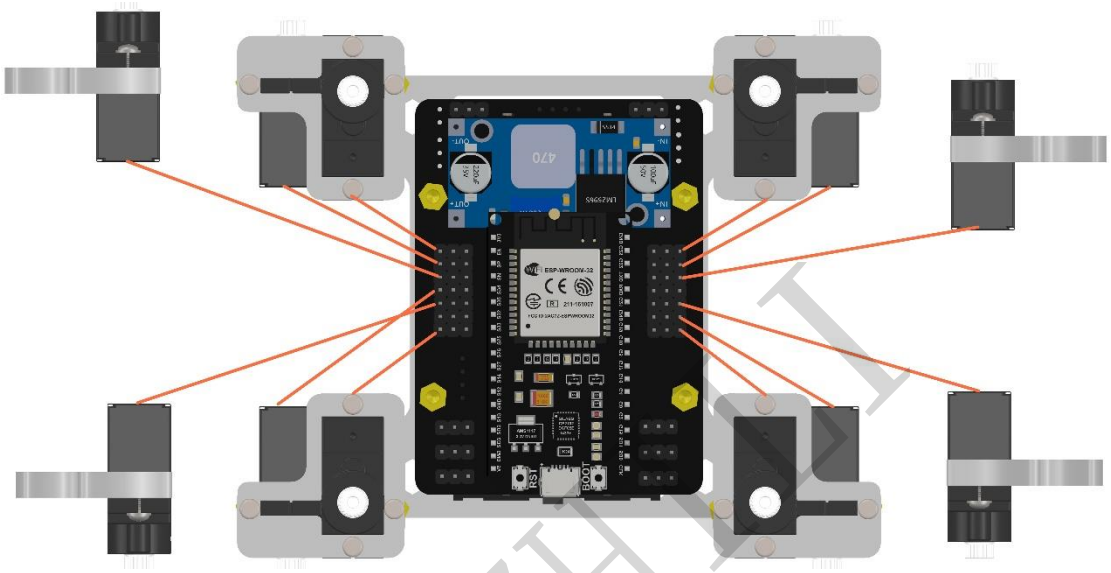


The effect after assembly is shown in the pictur below.



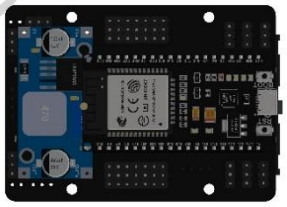
Step 12. Wiring the servo to the servo shield

Connect the servo and servo shield as shown in the figure below. (Note: The brown wire of the servo cable is the ground wire, the red wire is the power wire, and the orange wire is the signal wire. Connect the signal wire to the S end of the corresponding interface of the servo shield, the power wire is connected to V, and the ground wire is connected to G!!)

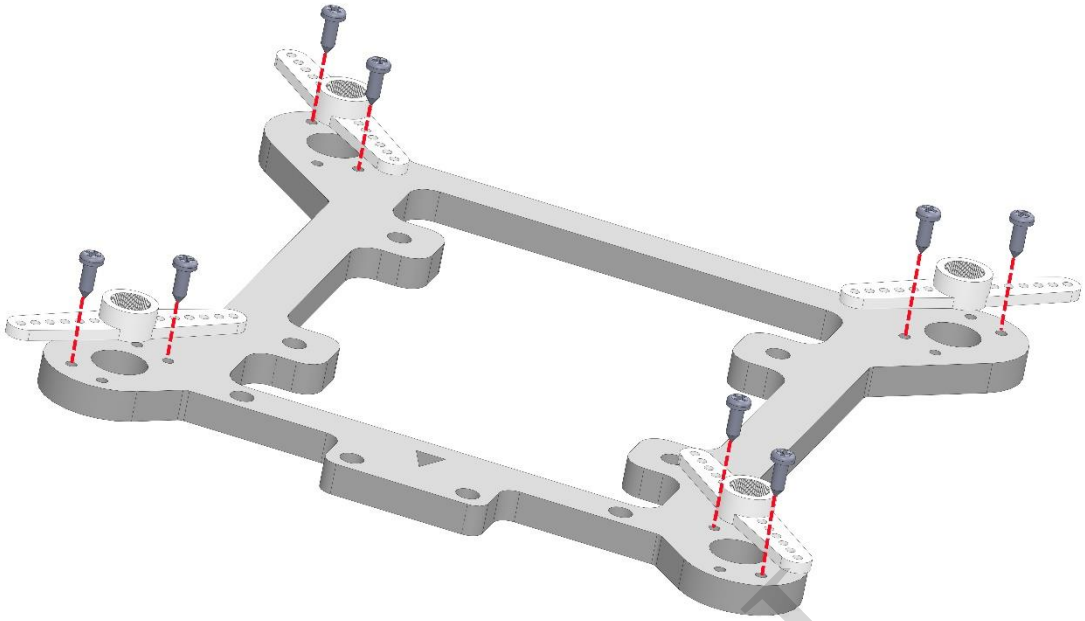


Step 13. Install servo arm on Body-Up

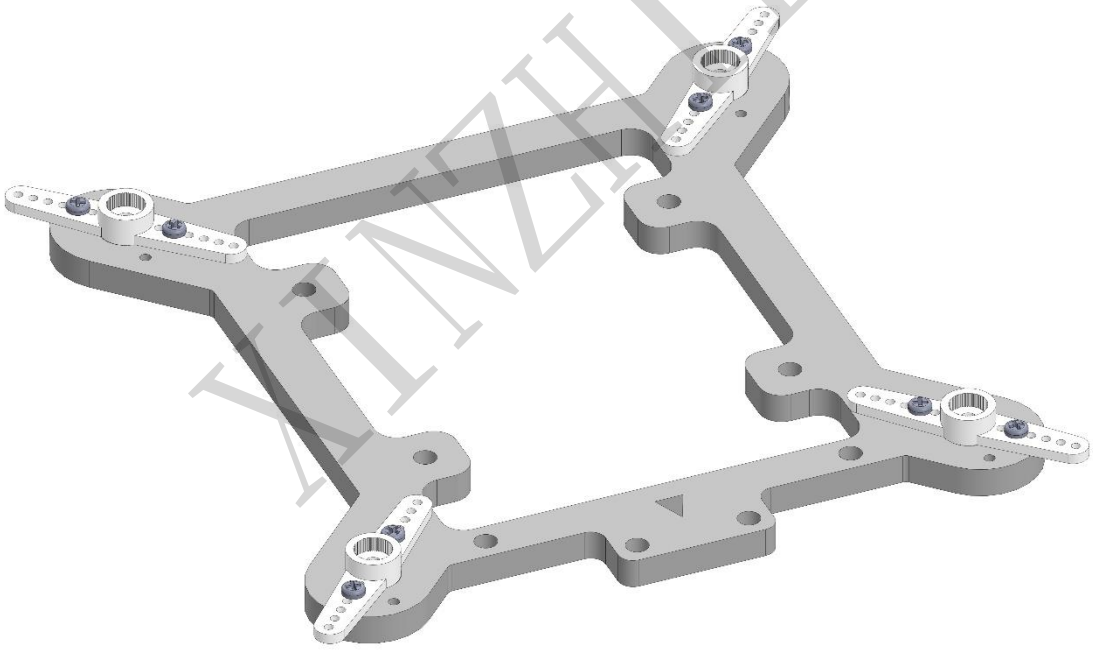
New accessories:

Name	Picture	Quantity
Body-Up		1
Servo arm		4
M1.7*6 screw		8

Fix the four servo arms on the Body-Up with eight M1.7 * 6 tapping screws.



The effect after assembly is shown in the pictur below.



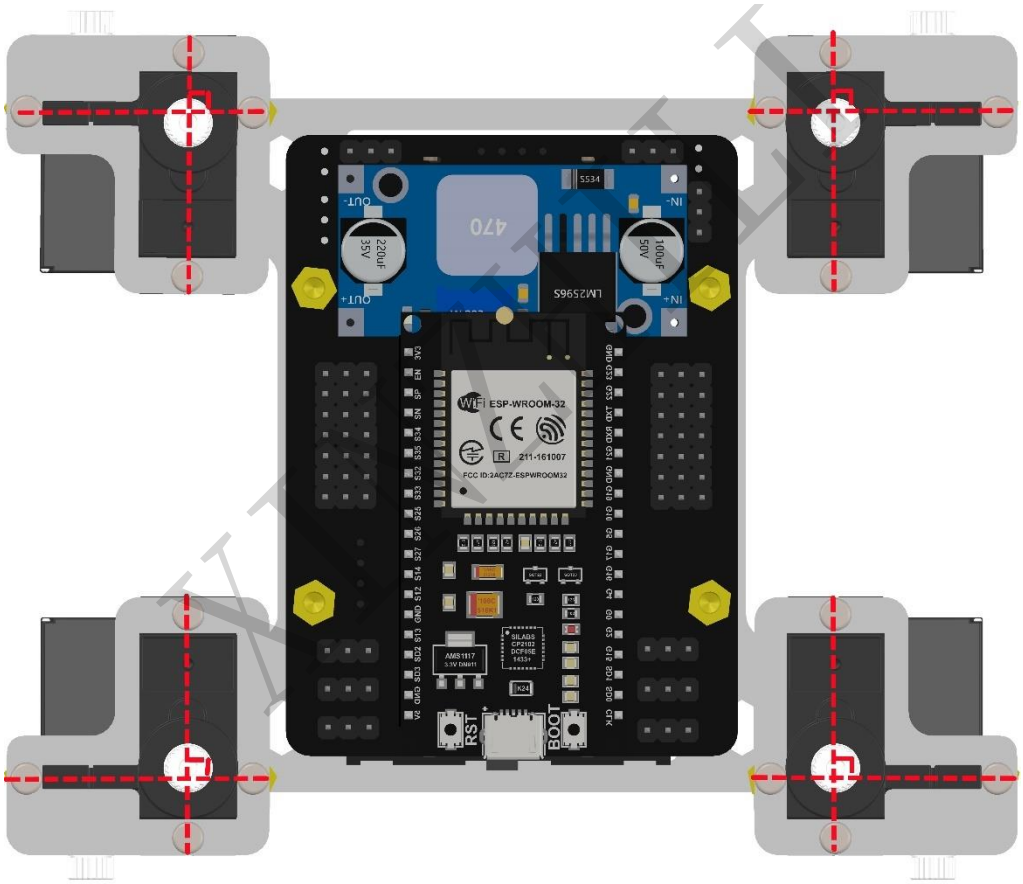
Step 14. Fix servo on Coxa

New accessories:

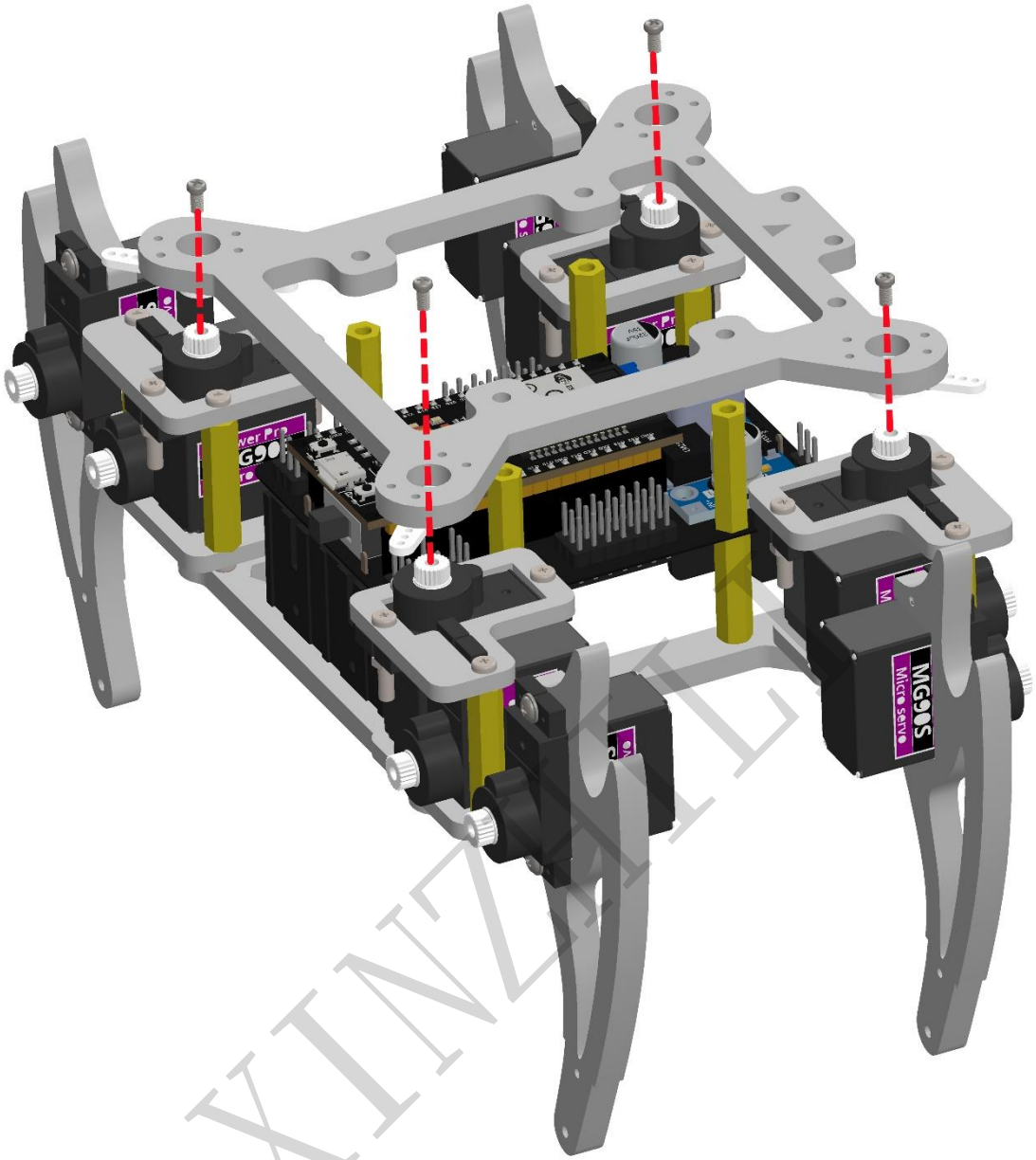
Name	Picture	Quantity

M2.5*4 screw(In the servo bag)		4

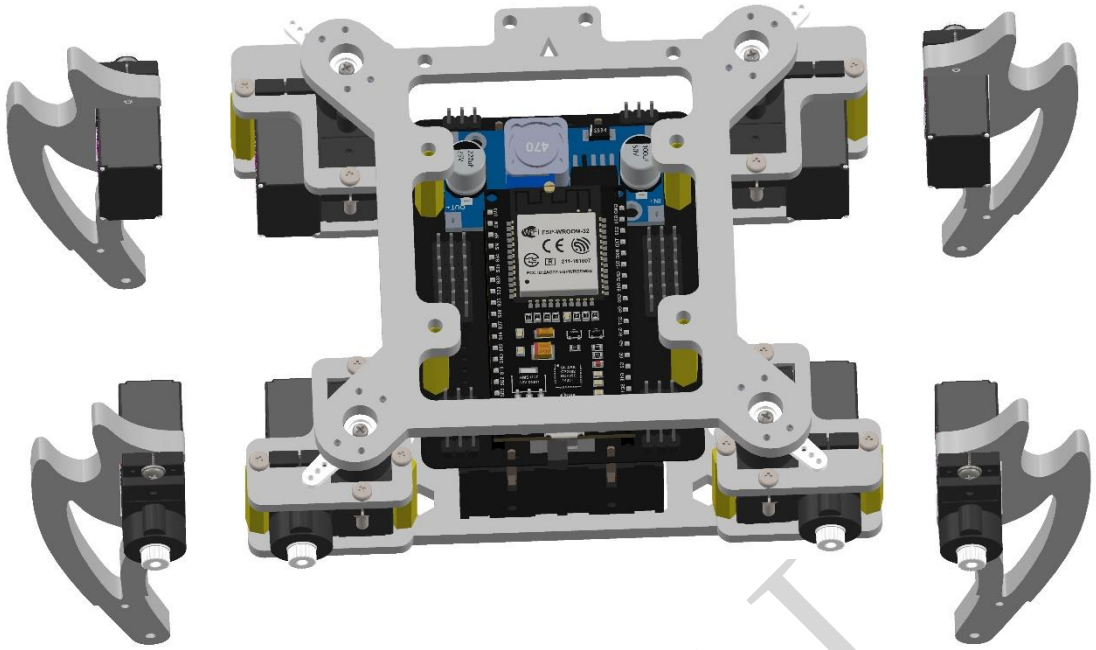
First, make sure that the switch on the circuit board is turned to OFF, and then install two 18650 batteries into the battery box (note that the positive pole of the battery is connected to the end of the circuit board switch with the "+" character printed on it, and the negative pole of the battery is connected to the end of the circuit board switch with the "-" character printed on it. Install Bofy-Up on the Cocs servo as shown in the following figure. Pay attention to the vertical installation as shown in the following figure (note: when the servo is installed into the circular hole of the servo arm, the servo rotation axis cannot be rotated)



Take out four M2.5 * 4 screws from the servo bag to connect the four servo arms on the Body-Up with the servo at the Coxa. The specific operation is shown in the following figure.



The effect after assembly is shown in the pictur below.

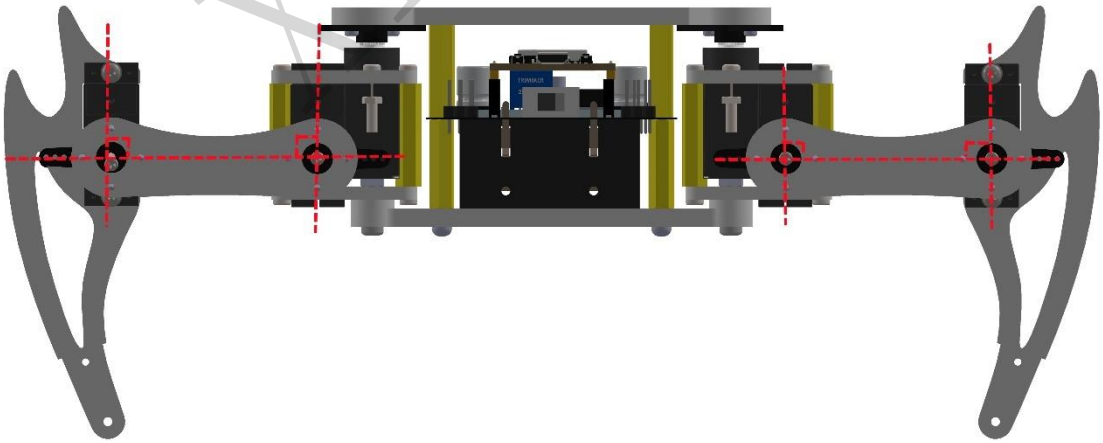


Step 15. Fix servo at Femur and Tibia

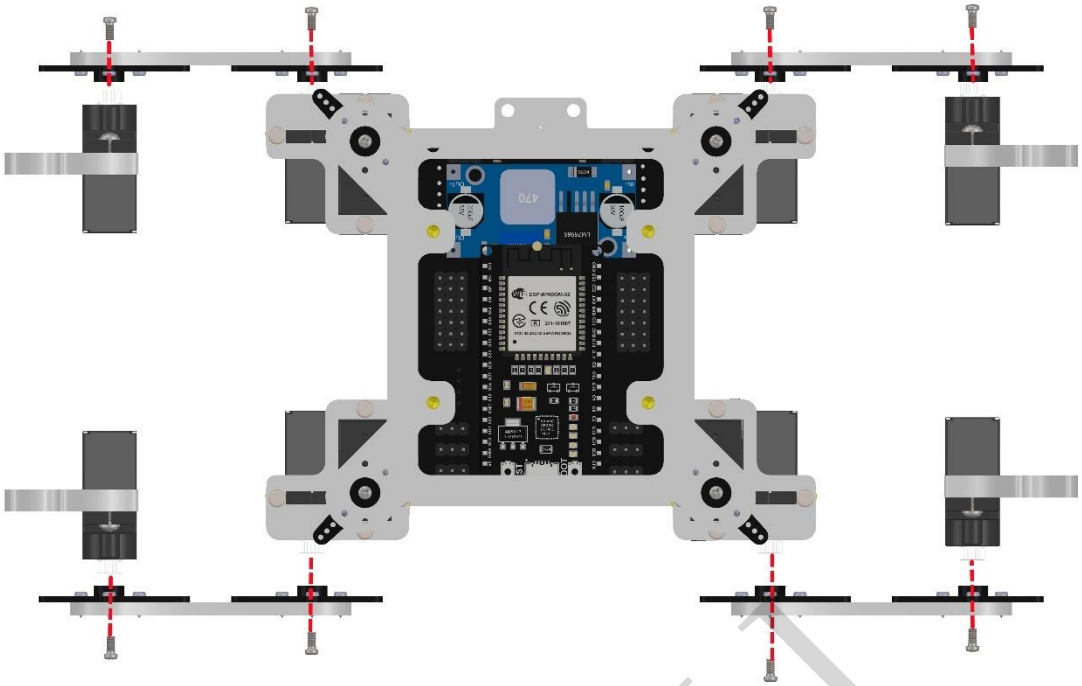
New accessories:

Name	Picture	Quantity
M2.5*4 screw(In the servo bag)		8

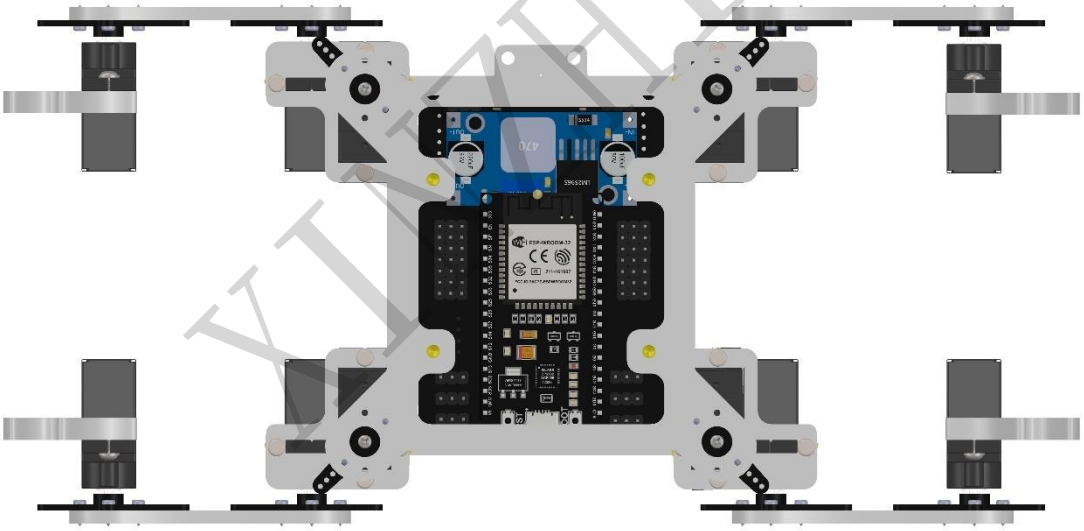
Connect Femur to Tibia and Coxa according to the vertical relationship shown in the figure below.



Take out eight M2.5 * 4 screws from the servo bag to connect the two servo arms on Femur with the servo at Tibia and the servo outside Coxa. (Note: Do not rotate the rotating shaft of the servo during installation!!!!!)



The effect after assembly is shown in the pictur below.



Step 16. Install ultrasonic mounting bracket

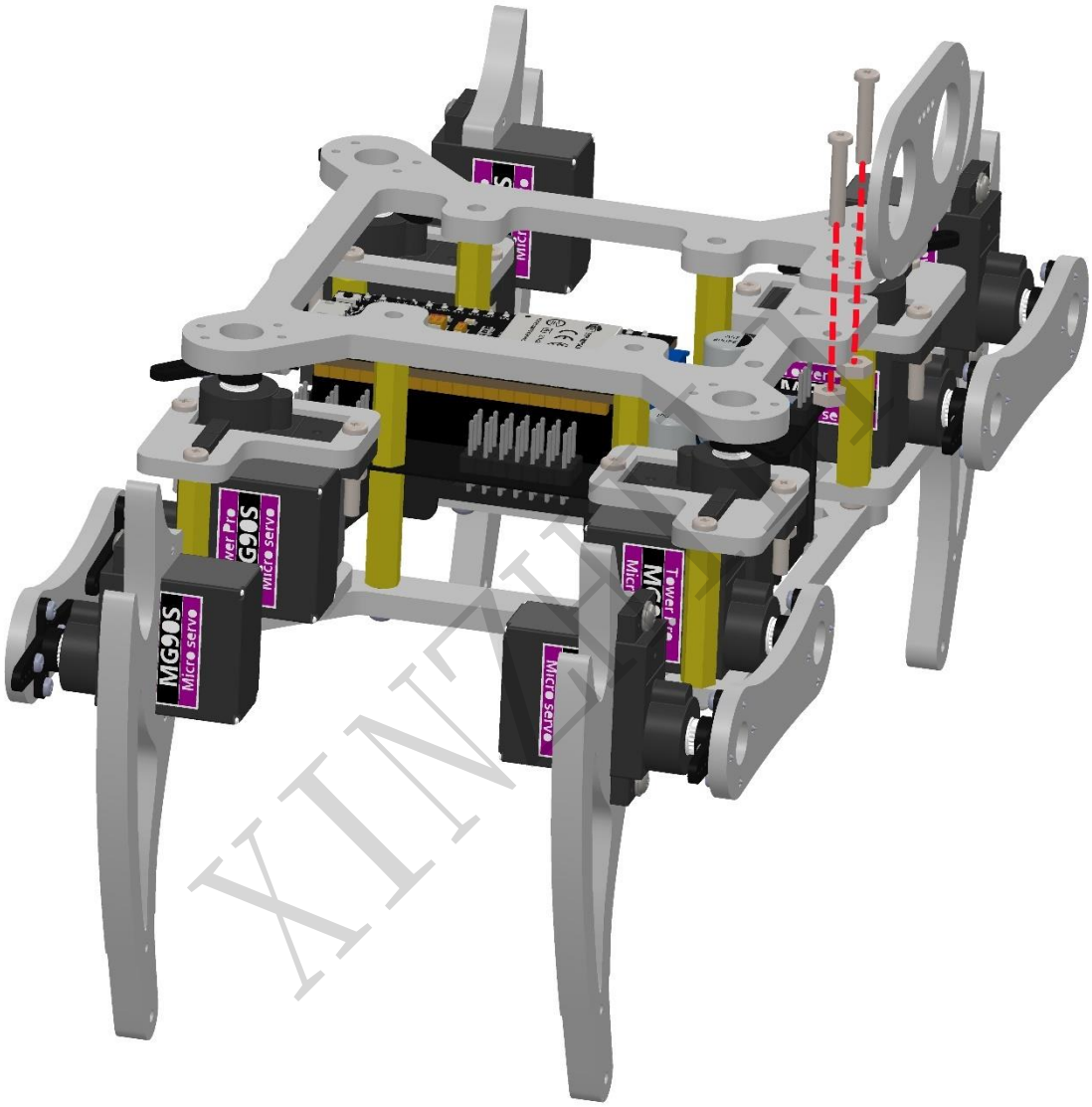
This step is only required for packages containing ultrasonic modules.

New accessories:

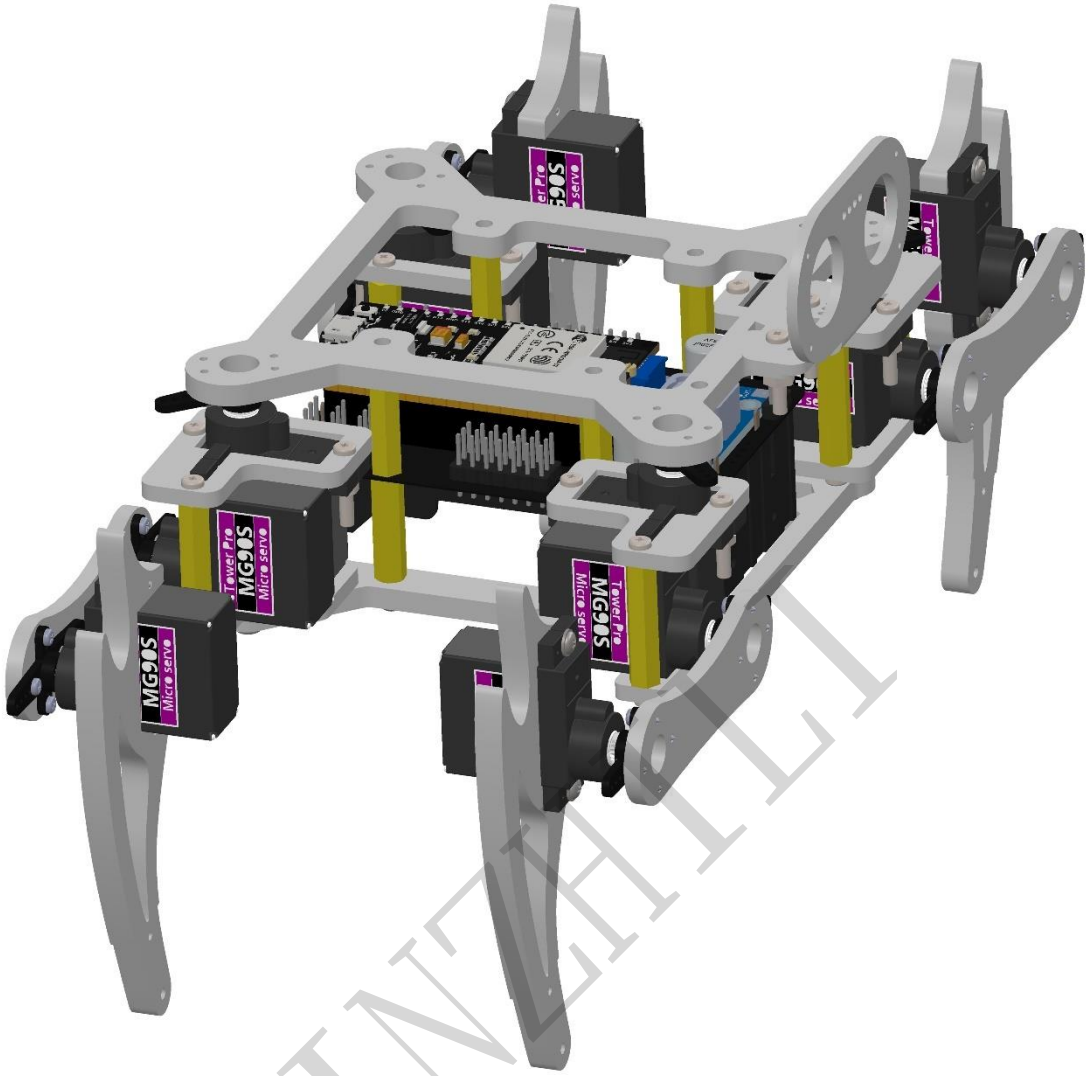
Name	Picture	Quantity
M2.5*10 screw		2

M2.5 nut		2
Sonar-Holder		1

Install the Sonar-Holder on the Body-Up with two M2.5 * 10 screws and two M2.5 nuts.

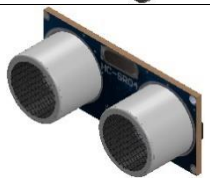


The effect after assembly is shown in the pictur below.

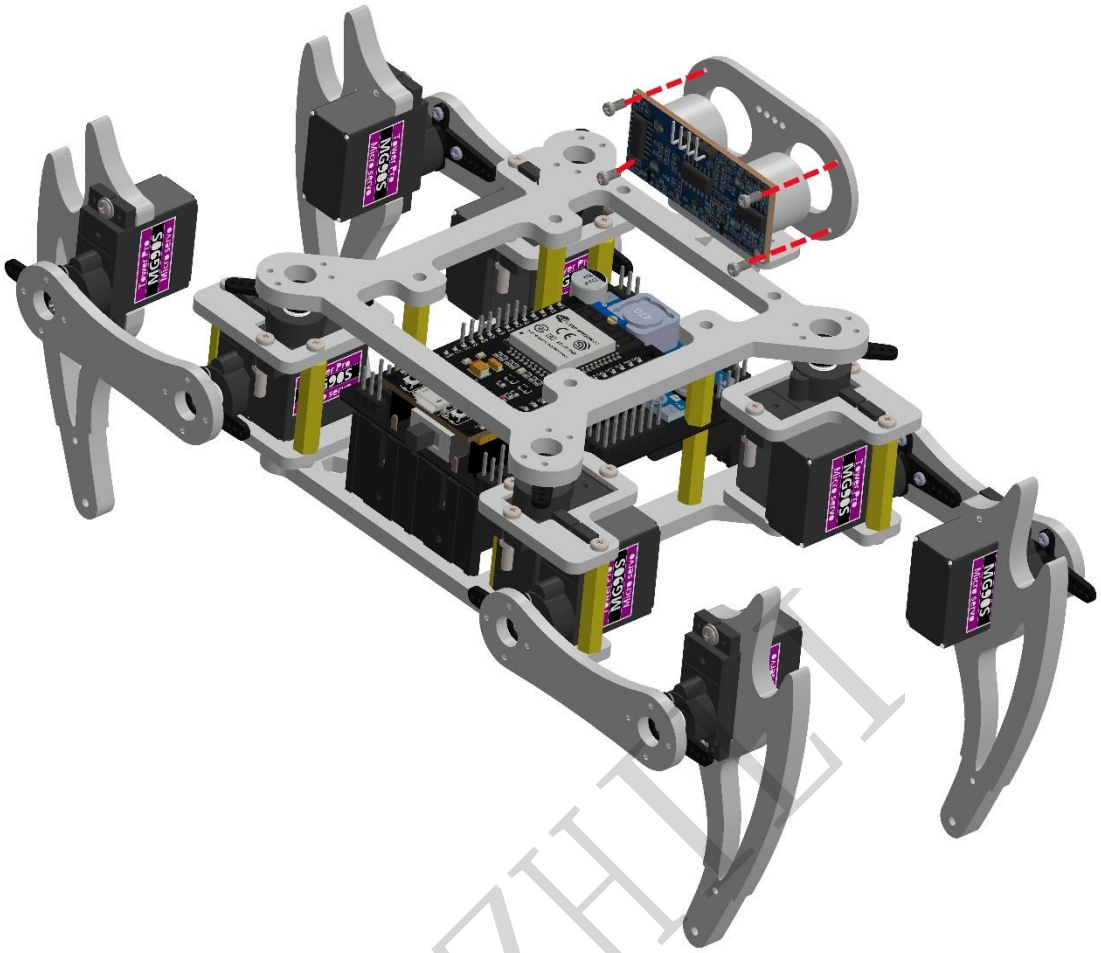


Step 17. Install the ultrasonic module

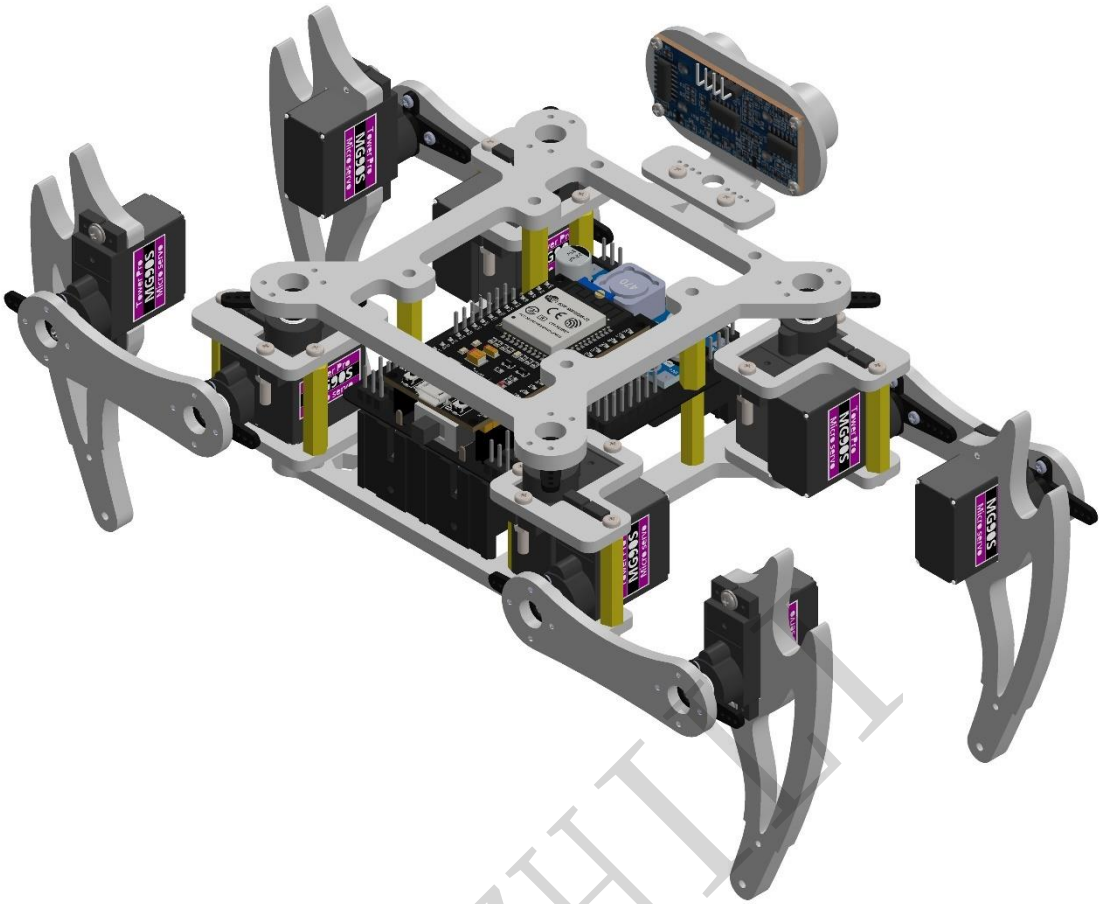
New accessories:

Name	Picture	Quantity
M1.7*5 screw		4
Ultrasonic module		1

Fix the ultrasonic module on the Sonar-Hold with four M1.7 * 5 screws.

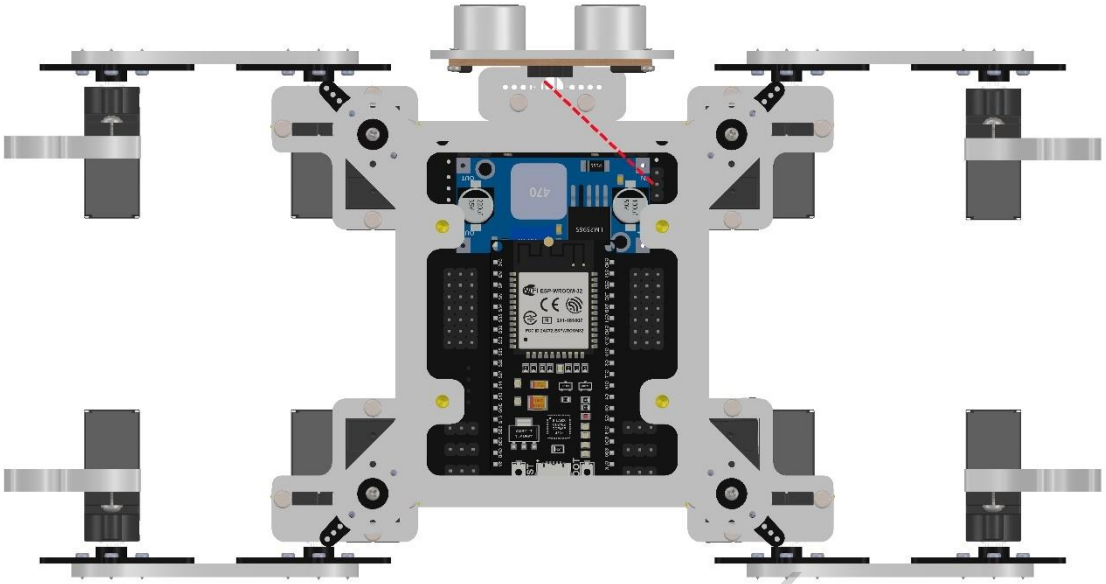


The effect after assembly is shown in the pictur below.



Step 18. Wiring ultrasonic module and servo shield

Connect the ultrasonic module to the interface printed with 23 on the expansion board with wires (the VCC of the ultrasonic module is connected to the 3V3 interface of the expansion board as shown in the figure below, the Trig is connected to the 23 interface, and the GND is connected to the GND interface)

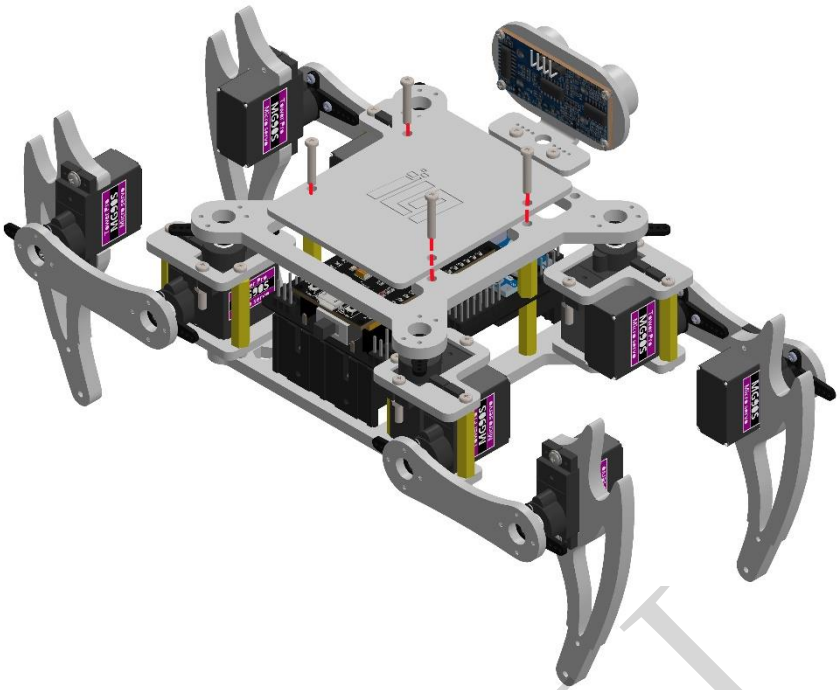


Step 19.Install Cover

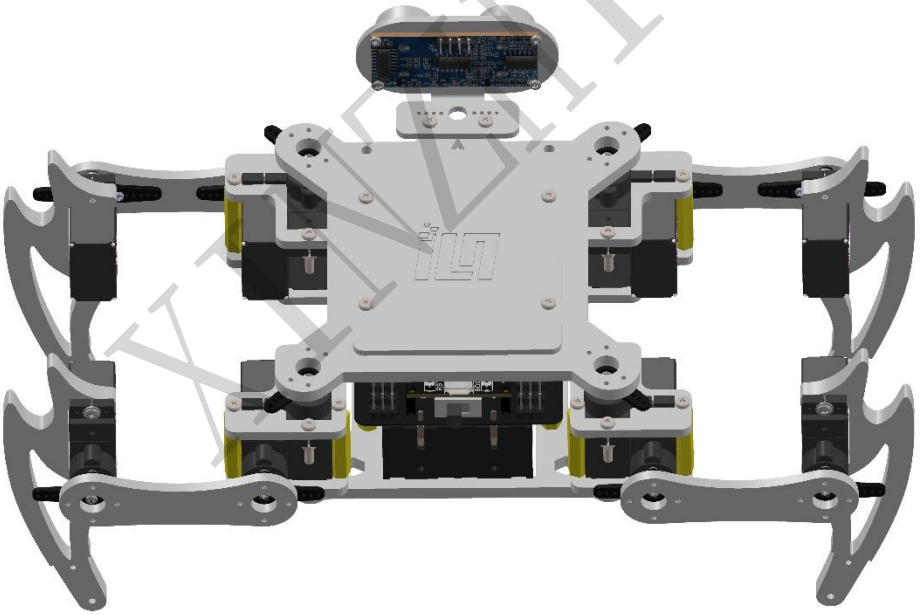
New accessories:

Name	Picture	Quantity
M2.5*10 screw		4

First, arrange the servo cable with a tie (note that the length of the reserved cable should ensure that the four legs can rotate normally!!!!!), and then use four M2.5 * 10 screws to fix the Cover on the Body-Up.



The effect after assembly is shown in the pictur below.



Step 20. Calibration

Step 21. Downloading program

After calibration, locate the data package, double-click to open the "QuadBot_T_ESP.ino" in "03_Tutorial_&_Code → Lesson4 APP Control Robot QuadBot_T_ESP", and download it to the microcontroller. Then open the "Lesson 4 App Control Robot ESP. pdf" under the previous directory, and control the robot according to the tutorial.

3. Core Code Interpretation

3.1. Inverse kinematics

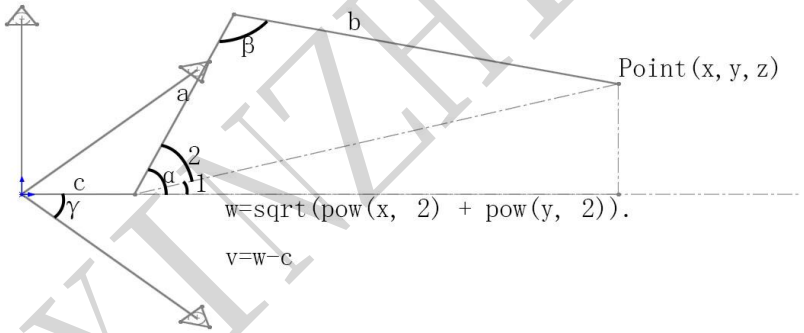
This paper focuses on how to convert the coordinates at the end of each leg to the rotation angle of each steering gear. First check the function void cartesian_to_polar(volatile float &alpha, volatile float &beta, volatile float &gamma, volatile float x, volatile float y, and volatile float z)。

These are the core of quadruped robot code, which converts the leg coordinates into servo rotation angles.
Parameter: alpha, beta, gamma, Store the address of the output angle variable。
Parameter: x,y,z, leg end position coordinates。
cartesian_to_polar
The source code is as follows:


```
/*- trans site from cartesian to polar

- mathematical model 2/2

* ---------------------------------------------------------------------------*/

void cartesian_to_polar(volatile float &alpha, volatile float &beta, volatile float &gamma, volatile float x, volatile float y, volatile float z)
{
    //calculate w-z degree
    float v, w;
```

```
    w = (x >= 0 ? 1 : -1)*(sqrt(pow(x, 2) + pow(y, 2)));
    v = w - length_c;
    alpha = atan2(z, v) + acos((pow(length_a, 2) - pow(length_b, 2) +
    pow(v, 2) + pow(z, 2)) / 2 / length_a / sqrt(pow(v, 2) + pow(z, 2)));
    beta = acos((pow(length_a, 2) + pow(length_b, 2) - pow(v, 2) - pow(z,
    2)) / 2 / length_a / length_b);
    //calculate x-y-z degree
    gamma = (w >= 0) ? atan2(y, x) : atan2(-y, -x);
    //trans degree pi->180
    alpha = alpha / pi * 180;
    beta = beta / pi * 180;
    gamma = gamma / pi * 180;
}
```

First, build a 3D model of a leg. The coordinate direction shall be consistent with that on the calibration map, as shown in the following figure:



Here we only analyze the first quadrant of the leg end: Given end position Point(x,y,z) And side a, b, c (length of each leg), To calculate the servo rotation angle α、β、γ。π/2≤α≤π/2，0≤β≤π，-π/2≤γ≤π/2。In this way, these are transformed into basic mathematical models.

Model proof：

$$w = \sqrt{x^2 + y^2}$$

$$v = w - c$$

According to the cosine law, $\cos\alpha = \frac{b^2 + c^2 - a^2}{2*b*c}$, The result of ∠2 can be calculated。

$$\angle 2 = \arccos\frac{a^2 + (z^2 + v^2) - b^2}{2*a*\sqrt{z + v^2}}$$

$$\therefore \angle\alpha = \angle 1 + \angle 2 = \arctan(z/v) + \arccos\frac{a^2 + (z^2 + v^2) - b^2}{2*a*\sqrt{z + v^2}}$$

code:

```
alpha = atan2(z, v) + acos((pow(length_a, 2) - pow(length_b, 2) + pow(v,

2) + pow(z, 2)) / 2 / length_a / sqrt(pow(v, 2) + pow(z, 2)));
```

Similarly, $\angle\beta = \arccos\frac{a^2 + b^2 - (z^2 + v^2)}{2*a*b}$

code:

```
beta = acos((pow(length_a, 2) + pow(length_b, 2) - pow(v, 2) - pow(z, 2))

/ 2 / length_a / length_b);
```

Similarly, $\angle\gamma = \arctan(y/x)$

code (Only the leg end of the first quadrant is analyzed here):

```
gamma = (w >= 0) ? atan2(y, x) : atan2(-y, -x);
```

So far, all transformations from leg end coordinates to servo rotation angle have been completed.
Each leg has its own coordinate system, which is calculated independently

3.2. Servo_Service function

After function **cartesian_to_polar** is completed in the code, immediately call function **void polar_to_servo(int leg, float alpha, float beta, float gamma)** to adjust the steering gear rotation angle to the set angle. These two functions will be called one by one in 50HZ service function **void server_service(void)**. This is a key function, and you need to pay special attention here.

3.3. Program flow

After understanding the core code and work flow, view the code:

```
/* Installation and Adjustment ------------------------------------------
*/
#define INSTALL //uncomment only this to install the robot
//#define ADJUST //uncomment only this to adjust the servos
//#define VERIFY //uncomment only this to verify the adjustment
```

Uncomment the INSTALL command line and add a for () loop in setup。

```
void setup()
{
```

```
#ifdef INSTALL
//initialize all servos
for (int i = 0; i < 4; i++)
{
    for (int j = 0; j < 3; j++)
    {
        servo[i][j].attach(servo_pin[i][j]);
        delay(100);
    }
}
while (1);
```

Set the axis of each servo at the center position here to minimize the error during installation。