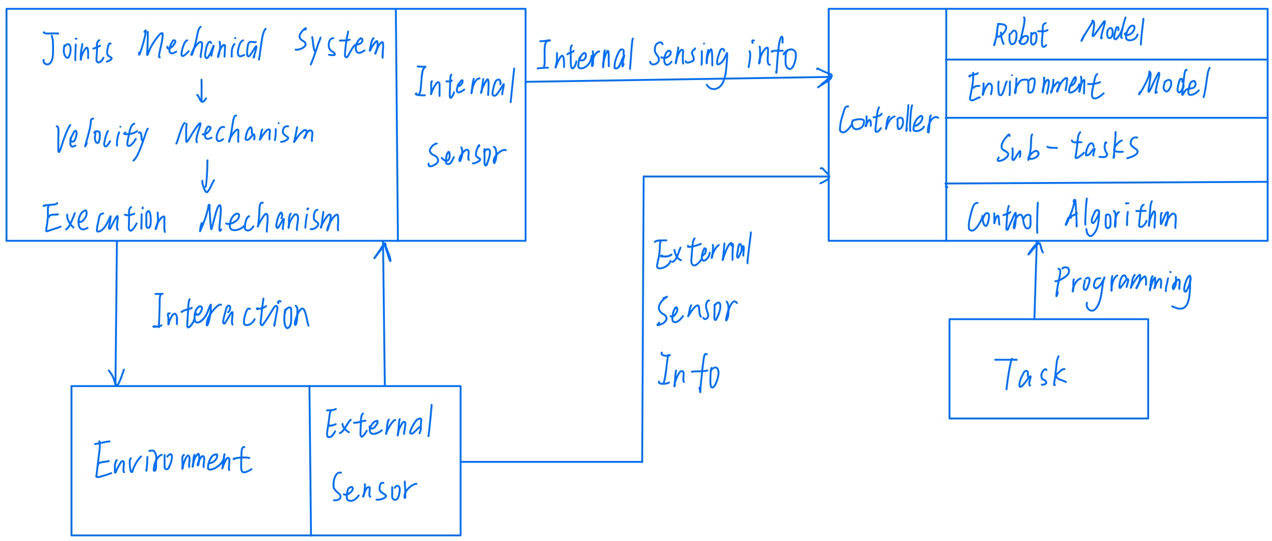
1. What are the characteristics of robot? (5 points)

Movable, Automatic, Programmable

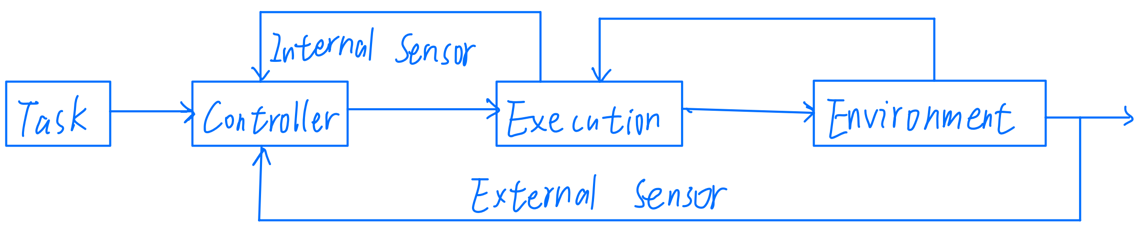
Task-oriented, Intelligent

2. Draw the configuration of robotics system. (5 points)

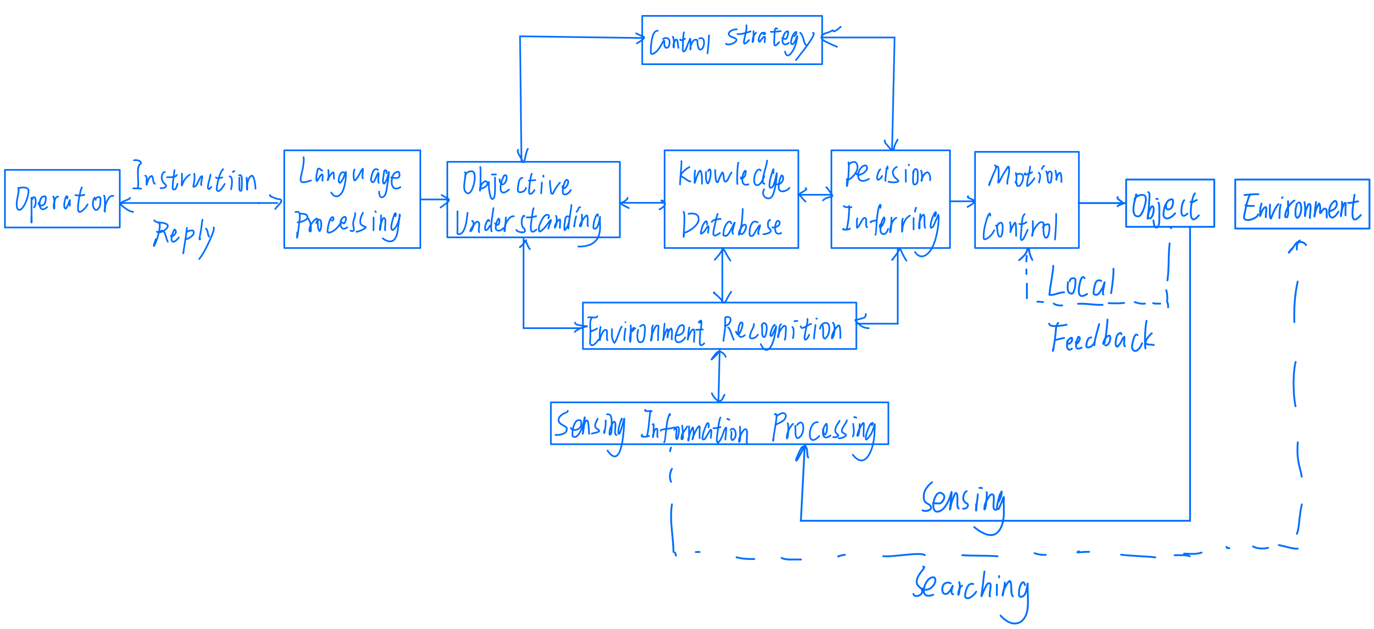
(1)



(2)



3. Draw the System block diagram of Intelligent Robot. (5 points)



4. What is DOF? How many DOFs does a mobile robot moving in a plane have? How many DOFs does an underwater robot have? How many DOFs does a mass point have in 3D space? Specify the translation DOF and rotation DOF respectively for each question. (10 points)

DOF (Degree of Freedoms): Degree of freedom, in a mechanics context, is specifically defined mode in which a mechanical device or system can move. The number of DOF is equal to the total number of independent displacements or aspects of motion.

Mobile robot moving in a plane: 1 rotation DOF, 2 translation DOFs

Underwater robot: 3 rotation DOFs, 3 translation DOFs

Mass point: 0 rotation DOFs, 3 translation DOFs.

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5. What's the categories of articulated robots? What are their features, respectively? (5 points)

(1) Spherical Coordinates Robot: ① Joints 1-5 are on the same plane ② Axes of joints 2-3 are parallel; ③ Axes of joints 4-6 intersects on same point; ④ End-effector's pose is adjusted by the coordinating of the 6 DOFs.

(2) Cylindrical Coordinates Robot: ① All four joint axes are parallel; ② Joint 1-3 can be viewed to be in the same surface; ③ End-effector's orientation and position is weakly correlated; Joint 4 determines the position along Z; Joint 3 determines the orientation; Joint 1 and 2 determines the end-effectors position in X-Y plane.

(3) Cartesian Coordinates Robot: ① Joint axes are orthogonal to each other; ② Different joints are independent.

6. What's the categories of Parallel robots? What are their features, respectively? (5 points)

(1) 2D Parallel Structure: Moving in plane

(2) 3D Parallel Structure: Delta Structure, 4 DOF

① High Motion Velocity, High Positioning Accuracy: Supporting high-speed object picking up in quite limited space; ② Motion platform is parallel to the supporting platform.

(3) 3D Parallel Structure: Stewart Structure, 6 DOF

① High Accuracy, High Stiffness, Heavy Load; ② Limited Motion Range; ③ High Correlation between Position and Orientation.

(4) 3D Parallel Structure: Orthogonal Structure, 6 DOF

① Low correlation between position and orientation; ② Motion range and accuracy depends on chain structure and accuracy; ③ Kinematics and Dynamics is simple.

(5) 3D Parallel Structure: Cable Structure, 6 DOF

① Low cost; ② Large motion range; ③ Difficult on control.

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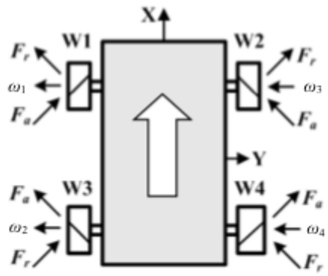
7. Consider a mobile robot equipped with four Mecanum wheels (one kind of Omnidirectional Wheel).
    a. Describe the motion that mobile robot equipped with Mecanum wheels can do but the ordinary mobile robot cannot. (5 points)
    b. How many DOFs of the four Mecanum wheel mobile robot? (5 points)
    c. How to allocate angular velocities ω_1, ω_2, ω_3 and ω_4 of the Mecanum wheels enabling mobile robot has different kinds of motion direction (corresponding to the DOFs of the Mecanum wheel mobile robot), draw a force diagram and indicate the relationship among the angular velocities of the Mecanum wheels. (15 points)

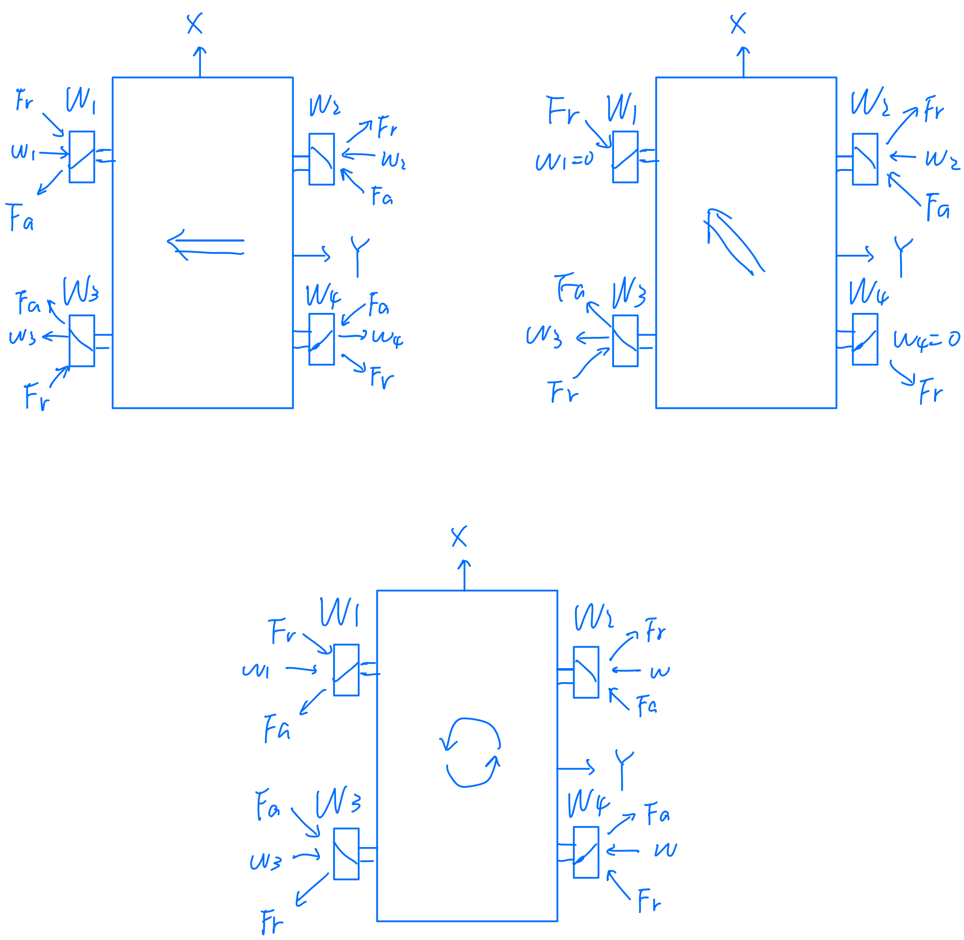


This figure is an example of force diagram. Here, to ensure the robot move along x-axis, angular velocity should satisfied relation $\omega_1 = \omega_3$ and $\omega_2 = \omega_4$.

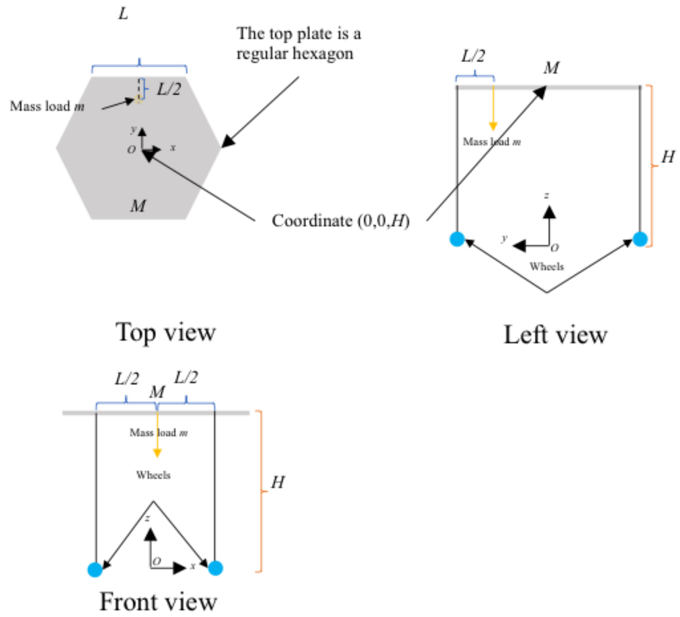
(a.) Longitudinal Motion ; Transverse Motion; In-situ Rotating; Oblique Motion.

(b) 3 DOFs.

(c)



8. Consider a mobile robot equipped with four Mecanum wheels, its geometry is given as follow. Assume its mass is M and distributed uniformly at the top plate. Mass of wheels and legs are ignored.



a. Where is the ZMP? Describe the support polygon in mathematic form. (10 points)

b. What are the largest accelerations of this robot along x-axis and y-axis (including positive and negative directions). (10 points)

c. When the robot moves along y+ direction with acceleration a ~~(it can ensure that a is smaller than maximum acceleration without load)~~, what is the ~~largest~~ minimum mass of load. (The load can be viewed as a mass point. Position of the load is given as follow). (20 points)

a. $\begin{cases} |x| \le \frac{L}{2} \\ |y| \le \frac{\sqrt{3}}{2}L \end{cases}$

b. $(M+m)\,|a_x|\,H = (M+m)\,g\,\frac{L}{2}$ $\quad |a_x| = \frac{gL}{2H}$ $\quad a_{x+} = \frac{gL}{2H}$ $\quad a_{x-} = \frac{-gL}{2H}$

$(M+m)|a_y|H = (M+m)g\frac{\sqrt{3}L}{2}$ $\quad |a_y| = \frac{\sqrt{3}gL}{2H}$ $\quad a_{y+} = \frac{\sqrt{3}gL}{2H}$ $\quad a_{y-} = -\frac{\sqrt{3}gL}{2H}$

c. $aH = \frac{\sqrt{3}}{2}gL + \frac{\frac{\sqrt{3}-1}{2}m}{M+m}gL$

$aH - \frac{\sqrt{3}}{2}gL = \frac{\frac{\sqrt{3}-1}{2}m}{M+m}gL$

$(aH - \frac{\sqrt{3}}{2}gL)M = (\frac{\sqrt{3}-1}{2}L + \frac{\sqrt{3}}{2}gL - aH)\,m$

$m = \frac{aH - \frac{\sqrt{3}}{2}gL}{\frac{\sqrt{3}-1}{2}gL + \frac{\sqrt{3}}{2}gL - aH}M = \frac{aH - \frac{\sqrt{3}}{2}gL}{(\sqrt{3}-\frac{1}{2})gL - aH}M$