II. DEGREES OF FREEDOM

In robotic arms, a 'Degree of Freedom' (DoF) is an independent joint that allows the manipulator to move in either a rotational or translational (linear) direction. In addition, a robot's ability to move along how many independent axes or motions. It stands for the total number of independent parameters that affect how the robot is configured or posed.

Accordingly, to solve a DOF of a specific manipulator the first thing to do is to determine whether it is a spatial with 6 DOF or planar with 3 DOF. The next step is to figure out the number of joints and moving links on the manipulator. After that, the calculation of the number of joint constraints in the given manipulator and determining if it is spatial or planar with the help of Grubler's Criterion. Lastly is to determine the types of manipulator based on the number of degrees of freedom.

Grubler's Criterion	
Mobility/DOF of Planar Manipulator	**Mobility/DOF of Planar Manipulator**
Ci: Connectivity of i-th joint; i = 1, 2, 3, ...,m No. of constraints put by i-th joint = (6-*Ci*) Total no. of constraints =Σm i =1 (6-*Ci*) Mobility of the manipulator or M = 6n - =Σm i =1 (6-*Ci*) It is known as Grubler's criterion.	*Ci:* Connectivity of i-th joint; i = 1, 2, 3, ...,m No. of constraints put by i-th joint = (3-*Ci*) Total no. of constraints =Σm i =1 (3-*Ci*) Mobility of the manipulator or M = 3n - Σm i =1 (3-*Ci*) It is known as Grubler's criterion.

Types of Manipulator based on the Number of Degrees of Freedom

- **Under-actuated Manipulator**
  Either a Spatial Manipulator w/less than 6-DOF or a Planar Manipulator w/less than 3-DOF.
- **Ideal Manipulator**
  Either a Spatial Manipulator w exactly 6-DOF or a Planar Manipulator w/exactly 3-DOF.
- **Redundant Manipulator**
  Either a Spatial Manipulator w/more than 6-DOF or a Planar Manipulator w/more than 3-DOF.

Calculating the DOF of an articulated manipulator allows you to grasp its capabilities and limitations, enabling you to design, program, and control these remarkable machines effectively. An articulated manipulator, often referred to as a robotic arm, consists of interconnected links and joints that mimic the movement capabilities of a human arm. Each joint provides a rotational or translational degree of freedom, allowing the manipulator to perform intricate tasks with remarkable dexterity. By calculating the DOF, we can quantitatively determine the range of motions and positions that the manipulator can achieve. The Articulated Manipulator has a total of 3 degrees of

freedom that consist of 3 revolute joints also referred to as RRR (REVOLUTE REVOLUTE REVOLUTE).

Degrees of Freedom Calculation

Spatial Manipulator

$M = 6n - \sum_{i=1}^{m} (6-Ci)$

$M = 6(3) - [(6-1)+ (6-1)+ (6-1)]$

$M = 6(3) - (5+5+5)$

$M = 18 - 15$

$M = 3$

m = 3
n = 1
$\mathbf{C_r}$ = 1

∴ This is an under actuated spatial manipulator with 3-DOF.

Supplementary Video about the Degrees of Freedom

To further understand how to get the Degrees of Freedom of an Articulated Manipulator, here is a supplementary video explaining how to get it.

(**https://drive.google.com/file/d/13NccGlxma1fw7g3MDnbqmGmPHvtEQ4wS/view?usp=sharing)**