Robotics Formulas

- Grippers

① Mechanical

$$F_g = \frac{mg\sin\theta}{\mu n} = \frac{m(a+g)}{\mu n}$$

a → velocity

m = mass g = acceleration due to gravity = 9.8
μ = Friction coefficient θ = angle
n = no. of pairs of contact surfaces.

② Vacuum Gripper

$$\text{Area} = \frac{\text{Weight}}{\delta p \times FS \times N}$$

δp → Pressure difference
FS → safety factor
N → No. of caps

③ Magnetic Gripper

$$P = \frac{(IN)^2}{25 A_c (R_a + R_m)}$$

- Sensors

$S = f(s)$ S = O/P signal s = stimulus
$S = C + ms$ m = proportionality constant
C = O/p value of stimulus at 0.

- Actuators

① Stepper Motor

Step angle = $\alpha = 360/n_s$ n_s = no. of steps
Total angle = $A_m = n_p \alpha$ n_p = no. of pulses
Angular velocity = $\omega = \frac{2\pi f_p}{n_s}$ f_p = pulse frequency

Speed of rotation = $N = \frac{60 f_p}{n_s}$

- Blending $\Rightarrow t_b = \dfrac{+aT \pm \sqrt{a^2T^2 - 4a(\theta_f - \theta_0)}}{2a}$

$$2\theta_b = 2\theta_0 + a t_b^2 \qquad 2\theta_h = \theta_f + \theta_0$$

- ADC

① Quantisation Levels $= N_q = 2^n$, n = No. of bits

② Resolution $= R_{ADC} = \dfrac{L}{N_q - 1} = \dfrac{L}{2^n - 1}$ | L = length of full scale.

③ $Quan_{error} = \pm\frac{1}{2}(R_{ADC})$

- DAC

$E_0 = E_{ref}\{0.5B_1 + 0.25B_2 + \ldots + (2^n)^{-1} B_n\}$

- Image Processing

① Area $= M_{0'0'} = \sum_{x',y'} x'y'$ = Count all 1's

② Minimum aspect ratio $= \dfrac{\text{Length}}{\text{Width}}$ | (x-axis) (y-axis)

③ Perimeter = Count edges.

④ Compactness = $(\text{Perimeter})^2$ / Area

⑤ Thinness = Diameter / Area

- Trajectory planning

① Cubic polynomial fit

ⓐ $\theta(t) = a_0 + a_1 t + a_2 t^2 + a_3 t^3 \rightarrow$ Position

$\theta'(t) \rightarrow$ ~~Position~~ Velocity $\theta'' =$ acceleration

$a_0 = \theta_0 \quad a_1 = 0 \quad a_2 = \dfrac{3(\theta_f - \theta_0)}{t_f^2} \quad a_3 = \dfrac{-2(\theta_f - \theta_0)}{t_f^3}$

ⓑ $(t_0 \text{ to } t_v)\ (t_v \text{ to } t_f)$

$$\theta(t) = \theta_v = a_0 + a_1 t_1 + a_2 t_1^2 + a_3 t_1^3$$

$$\theta(T) = \theta_f = b_0 + b_1 t_2 + b_2 t_2^2 + b_3 t_2^3$$

$a_0 = \theta_0 \quad a_1 = 0 \quad a_2 = \dfrac{(12\theta_v - 3\theta_f - 9\theta_0)}{4t_1^2} \quad a_3 = \dfrac{(-8\theta_v + 3\theta_f + 5\theta_0)}{4t_1^3}$

$b_0 = \theta_v \quad b_1 = \dfrac{(3\theta_f - 3\theta_0)}{4t_1} \quad b_2 = \dfrac{(-12\theta_v + 6\theta_f + 6\theta_0)}{4t_1^2}$

$b_3 = \dfrac{(8\theta_v - 5\theta_f - 3\theta_0)}{4t_1^3}$

- Robot Classification : PWDKTM

① Power Supply
- Electrical
- Phematic
- Hydraulic
- Non-convenetional

② ~~Workspace Geometry~~ DOF
- Planar
- Spatial
- 6-DOF
- Redundant Robots
- Limited DOF

③ Workspace Geometry
- Cartesian Co-ordinate Configuration [PPP]
- Cylindrical [RPP]
- Spherical [RRP] [Polar
- Articulated Arm

④ Kinematic
- Open Loop - Serial robot
- Closed Loop - Parallel robot
- Hybrid or tree type structure
- Anthropomorphic robots

⑤ Type of Applications

⑥ Movement
- Fixed
- Mobile
- Swimming and underwater
- Aerial or Flying

Date / /

- Classification by JIRA
  Class 1 – Manual Handling Device
  Class 2 - Fixed sequence robot
  Class 3 - Variable sequence robot
  Class 4 - Playback robot.
  Class 5 - Numerical Control Robot
  Class 6 - Intelligent Robot.

- Classification by AFR

Type A - Telerobotic	Class 1
Type B - Sequencing	Class 2-4
Type C - CNC	Class 5
Type D - Intelligent	Class 6

- Characteristics of robots
  Size of class
  DOF
  Velocity — Speed, Movement
  Actuator Type
  Yaw, Pitch, Roll
  Repeatability — Precision, Accuracy
  Weight.

- Robot selection (WALD
  ① Control system to be adopted
  ② Work volume
  ③ Accuracy and repeatability.
  ④ Load-carrying capacity
  ⑤ Degrees of Freedom

Page No.
Date

- Power Sources
  1. Electrical Drive
  2. Hydraulic Drive
  3. Pneumatic Drive

- Joints
  1. Rotational movement Joint
  2. Radial movement Joint
  3. Revolving Movement Joint
  4. Twisting Joint

  1. Rotational movement
  2. Radial
  3. Vertical

- Classification based on Control system
  1. Point-to-Point control robot
  2. Continuous-path (CP) control robot
  3. Controlled path robot.

- End effectors
  1. Grippers - Grasp and manipulate objects
  2. Other tools - To perform process

- Grippers
  1. Mechanical Gripper
     - Linkage Actuation
     - Gear and rack Actuation
     - Cam Actuation
  2. Magnetic
  3. Vacuum
  4. Adhesive
  5. Miscellaneous Devices

Date / /

- Compliance
  - Active
  - Passive

- Selection of Gripper PPPSCW
  1. Part of surface to be grasped
  2. Power
  3. Physical constraints
  4. Size variation
  5. Change in shape that occur between loading and unloading
  6. Weight of object.

- Robot Anatomy TECHROG
  1. Teach Pendant for programming
  2. End-effector Tool
  3. Connecting Cable
  4. Hardware and software controller
  5. Robot Manipulator
  6. Optional accessories
  7. GUI and I/Os.

Page No.
Date

(6) Sensors

- Physical Medium $\xrightarrow{\text{stimulus}}$ Sensing Element → Conditioning → Target Handling → signal(s)

- Sensors are transducers that convert a physical stimulus from one form into a more useful form to measure stimulus.
  Two categories
  1. Analog
  2. ~~Digital~~ Discrete → (a) Binary (b) Digital.

- Actuator is a hardware device that convert a controller command signal into change in physical parameter.
  Types:
  1. Hydraulic Actuators : Hydraulic Fluid
  2. Pnematic Actuators : Compressed air
  3. Electrical Actuators
     - (a) Electrical Motors
       - i) DC servomotor
       - ii) AC motors
       - iii) Stepper motors
     - (b) Selenoids

- Analog-to-Digital Conversion
  1. Sampling continuous to discrete analog signal
  2. [Quantizing] Quantization each discrete signal into one finite no. of discrete amplitude level
  3. Encoding discrete amplitude level converted into digital code

Features:
1. Sampling rate
2. Quantization
3. Resolution
4. Conversion Time
5. Conversion method. (Ex. Successive Approximation Method)

- Features of Sensors APOSCRC
  1. Accuracy
  2. Precision
  3. Operating Range
  4. Speed of response
  5. Calibration
  6. Reliability
  7. Cost and ease of operation.

- Sensor classification
  1. Tactile
  2. Proximity and range sensors.
  3. Miscellaneous
  4. Machine Vision system

- Kinematics (x, y, z) (n, o, a)

$$Rot(x, \theta) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\theta & -\sin\theta \\ 0 & \sin\theta & \cos\theta \end{bmatrix}$$

$$Trans = \begin{bmatrix} 1 & 0 & 0 & d_x \\ 0 & 1 & 0 & d_y \\ 0 & 0 & 1 & d_z \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$Rot(y, \theta) = \begin{bmatrix} \cos\theta & 0 & \sin\theta \\ 0 & 1 & 0 \\ -\sin\theta & 0 & \cos\theta \end{bmatrix}$$

$$Rot(z, \theta) = \begin{bmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

current and moving → Post Multiply
reference and fixed → Pre Multiply.

$$\begin{bmatrix} n_x & o_x & a_x & p_x \\ n_y & o_y & a_y & p_y \\ n_z & o_z & a_z & p_z \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Page No.
Date

$\bar{n}\cdot\bar{o} = \bar{n}\cdot\bar{a} = \bar{a}\cdot\bar{o} = 0$ → Multiply corr. values of columns

$|\bar{n}| = |\bar{a}| = |\bar{o}| = 1$ → $n_x^2 + n_y^2 + n_z^2 = 1$

$$A = \sqrt{P_x^2 + P_y^2 + P_z^2} \qquad \bar{P} = \begin{bmatrix} a \\ b \\ c \\ 0 \end{bmatrix}$$

$$P_x = \frac{a}{A} \qquad P_y = \frac{y}{A} \qquad P_z = \frac{z}{A}$$

- Robot Economics

$$y = \frac{(P+A+I)-C}{(L+M-O)H(1-TR)+D(TR)} = \frac{(A+P+I)-C}{(M+L-O)H(1-TR)+D(TR)}$$

$$D = \frac{[(P+A+I)-S]}{\text{tax life yrs.}}$$ → Salvage Value

$$ROI = \frac{\text{total annual saving}}{\text{total investment}} \times 100\%$$

$$= \frac{(L+M-O)H - D\cancel{TR}}{(P+A+I)-C}$$

- Dynamic Properties of Robots : SC SCAR

① Stability
② Control resolution : Smallest increment of motion
③ Spatial resolution : Control resolution + mechanical ina
④ Compliance
⑤ Accuracy
⑥ Repeatability

```
PROGRAM PALLETIZE
DEFINE PICKUP = JOINTS(1,2,3,4,5)
DEFINE CORNER = JOINTS(1,2,3,4,5)
DEFINE DROP = CO-ORDINATES (X,Y)
OPENI
5 SIGNAL 1
WAIT 11
CALL PALLET(MAXCOL=6, MAXROW=4, XSPACE=40, YSPACE=50)
SIGNAL 2
WAIT 12
GOTO 5
END PROGRAM

SUBROUTINE PALLET(MAXCOL, MAXROW, XSPACE, YSPACE)
ROW=0
10 Y=ROW * YSPACE
COLUMN=0
20 X= COLUMN * XSPACE
DROP = CORNER+<X,Y>

APPRO PICKUP,50
MOVES PICKUP
CLOSEI
DEPART 50
APPROS DROP,50
MOVES DROP
OPENI
DEPART 50
COLUMN = COLUMN+1
IF COLUMN LT MAXCOL GOTO 20
ROW= ROW+1
IF ROW LT MAXROW GOTO 10
END SUB ROUTINE
```