Robot Languages and Programming

- WAVE and AL

-Trajectory calculations

AL has a source language, a translator to generate runnable code and a run time system for effecting various motions of the robot manipulator.

- Syntax of language can implement various subroutines, involving activities between robot and a run time system for effecting various statements concerning SIGNALS and WAFT to carry on tasks in sequence.

- Robot Language VAL
- AML Manufacturing Language
- MCL- Manufacturing control language
- RAIL-
- HELP
- JARS
- RPL
- AUTOPASS

- Classification of Robot languages

① First Generation Language

Provides an off-line programming in combination with the programming through robot pendant teaching.
Capability limited to handling of sensory data.
Branching, I/O interfacing, opening/closing of end-effectors.
Ex. VAL

② Second Generation Language

Structured programming language performing complex tasks. For. ex. AML, RAIL, MCL, VAL II, etc.
Complex motions can be generated. Handle both digital and analog besides binary signal. Recover event of malfunction.

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③ World modelling and task-oriented object level language.
Task is defined through a command.
Three dimensional model.

- Computer Control and Robot Software.
① Monitor mode
② Run mode / Execute
③ Editor Mode.

- VAL
- User VAL Programs
- Contains editor
- Record
- Include subroutine.
Each subroutine can call other subroutines with up to ten such levels possible.
- Once loaded in VAL system, execute any no. of times

- Locations
Refers to data that represents position and orientation of robot tool [end point]
Ways of representing robot locations:-
① Position of individual joints. Precision Point
② Cartesian Co-ordinates (x,y,z) & orientation angle of robot tool relative to a reference frame fixed in robot base. Transformations.

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- Trajectory Control
2 ways to control path from one location to another.
① Interpolate bet^n initial & final ~~joint~~ position of each joint, producing a complicated tool-tip curve in space.
② Move the line instruction is a complete statement. Sequential until return or Jump identified by level.

- Monitor Commands → To enter and execute a program.
VAL command categories:-
① Defining and determining locations
② Editing Programs
③ listing program and location data.
④ Storing and retrieving prgm. and location data.
⑤ Program Control.

VAL II
STORE, COPY, LOAD, FLIST, RENAME, DELETE

DO command causes robot to execute a specified programming instruction.
DO (instruction)

- Determining and defining ~~locat~~ Locations
HERE and POINT command
Current location can be displayed using WHERE comman
TEACH command records a series of location values under the control of RECORD button on manual control un

POINT PART = P1

Motion path is taught by command ~~T~~ TEACH.
TEACH P1

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- VAL-II

All distance and co-ordinate values are in mm.

① HERE P1

② WHERE → display current location of robots in Cartesian world co-ordinates. Current gripper opening

③ The TEACH command is used to record a series of location values under the control of record button on tech pedant.

④ POINT PA = P1

- Motion Control

① MOVE → Moves robot to specified location.

② MOVES → Moves robot in straight line path.

③ DRAW → Moves in straight line through specified dist in x, y, z dir

④ APPRO → Moves to location which is at an offset from specified point (Z axis)

⑤ DEPART → Move tool along the current tool Z-axis.

⑥ CIRCLE → Moves robot through circular interpolation via 3 specified point locations.

MOVE P1 → Move by a join-interpolated motion to point P1.

MOVES P1

DEPART P1, 50

SPEED 60
SPEED 15 IPS
→ 100 = normal, 12800 = very fast

SPEED 30 MMPS

DRIVE 4, -6.25, 75 → speed % of monitor

4 → Joint 4

-6.25 → drive it in 6.25 in -ve dir.

ALIGN → Tool to be rotated so that its z axis is aligned parallel to nearest axis of world co-ordinate system.

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- Hand Control

OPEN and CLOSE, indicate respectively the opening and closing of gripper during next instruction.
OPENI and CLOSEI, immediately.
~~to~~
CLOSEI 75 → Cause Gripper to close immediately to 75 mm.
GRASP 20, 15 → Immediate check whether the opening is less than 20 mm, yes branches to statement 15.

MOVEST PART, 30
→ Move in straight ligne motion to a point defined by PART and gripper opening of 30 mm.

MOVET PART, 30
→ Cause gripper to move to position, PART with opening of 30 mm by joint-interpolated motion.

- Editing Programs

① LISTF → Displays the file directory.
② STORE P (Program) — STOREL (Location) — STORE (Both)
③ LOADP — LOADL — LOAD

VALII ① FLIST → file kept on disk
Both ② COPY, RENAME, DELETE

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- Robot Configuration Control

RIGHTY or LEFTY

ABOVE or BELOW, makes elbow of robot to point up or down resp.

- Program Control

1. SETI
2. TYPEI → display name and value to integer var.
3. PROMPT "Enter Value:"; Y1
4. GOSUB
5. RETURN
6. IF-THEN
7. PAUSE
8. PROCEED
9. SIGNAL
10. RESET
11. SIGNAL 2,-3 → O/P signal 2 (+ve) is to be turned ON and O/P signal 3 (-ve) is to be turned OFF
12. WAIT SIG(-1,2) → Wait until external I/P signal is turned OFF and 2 is turned ON.

13. MAXCOL → no. of cols on pallet
14. MAXROW
15. YSPACE → Space between rows
16. XSPACE → Space betn cols.

- REACT-VAR 2, SUB TRAY
- REACTI → interrupts robot motion immediately.

VALI IOPUT IOGET

- Welding Instructions
WSET instructions set the speed, welding voltage and current as a welding condition identified by no. 1-4.
WSET 1=13, 54.3, 63 → current = 63%.
speed 13mm/s & voltage = 54.3%

WVSET 1 = 10 7 2 0 1 3 0
cycle distance; amplitude; right end stop dist.; right end stop time; center stop distance; left end stop dist; left end stop time

- WSTART
WEND → Inactivates a welding start signal
CRATERFILL → When cater filler is req. at a welding end.

- Joint-Level Programming
  Robot-level Programming
  High-level Programming
  - Object-level , task-level

- On line
  ① Teach Pendant
  ② Lead through Programming
- Off line
  ① Robot Programming language
  ② task level programming
- Combination Programming

- Co-ordinate Systems
  ① World co-ordinate system
  ② Tool co-ordinate system

• Trajectory Planning for Robotics

① Cubic Polynomial fit

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

$\theta(t)|_{t=0} = \theta_0$ $\theta(t)|_{t=t_f} = \theta_f$; $\theta_0, \theta_f, t_f \Rightarrow$ given

$t=0$, $a_0 = \theta_0$

$$\theta'(t) = a_1 + 2a_2 t + 3a_3 t^2$$

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

Ex① $\theta_0 = 15^\circ$ $\theta_f = 75^\circ$ $t_f = 3.0s$

$a_0 = 15$ $a_1 = 0$ $a_2 = 20$ $a_3 = -4.44$

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

$= 15 + 20t^2 + (-4.44)t^3$

$\theta(t) = 15 + 20t^2 - 4.44t^3$ → Position

$\theta'(t) = 20 \times 2t - 4.44 \times 3t^2$ → Velocity

$= 40t - 13.32t^2$

$\theta''(t) = 40 - 26.64t$ → Acceleration

② $\theta_0 = 20^\circ$ $\theta_f = 80^\circ$ $t_f = 4$

$a_0 = \theta_0 = 20^\circ$

$a_1 = 0$

$a_2 = \dfrac{3(\theta_f - \theta_0)}{t_f^2} = \dfrac{3(60)}{16} = 11.25$

$a_3 = \dfrac{-2(\theta_f - \theta_0)}{t_f^3} = \dfrac{-2(60)}{4^3} = -1.875$

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

$= 20 + 11.25(t)^2 + (-1.875)t^3$

- Cubic Polynomials with via Points

2 intervals $(t_0$ to $t_v)$ and $(t_v$ to $t_f)$
$t_v = (t_f + t_0)/2$: by convention: $t_0 = 0$.

First curve: $\theta(t) = a_0 + a_1 t + a_2 t^2 + a_3 t^3$
2nd curve: $\theta(t) = b_0 + b_1 t + b_2 t^2 + b_3 t^3$

$\theta_v = a_0 + a_1 t_1 + a_2 t_1^2 + a_3 t_1^3$
$\theta_f = b_0 + b_1 t_2 + b_2 t_2^2 + b_3 t_2^3$

Differentiating first curve
$\theta'(t) = a_1 + 2a_2 t + 3a_3 t^2$
$0 = b_1 + 2b_2 t_2 + 3b_3 t_2^2$

$a_0 = \theta_0$	$b_0 = \theta_v$
$a_1 = 0$	$b_1 = (3\theta_f - 3\theta_0)/4t_1$
$a_2 = \dfrac{(12\theta_v - 3\theta_f - 9\theta_0)}{4t_1^2}$	$b_2 = \dfrac{(-12\theta_v + 6\theta_f + 6\theta_0)}{4t_1^2}$
$a_3 = \dfrac{(-8\theta_v + 3\theta_f + 5\theta_0)}{4t_1^3}$	$b_3 = \dfrac{(8\theta_v - 5\theta_f - 3\theta_0)}{(4t_1^3)}$

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- Bending Scheme

$t_b = 0$ $t_f = T$ $t_h = t_f/2$ t_b= blending time

a= const. initial and final acceleration.

$\theta'(t) = at$ $\theta'(t_b) = at_b$

$\theta(t) = \theta_0 + \frac{1}{2}at^2$ $\theta(t_b) = \theta_0 + \frac{1}{2}at_b^2$

$$at_b = \frac{(\theta_h - \theta_b)}{(t_h - t_b)}$$

$t_h = T/2$ $2\theta_h = \theta_0 + \theta_f$

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

Example-2 ⇒ angular acceleration = $40°/s^2$ = a

$\theta_f = 75°$, $\theta_0 = 15°$ Let $t_f = 3$

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

$$= \frac{+(40 \times 3) \pm \sqrt{(40)^2(3)^2 - 4(75-15)}}{(2 \times 40)}$$

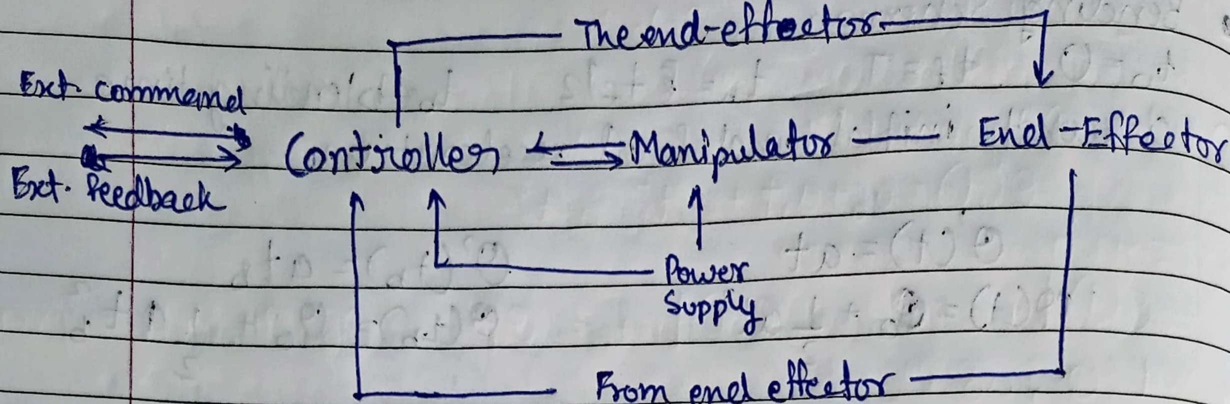
$= \underline{\underline{0.6325}}$

A $t = t_b$, $(40 \times 0.6325) = 25.4°/s$

$2\theta_b = 2\theta_0 + at_b^2$ ⇒ Main

$\theta_b = \frac{2\theta_0 + at_b^2}{2} = \frac{30 + 40 \times 0.6325^2}{2} = \underline{23°}$

Automation & Robot Economics



- International Standard Organization

- Automation
  ① Fixed - Used for high production volume and utilizes expensive special equipment to process only one product
  ② Flexible automation - Uses for medium production volume and utilizes a central computer to control the process of different products at the same time
  ③ Programmable automation -
  Low production volume.
  Processes one batch of similar products at a time
  One batch is completed, the equipment is reprogrammed to process the next batch

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

L = Hourly cost of labour including fringe benefits
M = Hourly saving in cost of material.
O = Cost of running and Maintaining robot sys.
H = no. of hours per year per shift.
D = Annual depreciation.
TR = Corporate tax rate.

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Y = No. of years to breakeven. [Payback Period]
P = Price of robot.
A = Cost of tooling and fixturing.
I = Installation cost
C = Investment tax credit

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

(2) $ROI = \dfrac{(L+M-O)H-D}{(P+A+I)-C} \times 100\% = \dfrac{\text{total annual saving}}{\text{total investment}}$

Ex
$P = 28,50,000$
$A = 15,00,000$
$L = 850$
$O = 300$
$D = \dfrac{50,00,000-5,00,000}{8}$
$= 5262500$ Rs/yr.

$I = 7,50,000$
$C = 5,00,000$
$M = 50$
$H = 2000$
$TR = 40\% = 0.4$

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

$= \dfrac{(2850000+750000+1500000)-500000}{(850+50-300)2000(0.6)+5262500\times 0.4}$

$= \dfrac{4600000}{600\times2000\times0.6+2105000} = \dfrac{4600000}{720000+2105000}$

$= \dfrac{4600000}{2825000} = 1.62$ yrs.