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PROGRAMMING A SCARA ROBOT FOR A

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Currently I am working on my masters degree in Purdue University Calumet. My major is Mechatronics. I had worked in some machine assembling & manufacturing company for industrial automation. In Purdue, I worked with Scara robot in lab for a project, from there I gain some knowledge in programming Scara robot. This is my first publication.

EDUCATION M.S. Engineering Technology, Purdue University Calumet , (currently working) B.S Electrical & Electronic Engineering , CUET , Bangladesh, August 2010

Ms. Mafruha Jahan

PROGRAMMING A SCARA ROBOT FOR A MANUFACTURING CELL TO ASSEMBLE AND PRODUCE MEDICAL DEVICES

Abstract:

This research paper focuses on a single cell manufacturing machine setup that can be programmed according to requirements to perform certain processing functions. Manufacturing cell operation depends on parts to be assembled. The Primary target of this manufacturing cell is to glue three parts together to produce a small medical device with limited human intervention. There are three different trajectory actions required to completely assemble the part. This research paper talks about how to program a low-cost Scara robot for the manufacturing cell which performs multiple sequential operations to produce the device.

First operation is to glue part “A” and part “B” together to produce a part ‘AB”. The second operation is the glue drying time of part “AB”. The third operation is to glue part “C” to part “AB”. The forth operation is to dry part “ABC”. Since there is a minimum robot trajectory activity during the glue drying process, a buffer of part “AB” is created to utilize that time. By utilizing the glue drying time the buffered part “AB” gets ready for the third operation. This means that as soon as the buffer part “AB” has been dried, the robot performs its third operation that is joining the part “C” with the dried buffer part “AB”. Then the robot performs again its 1st and 3rd operation sequentially. Although, a minimum robot trajectory activity is required during the fourth operation of glue drying of part “ABC, nevertheless it is a required step for the complete part assembly. In this way the process is maximizing its throughput and minimizing the production cycle time.

For multiple part-type operation in this single-machine cell, we provide an efficient algorithm that simultaneously optimizes the robot movement and part sequencing operation. The result of this research paper is promising for creating small and compact manufacturing cells.

INTRODUCTION

Scara are generally are the first choice of manufacturers because of their speed, ruggedness, price and durability. Scara's are ideal for a variety of general-purpose applications requiring fast, repeatable and articulate point to point movements such as palletizing, depalletizing, machine loading, unloading and assembly. Due to their 'elbow' motions, scara robots are also used for applications requiring constant acceleration through circular motions like dispensing. [1]

This paper considers the scheduling of operations in a single manufacturing cell that repetitively produces a family of similar parts. We provided a sequential scheme for performing certain jobs through programming. The single manufacturing cell can perform several operations and can be interfaced with windows based programming software tools by which we can easily teach the robot. In this paper we explained how a single cell manufacturing machine can be programmed according to job requirements to perform certain processing stages that depend upon the parts being manufactured. Without being involved with the complicated robot programming language this software tool allows for quick and easy teaching whatever our application may be. Figure 1 represents a typical Tracheostomy device to be assembled.

Figure 1: Tracheostomy Device [2]

DESCRIPTION OF PARTS AND THEIR ASSEMBLY PROCESS

At the beginning of the process Two Parts "A" & "B" will come under the robot through two conveyor belts. The arm will first put measured amount glue on part "A" from liquid dispenser valve. At the same time "B" will come through the second conveyer belt and robot will pick up "B" to join together with "A" which is the first operation. Figure 2 shows three different parts to be assembled. Figure 3 shows scara robot, conveyor, and parts arrangement inside the manufacturing cell.

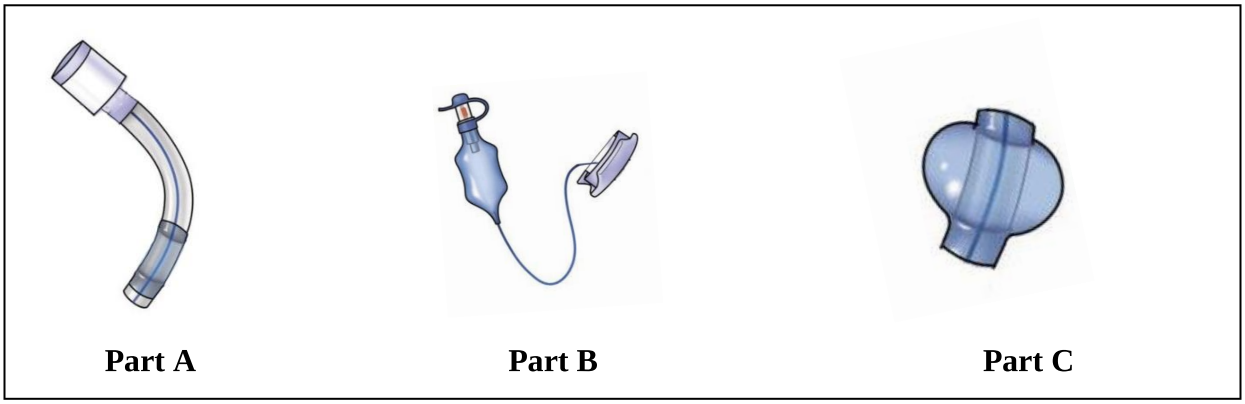


Figure 2: Three Different Parts to be Assembled

Figure 3: Arrangement inside the Manufacturing Cell

As mentioned earlier second operation is the glue drying time. That's why, at first the robot will do 1st operation 5 times and keep the joined part, “AB”, together on the 2nd conveyor for a while as it takes times to dry up part “AB”. If it takes 10 second to join part “A” with part ”B”, then it takes 50 seconds to complete the 5 joined products “AB”. Which is more than the ***glue drying***

time for a single joined product (assume glue drying time is 20 seconds). Figure 4 shows the 1st assembly operation.

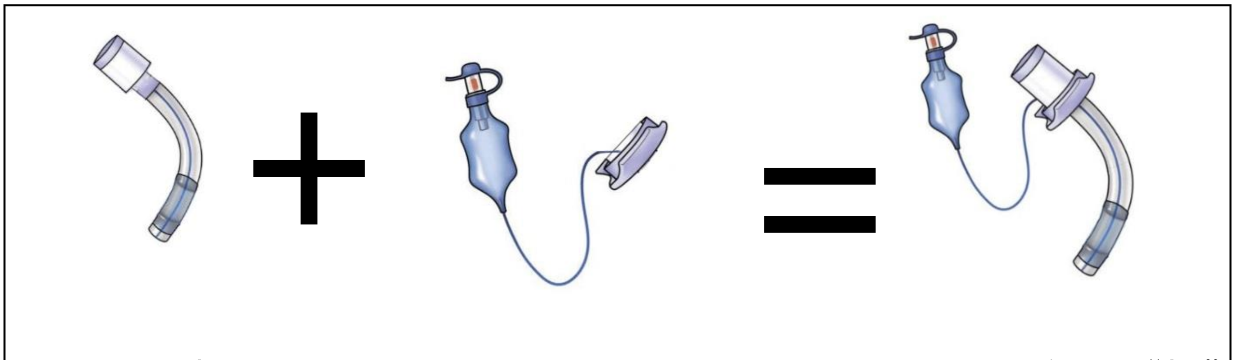


Figure 4: 1st Operation

Now we have 5 joined products "AB" ready for next operation. We consider this as a buffer product and from now on, robot will try to maintain 5 joined product "AB" on the 2nd conveyor. When the 5th joined product "AB" is ready (product "AB" is ready means completely dry) the part "C" will come on the 3rd conveyer belt. Figure 5 shows movement of parts on the three conveyor belts.

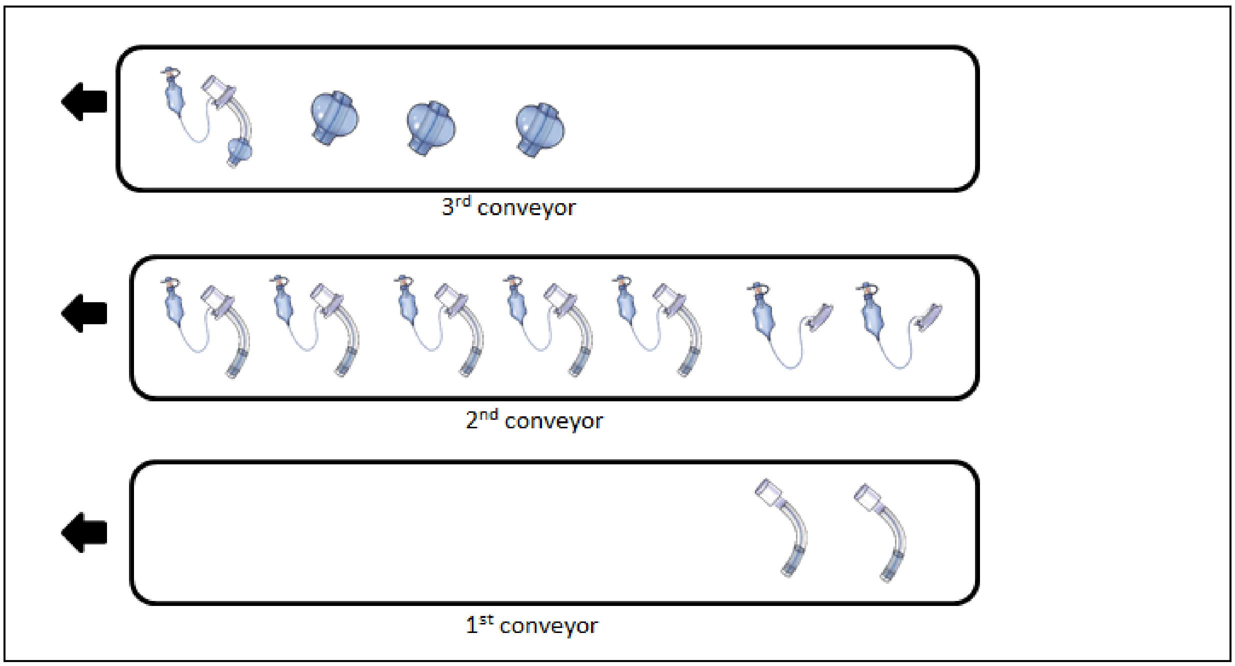


Figure 5: Movement of Parts on the Conveyors

After the 2nd operation the robot will glue the part “AB” with part “C” and produce part “ABC”, Joining part “AB” with part “C” to produce part “ABC” is the 3rd operation. Figure 6 shows 3rd operation process.

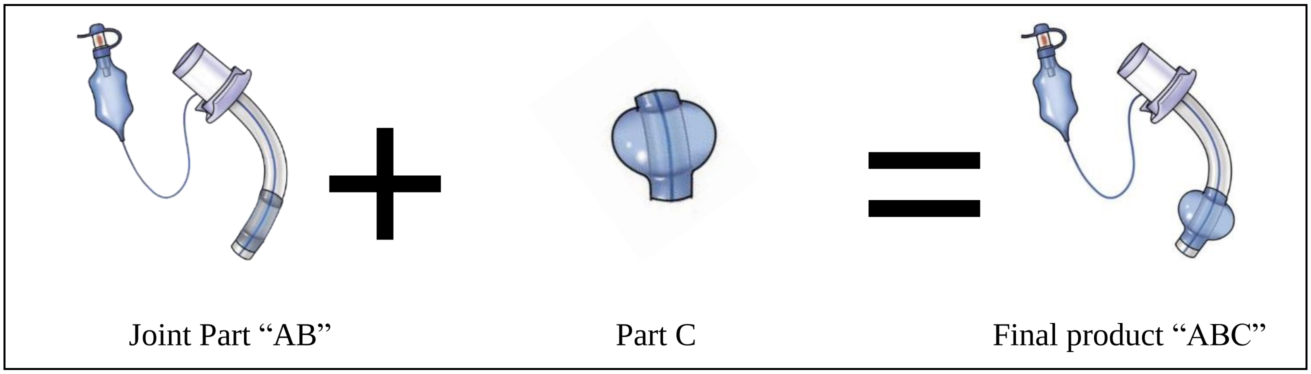


Figure 6: 3rd operation

Now robot will perform 1st and 3rd operation sequentially and eliminate the glue drying time, then send the whole product to production line. The Process will continue like this. Figure 7 shows different products in the operation.

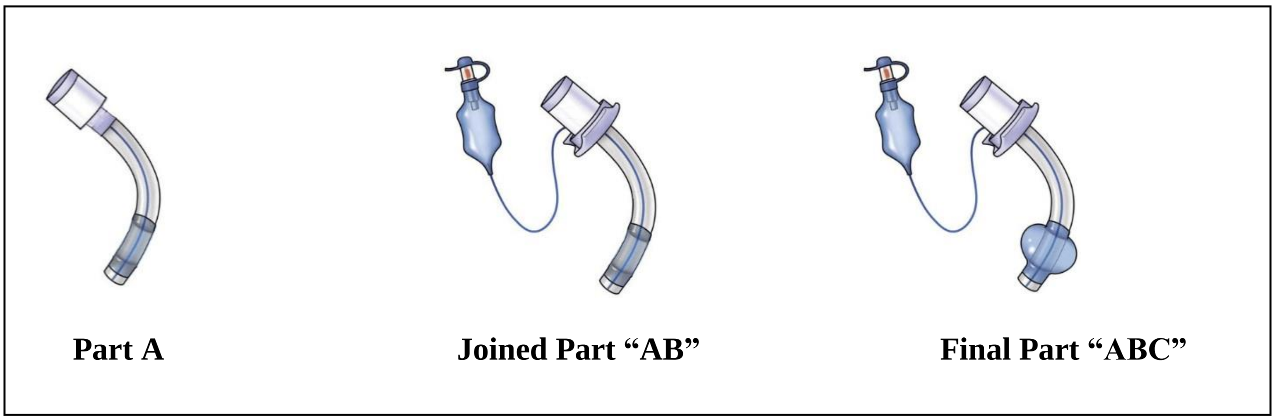


Figure 7: Different Parts [3]

HARDWARE AND SOFTWARE REQUIREMNT FOR ROBOT PROGRAMMING

Hardware

Personal computer: PC should be equipped with the CPU and software workable with the operating system of Microsoft windows.

COM Port: A vacant COM port to connect with the robot.

Scara Robot: Model TMB100 4-axis model

Table I

Operating range	J1 arm/±90° J2 arm/±150° Z axis/100mm R axis/ ± 360°
Arm length	J1 arm 260mm J2 arm 180mm J1 + J2 440mm
Load	Tool 5 kgf
R axis inertia	90 kg. cm2
Maximum Speed J1 + J2	1500mm/sec (1 kgf load) 1400mm/sec (3 kgf load) 1300mm/sec (5 kgf load)
Maximum speed Z & R axis	Z = 320mm/sec, R = 1000°/sec
Repeatability	XY ±0.02mm per axis Z ±0.02mm R axis < ± 0.02°
Data memory capacity	100 programs 6000 points
Drive system	5-phase stepping motor
Operation system	Point to point and continuous path
Interpolation	XYZ & R simultaneous 3D linear interpolation
Teaching method	Direct, remote & manual data Input (MDI) teaching
CPU	32 bit (MC68EC020, MC68882)
PLC	50 programs, 100 steps for each program
I/O signals	25 input & 24 output signals
External interface	RS232C - one channel for PC, one channel for the teach pendant and one channel for external equipment (optional)
Wiring & piping to tool	15 wires for signals, 4 air pipes (4mm)
Interface - interlocking	4 input signals from interlock equipment
Power supply 220V	AC 180-250V consumption 200VA
Working temperature	0 - 40°C
Relative humidity	20 - 95% no condensation
Weight	41kg

Table I: Scara TMB100 4-axis model specification [4]

Figure 8 shows a Scara robot Model TMB100 4-axis.

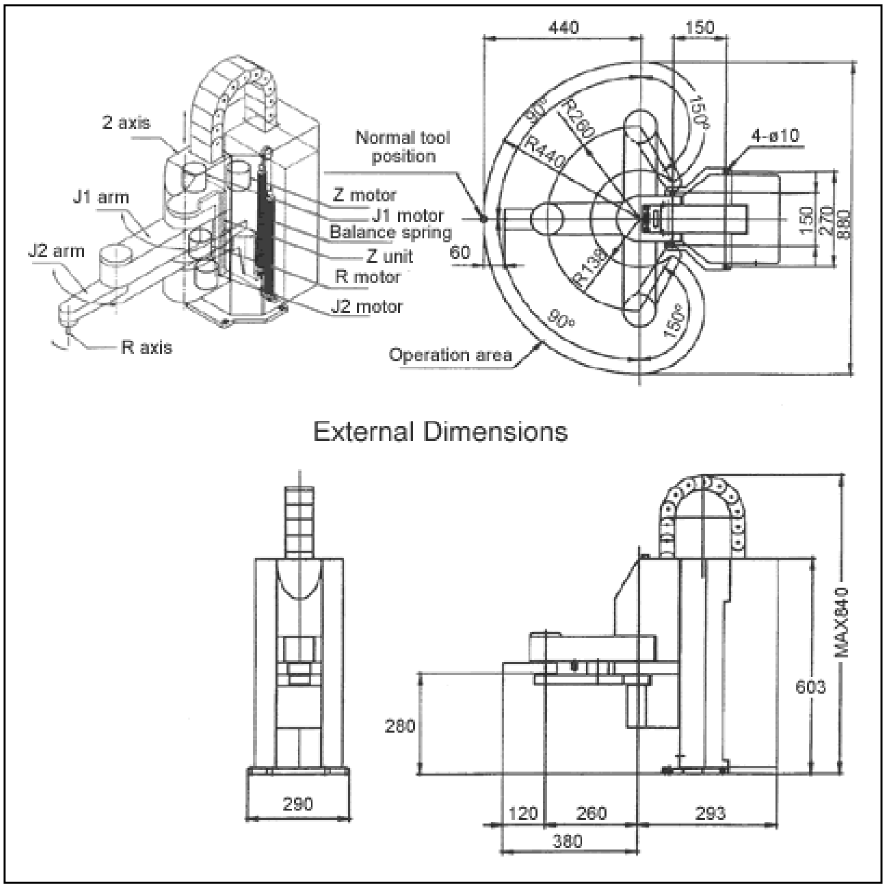


Figure 8: Scara Robot Model TMB100 4-axis

Software

Software tool "JR Points" is used to program the robot. Each program contains many location point data coupled with specified speed.

SCARA ROBOT PROGRAMMING

The way we have programmed the robot is given below by an example. A program is a set of commands in which a series of actions and movement performed by the robot and positions where dispensing is carried out are registered in order. The scara robot can store up to 100 programs from program number 1 to 100. A program consists of two parts. One is the program data which controls the program itself and the other part is point data (or a series of point data where there is more than one point) which contains information such as coordinates of the robots. The coordinate is a point where the robot may perform a job. The program data consists of following seven items: [5]

- Program name
- Work home position
- Dispense condition
- Cycle mode
- PTP condition
- Tool data
- Move area limit

Teaching:

We tried to make the teaching process as simple as possible. There is no need to learn the complicated programming language. Axes of the scara robot (TMB100) can be taught individually to perform certain task. This innovative teaching method allows the user to register work points by simply grabbing the robot arm and moving it to the desired location. This greatly simplifies the teaching process, making it fast for all users of all levels. The systems can also be taught by traditional teaching methods. The JOG teaching method allows the user to drive the robot arm to the desired location by pressing buttons on a teach-box.

A Typical Programming Example:

Figure 9 shows a typical scara robot arm movement trajectory for operation.

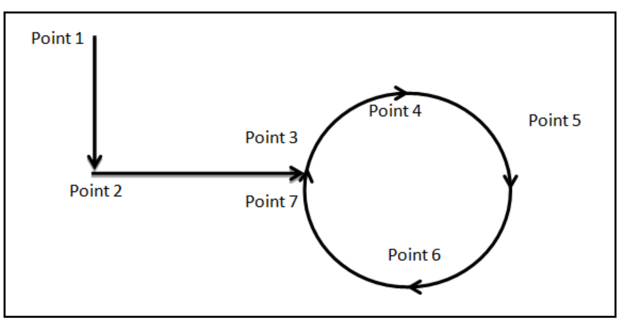


Figure 9: A Typical Scara Robot Arm Movement Trajectory

Desired Point Configuration

Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Point 7
CP Start Point	CP Stop Point	CP Stop Point	CP Arc Point	CP Passing Point	CP Arc Point	CP End Point

In JR Points under **program** menu, add new program. which is shown in figure 10.

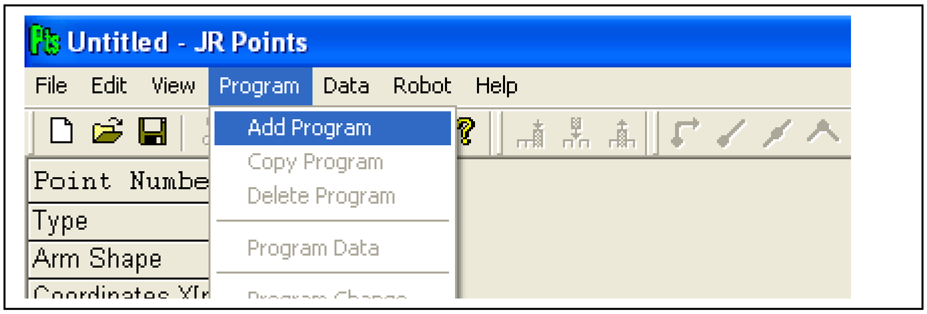


Figure 10: Add a Program in JR Points

Add program No. 1**,** which is showen in Figure 11.

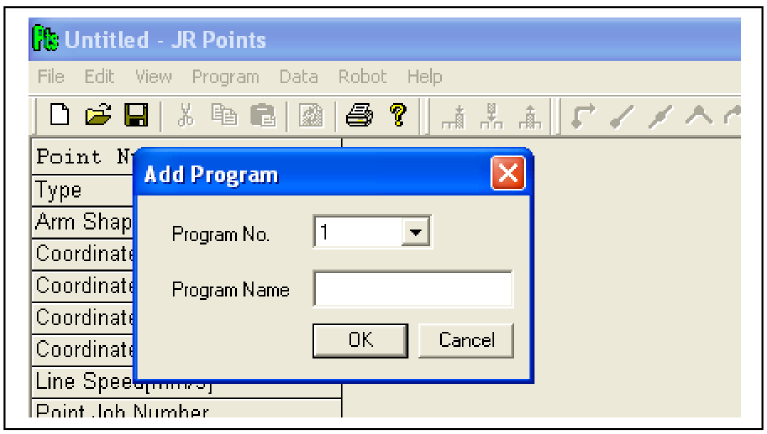


Figure 11: Add Program

Now select the point number 1 with mouse pointer. Which is shown in Figure 12.

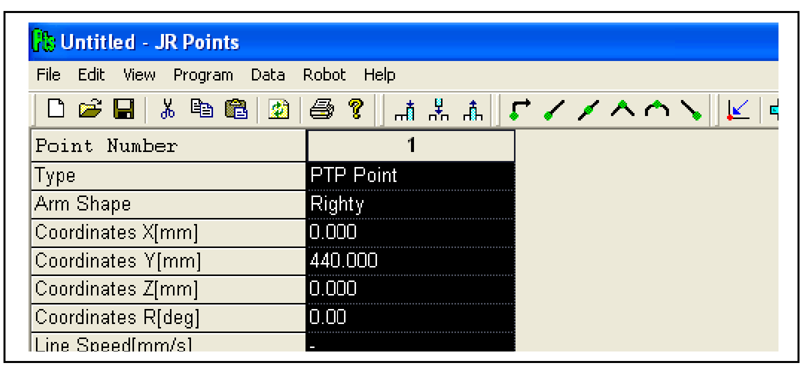


Figure 12: Select Point Number

Under **Robot** menu select **JOG**, which is shown in Figure 13.

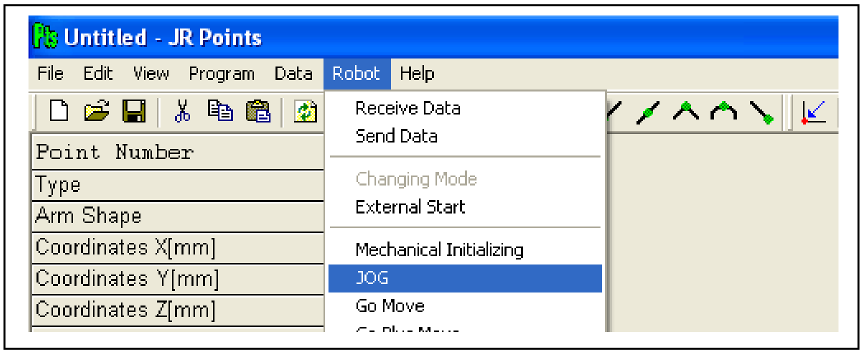


Figure 13: Select Jog Menu

Now we need to define cordinate values or we could change robot arm by clicking on these buttons shown in red in Figure 13. After moving on desired point, click on the **Register** button. In this screen line speed need to be selected. We selected line speed as 20. which is shown in Figure 14.

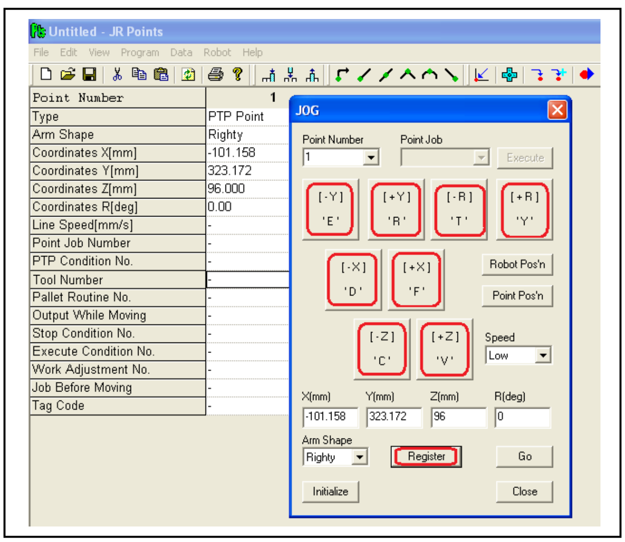


Figure 14: Define Cordinate Value

& line Speed

Now click this icon (Shown in red in Figure 15) to add additional new points. After this we need to define cordinate values in these data points. This is shown in Figure 15.

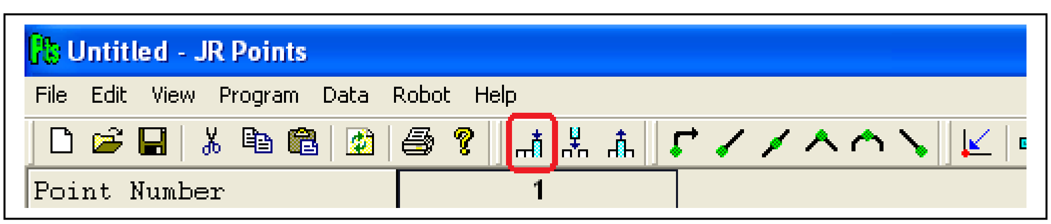


Figure 15: Add Additional Points

Now we need to send these values to the robot, which is shown in Figure 16.

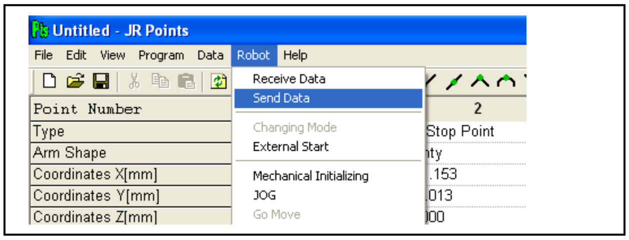


Figure 16: Sending Data Points to the Robot

Now use the drop down menu and perform as follows: **Robot >Test Running** to run the whole program. This is shown in Figure 17.

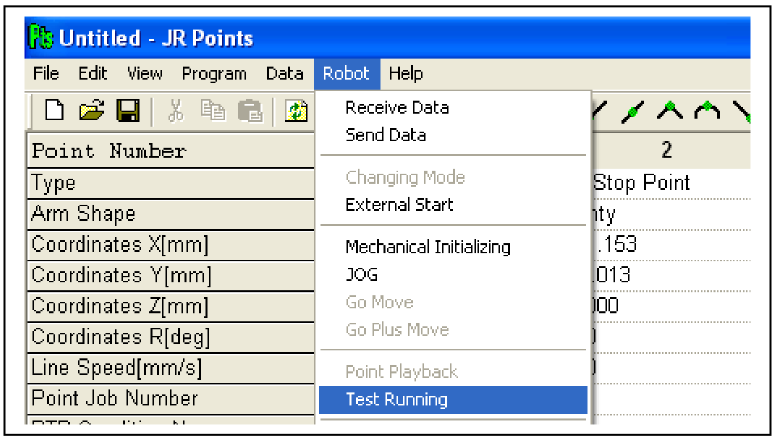


Figure 17: Running a Program

All the coordinates data are shown in Table II.

Table II

	point 1	**point 2**	**point 3**	**point 4**	**point 5**	**point 6**	**point 7**
point type	CP Start Point	CP Stop Point	CP Stop Point	CP Arc Point	CP Passing Point	CP Arc Point	CP End Point
arm shape	Righty	Righty	Righty	Righty	Righty	Righty	Righty
coordinates X	-101.158	-101.153	-111	-118.722	-126.366	-118.692	-111
coordinates Y	323.172	337.013	337	329.258	336.753	344.745	337
coordinates Z	96	96	96	96.136	96.136	96.136	96

coordinates R	0	0	0	0	0	0	0
Line Speed	20	20	20	20	20	20	-

Table II: All Data Point in JR Points

DISCUSION OF THE RESULT

Symbologies

A = time for moving part A (in second)

B = time for moving part B and gluing (in second)

C = time for moving part C and gluing (in second)

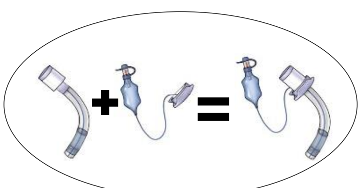
A+B = time for moving joined part "AB" and gluing (in second)

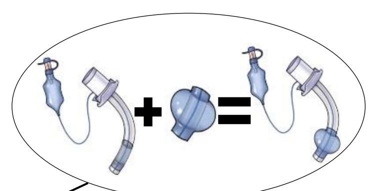
G = time glue dry (in second)

Comparison between Traditional & Enhanced Operational Sequences

Traditional Operational Sequence

If we move one part at a time and joined together, we need to wait for the glue to dry. We can calculate the time for this operation.





Step followed in tradition operation to produce one unit

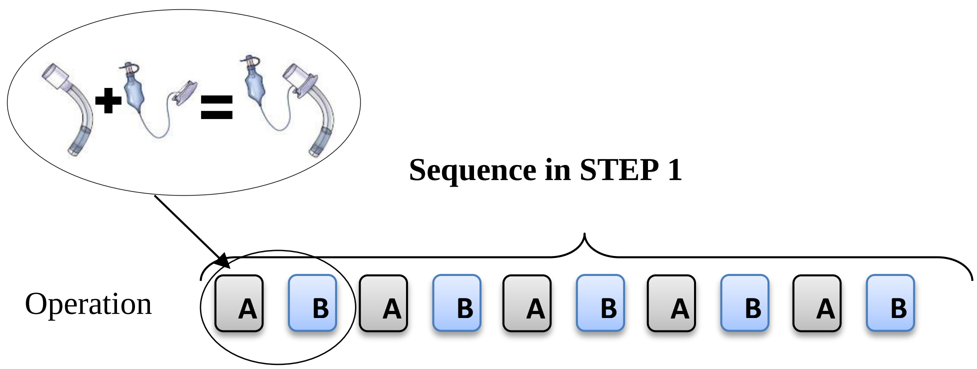
Operation	A	B	G	A+B	C	G
Time (in sec)	5	5	20	5	5	20

Total time required to produce 1 product =5+5+20+5+5+20

=60 second

Enhanced Operational Sequence

We divided enhanced operational sequence into two steps. Time required for STEP 1 is shown below:

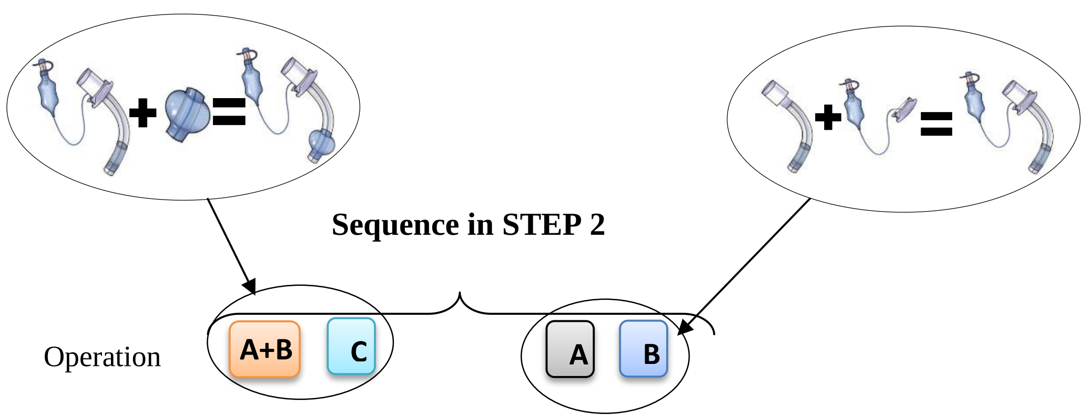


Operation

Time (in sec) 5 5 5 5 5 5 5 5 5 5

Total time required for STEP 1 = 5+5+5+5+5+5+5+5+5+5

= 50 second



Operation

Time (in sec) 5 5 5 5

Total time required for STEP 2 = 5+5+5+5

= 20 second

In first 50 seconds robot will follow **STEP 1**. After that robot will continuously follow sequence in **STEP 2.**

Total time required to produce the 1st products = 50+20

= 70 seconds

Data Generated from Traditional and Enhanced Sequences

Produced unit	time(second) traditional	time(second) enhanced
1	60	70
2	120	90
3	180	110
4	240	130
5	300	150
6	360	170
7	420	190
8	480	210
9	540	230
10	600	250
11	660	270
12	720	290
13	780	310
14	840	330
15	900	350
16	960	370
17	1020	390
18	1080	410
19	1140	430
20	1200	450
21	1260	470
22	1320	490
23	1380	510
24	1440	530
25	1500	550

Produced unit	time(second) traditional	time(second) enhanced
26	1560	570
27	1620	590
28	1680	610
29	1740	630
30	1800	650
31	1860	670
32	1920	690
33	1980	710
34	2040	730
35	2100	750
36	2160	770
37	2220	790
38	2280	810
39	2340	830
40	2400	850
41	2460	870
42	2520	890
43	2580	910
44	2640	930
45	2700	950
46	2760	970
47	2820	990
48	2880	1010
49	2940	1030
50	3000	1050

Produced unit	time(second) traditional	time(second) enhanced
51	3060	1070
52	3120	1090

Produced unit	time(second) traditional	time(second) enhanced
76	4560	1570
77	4620	1590

53	3180	1110	78	4680	1610
54	3240	1130	79	4740	1630
55	3300	1150	80	4800	1650
56	3360	1170	81	4860	1670
57	3420	1190	82	4920	1690
58	3480	1210	83	4980	1710
59	3540	1230	84	5040	1730
60	3600	1250	85	5100	1750
61	3660	1270	86	5160	1770
62	3720	1290	87	5220	1790
63	3780	1310	88	5280	1810
64	3840	1330	89	5340	1830
65	3900	1350	90	5400	1850
66	3960	1370	91	5460	1870
67	4020	1390	92	5520	1890
68	4080	1410	93	5580	1910
69	4140	1430	94	5640	1930
70	4200	1450	95	5700	1950
71	4260	1470	96	5760	1970
72	4320	1490	97	5820	1990
73	4380	1510	98	5880	2010
74	4440	1530	99	5940	2030
75	4500	1550	100	6000	2050

Analysis of the Collected Data

In this experiment, glue drying time = 20 seconds and for parts movement & gluing time = 5 seconds.

Figure 18 shows number of product versus time required to produce the product by using traditional and enhanced sequences.

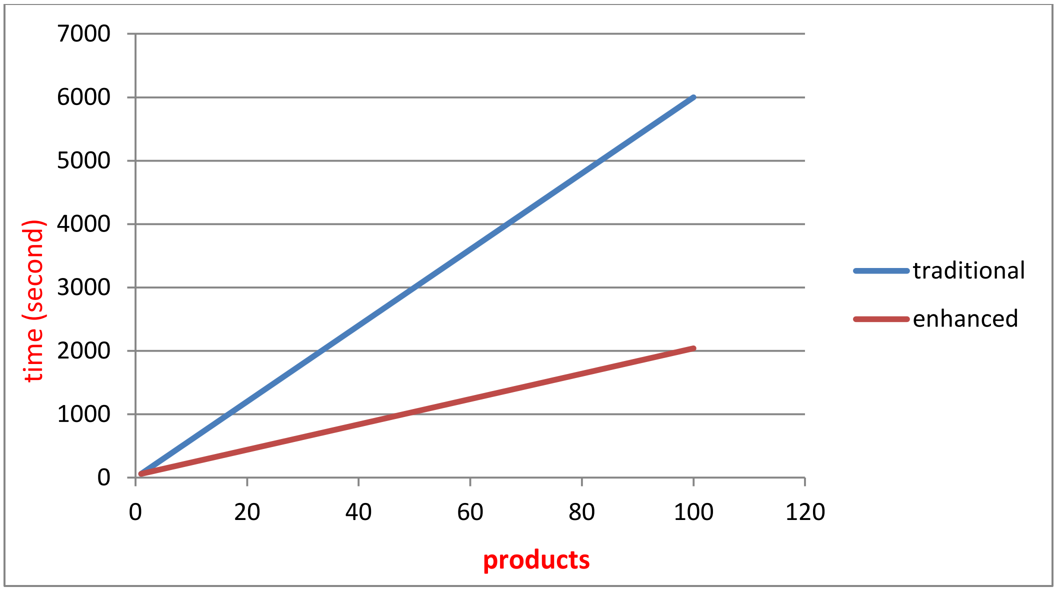


Figure 18: Product Produced Versus Time Required for Traditional and Enhanced Sequence

Product per minute (traditional sequence) = (100/6000)*60

= 1

Product per minute (enhanced sequence) = (100/2040)*60

= 2.926

Thus we could conclude enhanced sequence is almost 3 times faster than traditional sequence.

Gue drying time (second)	sequence improvement compare to traditional sequence
5	1.471
10	1.961
20	2.941
30	3.922
40	4.902
50	5.882
60	6.862
70	7.843
80	8.824
90	9.804
100	10.784

Figure 19 shows the improvement made using enhanced sequence compare to traditional sequence. Using the data (curve) we could benchmark our enhanced sequence with traditional sequence.

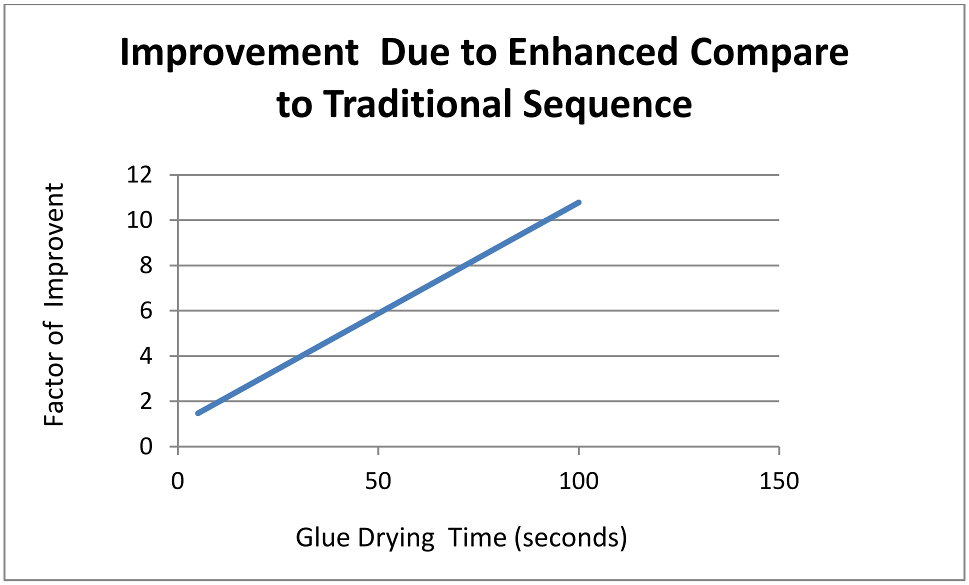


Figure 19: Factor of Improvement Comparing to Methods

CONCLUSION

To assemble and produce a medical device using scara robot is one of the cheapest solutions in the evaluation of the robot. Because of advances in hardware and software design, it is more compact, more efficient, easier to use and less expensive than its predecessors.

References

[1] http://www.robotics.org/content-detail.cfm/Industrial-Robotics-Featured-Articles/Scara-vs-Cartesian-Robots-Selecting-the-Right-Type-for-Your-Applications/content_id/1001

[2] http://endo.co.id/romsons-tracheostomy-tube.html

[3] http://www.aic.cuhk.edu.hk/web8/Tracheostomy%20tube.htm

[4] http://www.intertronics.co.uk/products/ctmb100.htm

[5] TMB100 Dispensing Manual from http://www.fisnar.com/