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The articulated R-12 robot arm and its industrial applications

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ABSTRACT

This paper presents the recent R12 series articulated robot arm commissioned at Robotics Laboratory as new research facility for students and faculties of Mechanical Engg. Dept. and all departments affiliated to research centre of MGM's Jawaharlal Nehru Engg. College, Aurangabad. This paper introduces the overview, functions and industrial applications of this type of robot. The R12 articulated robot motion resembles human arm with 5 degrees of freedom having 5 joints. This robot operates with point to point motion and continuous motion. The R12 Robot can carry a maximum effective payload of 1kg at the centre of gravity of the end effectors. There are five major components namely base, shoulder, elbow, hand and end effectors (mechanical/suction grippers). Hand has flange coupling to accommodate gripper for holding the object. The object gripping is enabled with the help of various types of "end effectors" which are designed for different types of object. Various types of end effectors can be designed and attached to the flange coupling using set of Allen screws for R-12 robot arm. The laboratory is equipped with two numbers of pneumatically operated end effectors namely, two finger/mechanical claw and vacuum suction gripper. The compressed air is passed through venturi attached to the Robot arm with high velocity to create vacuum at the junction which is attached through pipe to suction gripper. These R-series robot has industrial applications such as Pick & Place, Welding, Spray Painting, Inspection of precision screws, Sorting of components etc. The robot designed to sustain the shop floor environment. The R12 robot can be additionally integrated with "Flexible Manufacturing System (FMS)" in advanced industrial applications alongwith visual sensor facility.

Keywords: *R-12; Robot; End effectors; Grippers; Industry; Flexible Manufacturing System (FMS); Visual Sensor*

1. Introduction

Robot is a system that contains sensors, control systems, manipulators, power supplies and software all working together to perform a task [1]. Designing, building, programming and testing robots is a combination of physics, mechanical engineering, electrical engineering, structural engineering, mathematics and computing. A study of robotics means

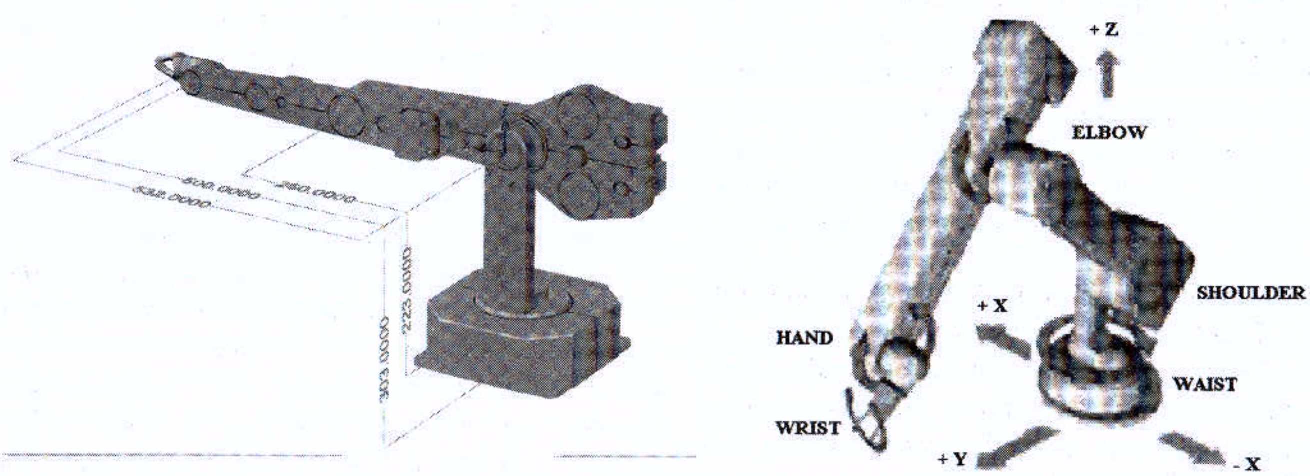

Fig. 1. Robot arm parts and movement [2]

that students are actively engaged with all of these disciplines in a problem-solving environment [1]. The Robot arm movement is as shown in Fig.1 [2].

There is no standard definition for a robot but it has some essential characteristics to call the machine as robot given as follows:

a) **Sensing** First of all your robot would have to be able to sense its surroundings. It would do this in ways that are not similar to the way that you sense your surroundings. Giving your robot sensors: light sensors (eyes), touch and pressure sensors (hands), chemical sensors (nose), hearing and sonar sensors (ears), and taste sensors (tongue) will give your robot awareness of its environment.

b) **Movement** A robot needs to be able to move around its environment. Whether rolling on wheels, walking on legs or propelling by thrusters a robot needs to be able to move. To count as a robot either the whole robot moves, like the Sojourner or just parts of the robot moves, like the Canada Arm.

c) **Energy** A robot needs to be able to power itself. A robot might be solar powered, electrically powered, battery powered. The way your robot gets its energy will depend on what your robot needs to do.

d) **Intelligence** A robot needs some kind of "smarts." This is where programming enters the pictures. A programmer is the person who gives the robot its 'program.' The robot will have some way to receive the program so that it knows what it is to do.

2. Common Types of Industrial Robots

There are six main types of industrial robots described briefly [2]:

i. **Articulated** - This robot design features rotary joints and can range from simple two joint structures to 10 or more joints. The arm is connected to the base with a twisting joint. The links in the arm are connected by rotary joints. Each joint is called an axis and provides an additional degree of freedom, or range of motion. Industrial robots commonly have four or six axes [2].

ii. Cartesian - These are also called rectilinear or gantry robots. Cartesian robots have three linear joints that use the Cartesian coordinate system (X, Y, and Z). They also may have an attached wrist to allow for rotational movement. The three prismatic joints deliver a linear motion along the axis [2].

iii. Cylindrical - The robot has at least one rotary joint at the base and at least one prismatic joint to connect the links. The rotary joint uses a rotational motion along the joint axis, while the prismatic joint moves in a linear motion. Cylindrical robots operate within a cylindrical-shaped work envelope.

iv. Polar - Also called spherical robots, in this configuration the arm is connected to the base with a twisting joint and a combination of two rotary joints and one linear joint. The axes form a polar coordinate system and create a spherical-shaped work envelope [2].

v. SCARA - Commonly used in assembly applications, this selectively compliant arm for robotic assembly is primarily cylindrical in design. It features two parallel joints that provide compliance in one selected plane [2].

vi. Delta- These spider robots are built from jointed parallelograms connected to a common base. The parallelograms move a single End of Arm Tooling (EOAT) in a dome-shaped work area. It is heavily used in the food, pharmaceutical, and electronic industries. This robot configuration is capable of delicate, precise movement [2].

3. Articulated R12 Robot at JNEC:

The R12 industrial robot was found helpful for various engineering applications and demonstration to the students at Jawaharlal Nehru Engineering College (JNEC), Aurangabad. Its advanced applications are being explored with FMS integration in the college [3, 4]. This low-cost, self-contained system features a five-axis, vertically articulated, industrial robot arm. Its high intelligence can accomplish the most complex of tasks, while its simple interface allows for easy adaptation to any application from machine feeding to testing to laboratory sample handling.

3.1.Description of R-12 Robot

The R12 firefly is a complete self-contained five axis vertically articulated robot arm system designed as a cost effective solution for bench top automation. Applications include testing, sample handling, and machine feeding. The hand terminates in a mounting plate for grippers, vacuum cups etc. Firefly is a very low cost entry to robotics, fast, accurate and reliable and easy to program. It has a useful 500mm reach. It is easy to apply and program yet is capable of the most complex tasks. It is a technological breakthrough in bench top robotics. Like the R17 it is a 5 axis articulated robot arm but smaller, lighter, faster and above all lower cost. Do not let the low cost mislead you - this is not a hobby robot. It is a professional tool made to industrial standards of quality, reliability and performance. Firefly uses new light weight, high efficiency digital motors driving through steel reinforced polyurethane timing belts. Optional incremental optical encoders provide exceptional integrity.

3.2. Specifications of JNEC R-12 Robot

The pictorial view of R-12 robot arm having five degrees of motion (i.e. five axes robot) is as shown in Fig.2 [3]. The specification like reach, pay load

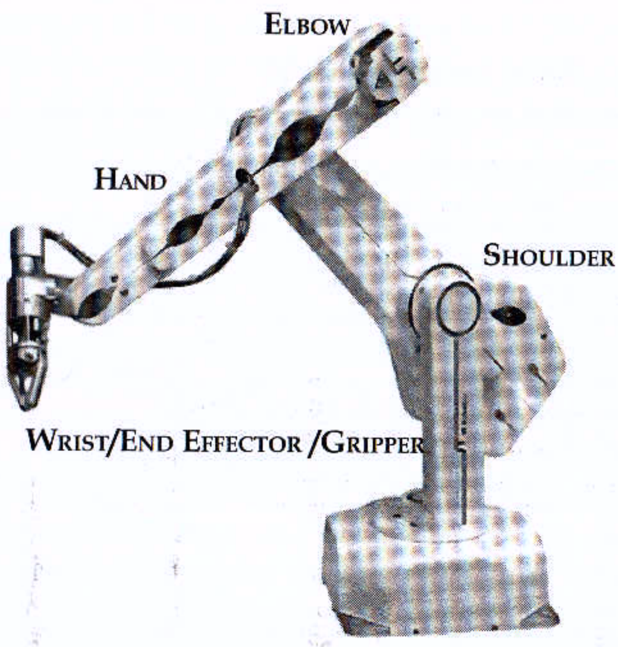

Fig. 2. JNEC R-12 Robot by ST Robotics [3]

capacity, maximum speed and other specifications of installed R12 robot are given in Table 1 in this paper.

3.3 Components of R-12 robot

The complete articulated robot arm R-12 consists of main components as shown in Fig. 3 [3] below:

i. Robot arm: The R12 robot arm comprises of five jointed components namely waist, shoulder, elbow, hand and wrist or end effectors/gripper. There are two grippers available in the college namely mechanical or finger type and suction type grippers. There are many types of grippers which can be designed for different industrial applications. The five axes of robot arm are shown in Fig. 3 [3].

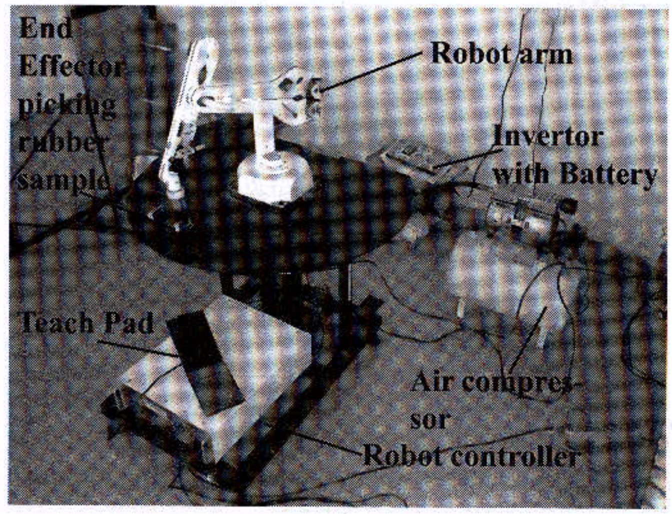

Fig. 3. JNEC R-12 Robot components [3]

ii. Encoders: The first role of the encoders in the R12 is as watchdogs. The loop is closed after completion of each individual motion which is not the same as servo control. The R12 encoder option comprises miniature optical incremental encoders fitted to each axis. Without encoders the R12 will run accurately and indefinitely open loop without error thanks to micro-stepping drives and accurate transmission. But if the robot suffers a collision then the controller does not know and carries on with the program even though the robot could be out of position. Such collisions usually only occur accidentally during programming and rarely during normal running. It is necessary to run the calibrate routine after such a collision. The robot can be positioned by hand and its position updated on pressing a key on the keypad. The kinematics software then computes the exact X-Y-Z position of the robot with the hand pitch and roll in degrees.

iii. Gripper: As standard the robot terminates in a mounting flange. End effectors currently include: electric gripper, SMC 10mm pneumatic gripper, vacuum pickups. Using a small motor and gearbox it is accurate and tough. Programming is an extension to the Cartesian functions of RoboForth. In this way the system can ensure the end effectors points in the same direction (same orientation to X Y Z axes) as the robot moves around, or indeed in any direction you choose.

iv. Robot controller with Teach-pad and laptop/ desktop: The package includes the new Mk5 controller which again is simple and reliable using a partnership of fast CPU and DSP processors and compact micro-stepping drives providing both speed and precise control, provided with a simple intuitive teach pad. The controller can also interface with or even control other equipment at the same time as the robot. In case of accident press stop button at the controller (Fig. 4.) and then the reset button at controller panel. There is provision of stop button on Teach-pad which can be operated/press in all the cases of robot emergency/ mishandling. After pressing controller reset button use Teach-pad to bring robot to home position.

Software platform is **ROBOFORTH II** which makes this robot really easy to get started with yet the most complex motions, interfaces and peripherals may be programmed, assisted by RobWin project manager which brings everything together on one Windows screen. Everyone who uses this system agrees it is the most flexible robot software on the planet. Commands to the controller were given through laptop/desktop computer interface using

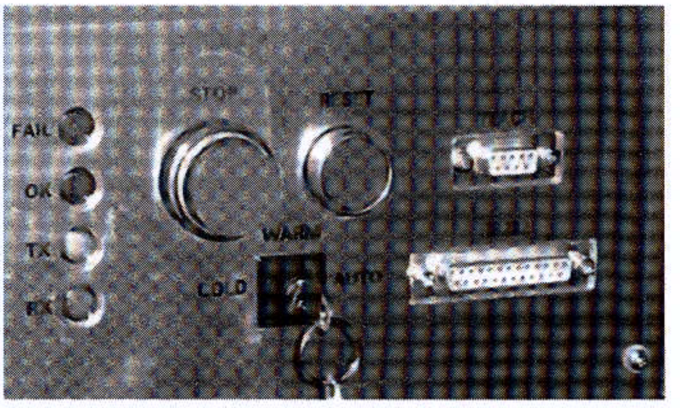

Fig. 4. R-12 robot controller at JNEC [3]

Table 1. Specification of R-12 Robot arm at JNEC [3]

Drives	High power micro-stepped hybrid stepping motors, optional encoder watchdogs
Reach	500mm/20ins in any direction; 360 degree waist rotation
Repeatability	0.1mm
Payload	nominal 500g, max 1Kg (2.2lbs) at flange (repeatability and speed degrade with increasing payload and reach).
Compliance droop at 250mm at nominal payload droop at max reach with max payload	0.4 mm 2.3 mm
Maximum speed	Shoulder 180 deg/sec, Elbow 270deg/sec, Waist 180 deg/sec.
Standard cycle time	2 sec
Max torque for hand pitch or roll	2 Nm
Weight	Robot 12.8Kg/29lbs Controller 11kg/25lbs
Power	110/240V ac 420VA (standard controller)
Temperature range	Preferably 0 - 28 ^{0}C (wider range optional)
MTBF	10,000 hours
Safety	Class 2 stop circuit, stall detect, risk assessment guide. High intensity red LEDs along the arm serve as awareness barrier.

string of characters with specific programming methodology.

v. Air compressor: The laboratory is equipped with two numbers of pneumatically operated end effectors namely, two finger/mechanical claw and vacuum suction gripper. There is air compressor unit for the supply of compressed air and create the vacuum required by the suction gripper. The air pressure is maintained at 6 to 8 bar in the air compressor for operation of all types of pneumatic grippers. The air compressor is kept near to work bench.

vi. Work Bench: The circular work bench is provided at the robotics laboratory to mount R-12 robot and position for Mk5 controller. The height of work bench is kept 1 m. The R-12 robot arm is mounted on this mild steel black coated work bench. In addition there is provision of 100Ah capacity battery as backup power supply to the robot in case of power cut.

4. Industrial applications of R-12 robot

There are following industrial applications of R-12 robot:

4.1 Spray Painting: Another popular and efficient use for robots is in the field of spray painting. The consistency and repeatability of a robot's motion have enabled near perfect quality while at the same time wasting no paint. The spray painting applications seems to epitomize the proper applications of robotics, relieving the human operator from a hazardous, albeit skillful job, while at the same time increasing work quality, uniformity, and cutting costs [4-7]. Similarly, robot is in use for mass production of welded furnitures at MGM Next furniture, Aurangabad as shown in Fig. 5 [5].

4.2 Pick and Place application: Robots pick and place is a cost effective choice as compared to manual labor for greater accuracy and to avoid human error in mass production with repetitive task. Robotic pick and place can work 24/7 and 365 days a year without tiring. Using a robot to automate your lifting and repetitive motion will help save valuable floor space. R12 is knowledgeable in integrating pick and place robots into most processes including simple redirection operations [6-8]. The various pick and place operations for R-12 robot arm is kept for demostration to the students and guest at robotics laboratary in Mechanical Engineering Dept. at MGM's JNEC, Aurangabad [3].

Fig. 5. R-17 robot (ABB make) for welding operation at MGM Next furniture [5]

4.3 Material Handling: Palletizing is the act of loading or unloading material onto pallets. In the newspaper industry Robot being used to palletize advertising inserts for a newspaper. In semiconductor industry's IC chip manufacturing facilities; various processes take place within a clean room. Robots do not breath, sneeze, or have dandruff, they are especially suited to the clean room environment demanded by the semiconductor industry [6-8].

5. Conclusion

The R12 robot has industrial applications in spray painting, pick and place, material handling, sorting, precision screw testing etc. The wide welding applications are achieved through higher versions with six degrees of freedom like R17 at Next furniture (Mahatma Gandhi Mission, Aurangabad) Fig. 5. The exposure of R12 articulated robot was found useful for various practicals and subjects in engineering. The advanced flexible manufacturing system (FMS) is under progress to demonstrate various industrial applications of this R12 robot. In addition to all these industrial applications, this R12 robot was programmed to write "WELCOME" on white board during JNEC annual function "Razzmatazz-2013" and demonstration of various pick and place operations [3].

6. References

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Appendix: Flow Sequence for R-12 Robot Arm Programming

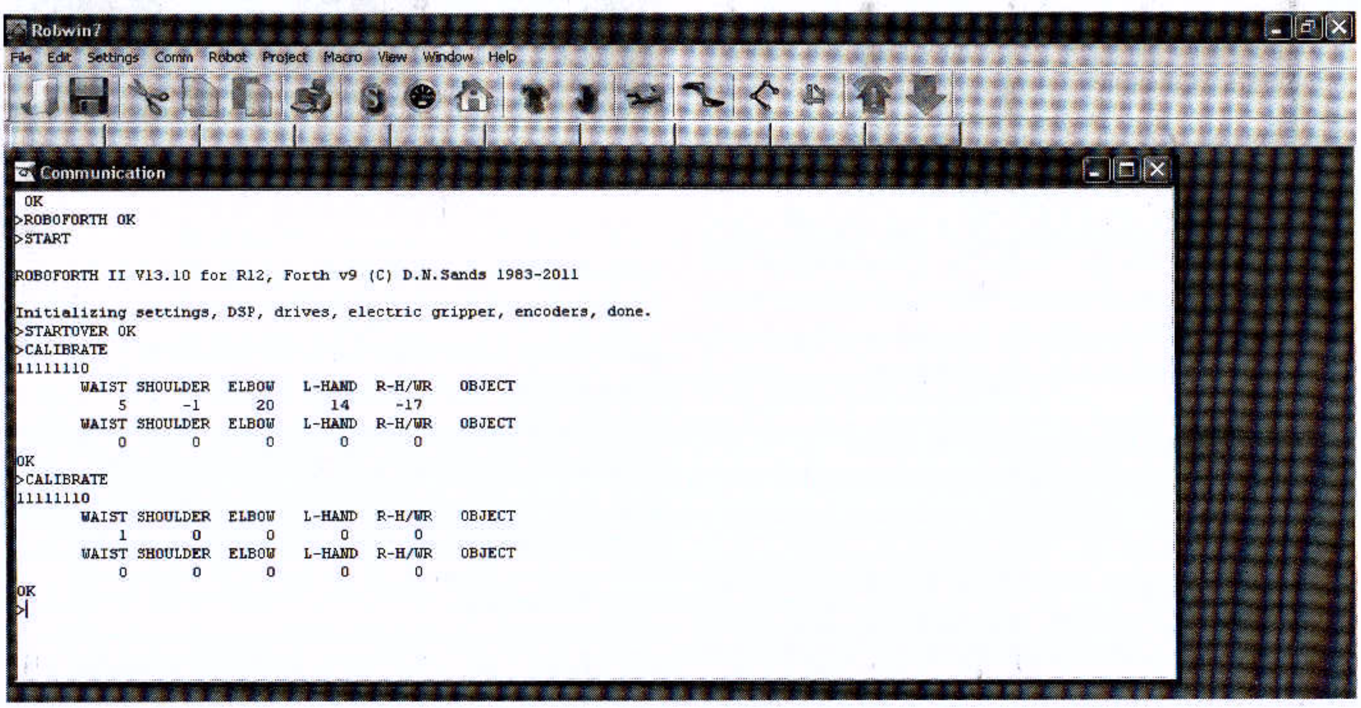

Fig. A1. Open Robowin-7 from desktop and calibrate

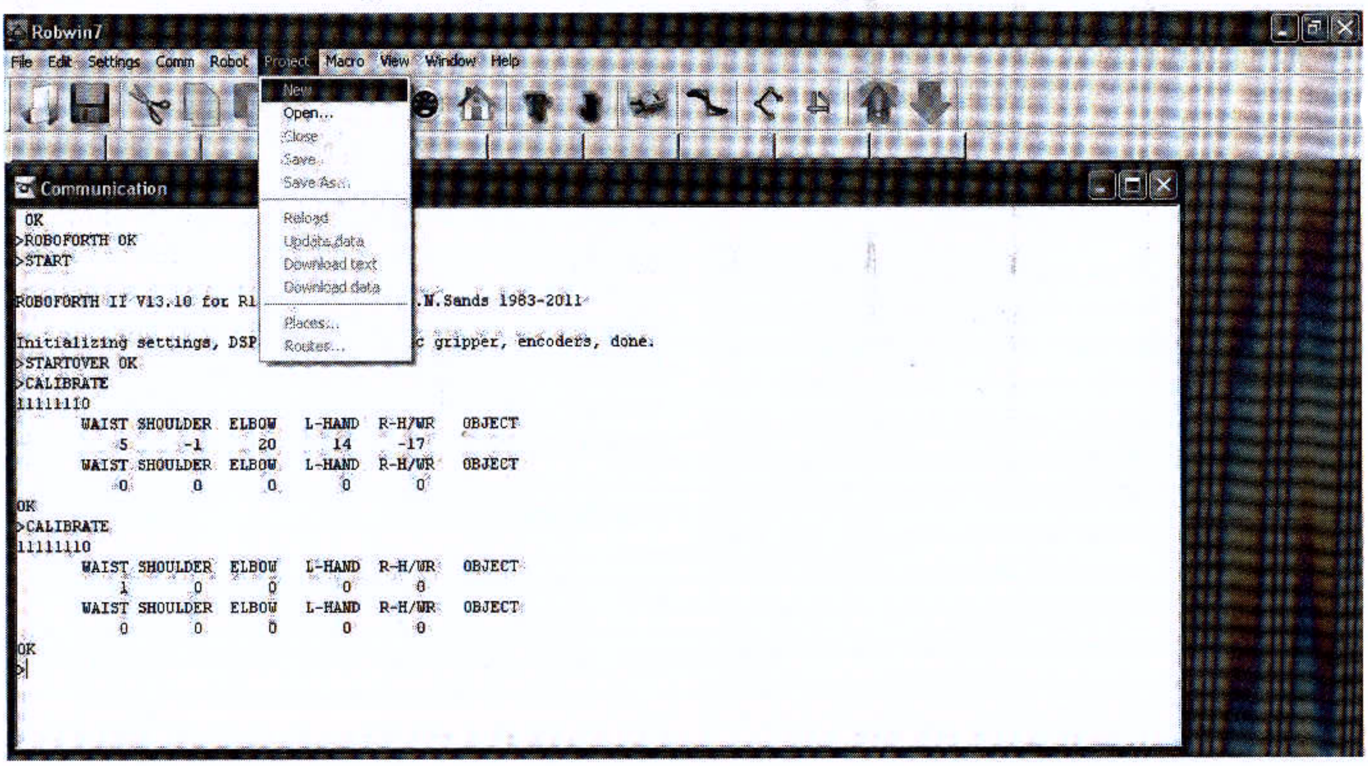

Fig. A2. Open New Project for new program

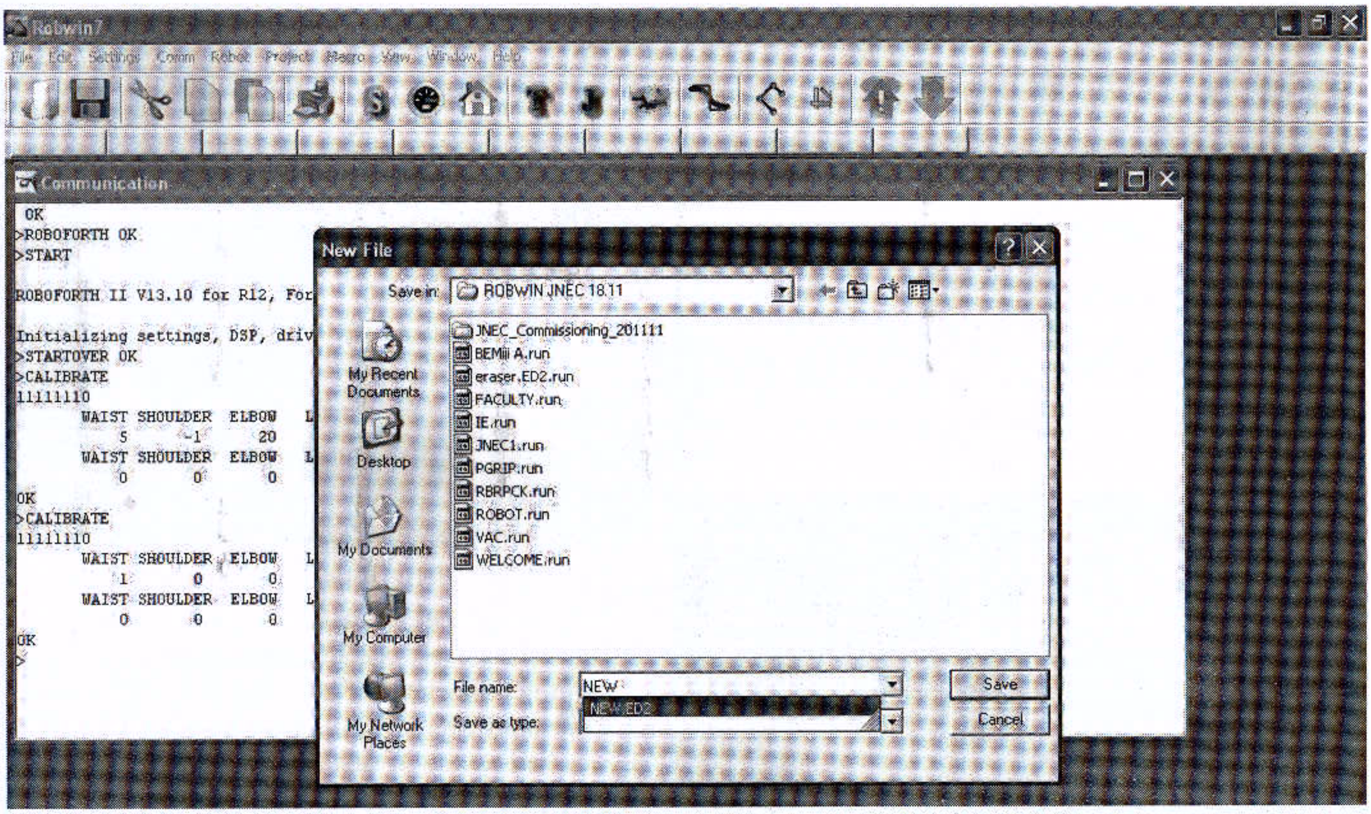

Fig. A3. Define Program name like NEW. EDC for the new program

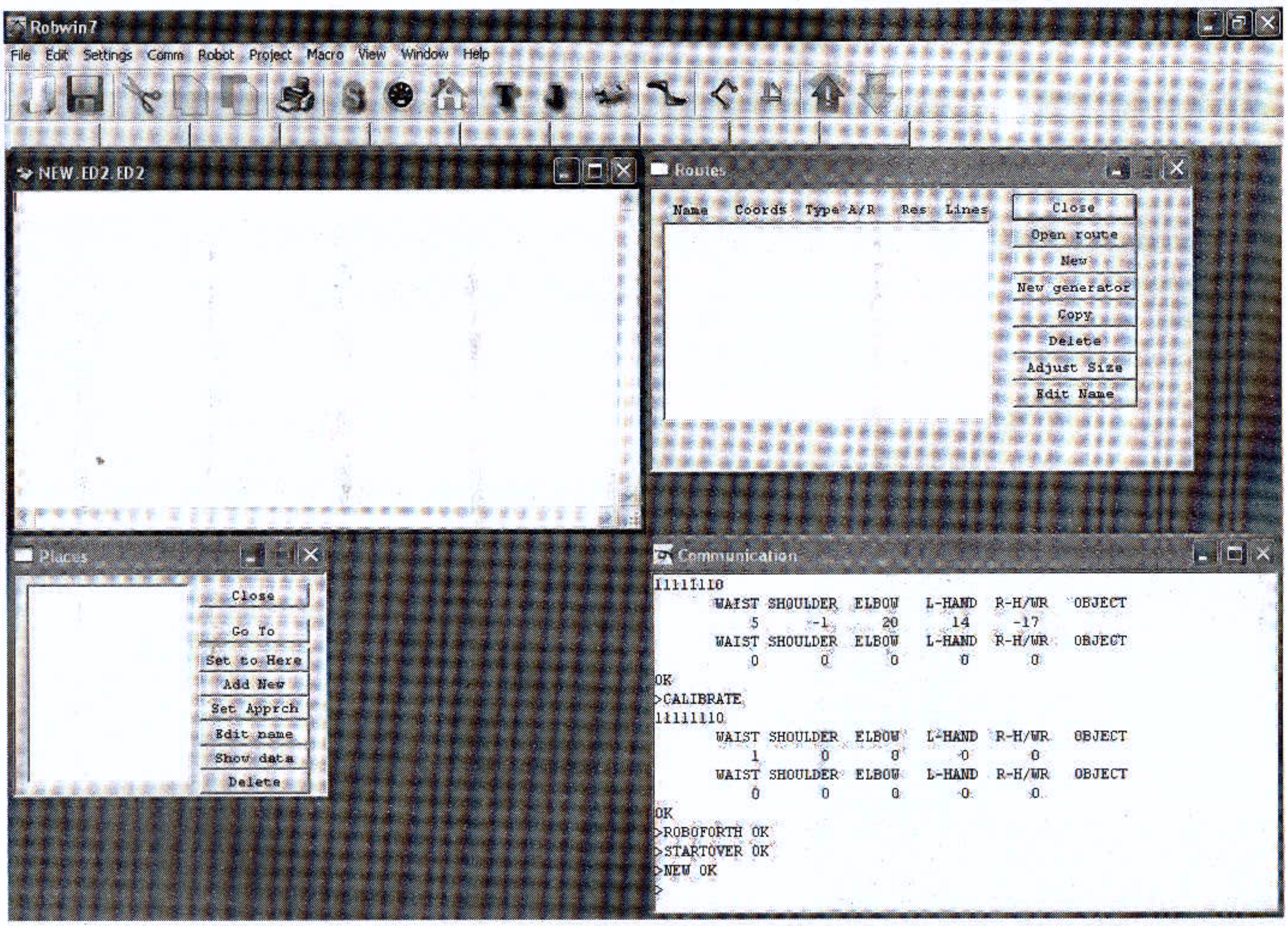

Fig. A4. Open window for new program have been tiled horizontally to show 4 windows
1. NEW.ED2, 2. Routes, 3. Places and 4. Communication

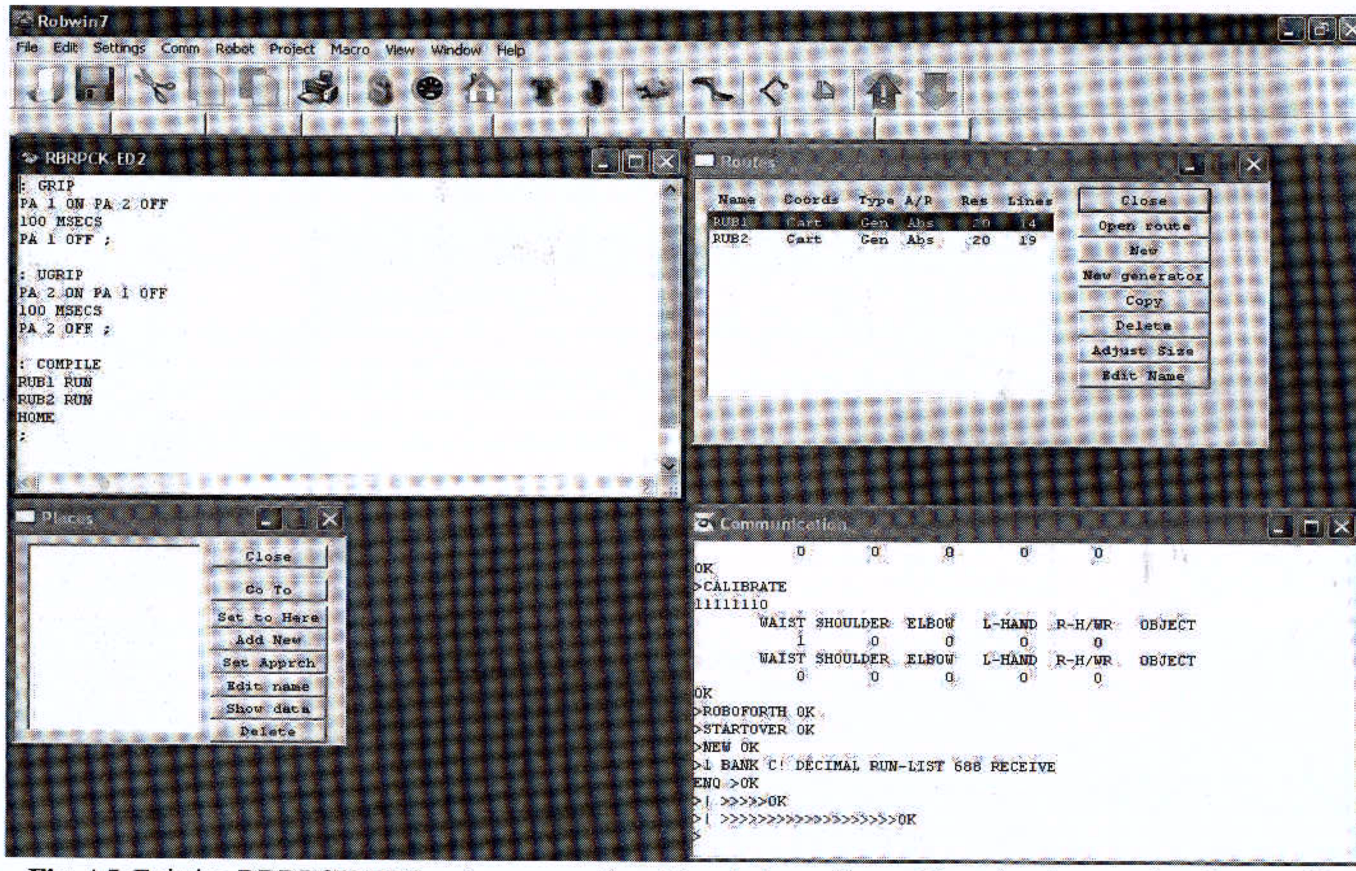

Fig. A5. Existing RBRPCK.ED2 main program for pick and place of two rubber pices is opened as shown with two routes. RUB1 and RUB2

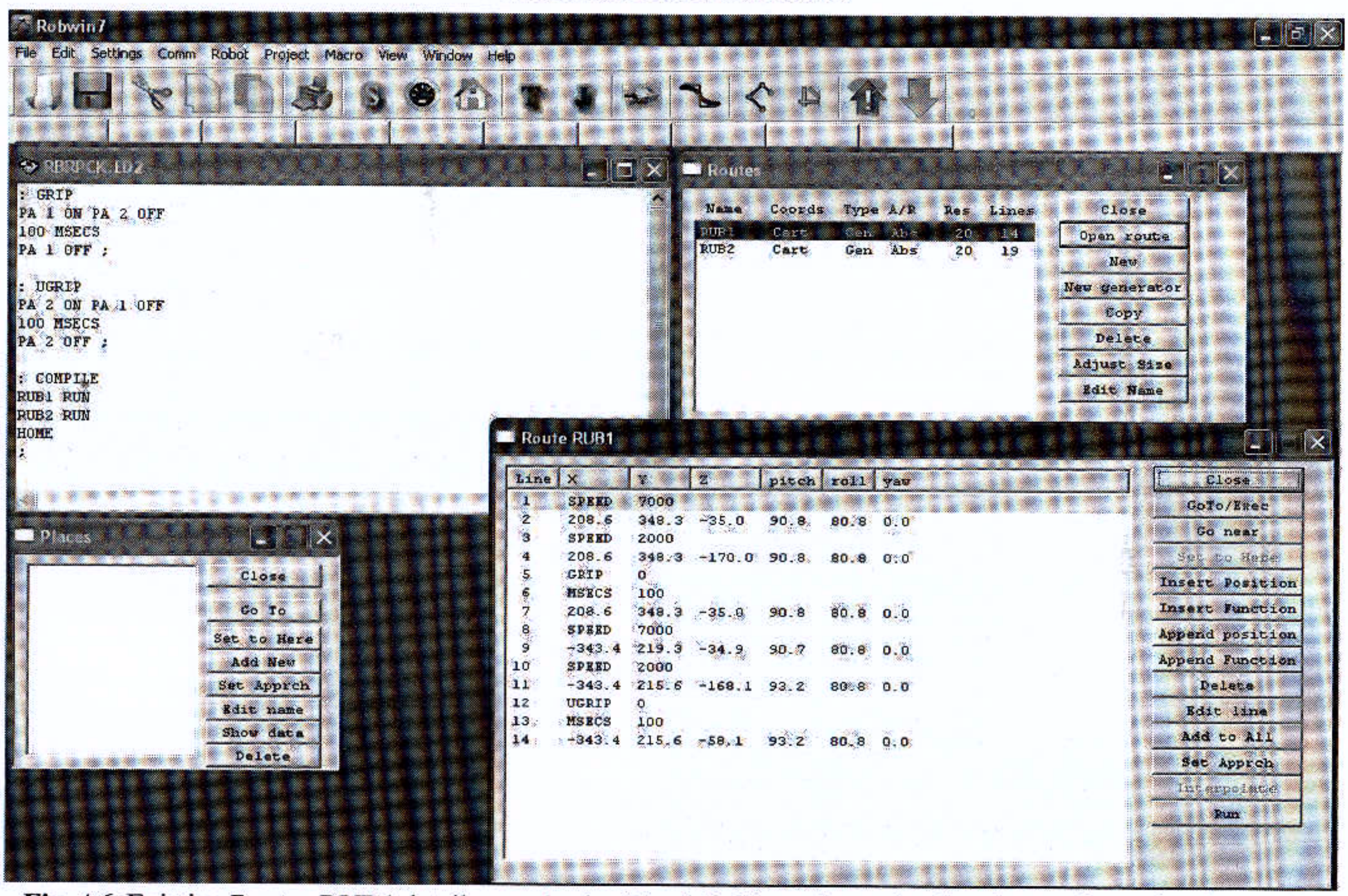

Fig. A6. Existing Route, RUB1 details saved using Teach Pad is as shown (each points are located and saved by programmer with actual location of end effector for locating Rubber 1 pick and drop points).