Survey of Robotic Arm and Parameters

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2 authors:

Virendra Patidar
ABV-Indian Institute of Information Technology and Management Gwalior

Ritu Tiwari
ABV-Indian Institute of Information Technology and Management Gwalior

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Virendra Patidar
Robotics & Intelligent System Design Lab
Indian Institute of Information Technology & Management,
Gwalior, India
virendra.iiitm24@gmail.com

Ritu Tiwari
Robotics & Intelligent System Design Lab
Indian Institute of Information Technology & Management,
Gwalior, India
ritutiwari@iiitm.ac.in

Abstract—**This is a survey paper on a robotic arm and their development. It gives a technical introduction to some of the recent research work in this field. This is a working field of research in which there are a number of outstanding open problems and an area of exploration. Nowadays, a different variety of robotic arms are commercially available. Some of them are excellent in accuracy and repeatability. In this paper, we understand the evolution of robotic arm in last 20 years and described different parameters of an arm. Type of robotic arm only depends on these parameters. Our survey may be used for knowledge and guidelines for future research work. The paper concludes with research gaps and proposed work. Robotic arm uses in the different fields like a household, workplace, and working station.**

Keywords- Robotic arm, axis, degree of freedom, working envelope and space, kinematics, payload, speed and acceleration, accuracy and repeatability.

I. INTRODUCTION

Robotic arm is a mechanical product, its manufacture and sold rate is very high over the world. Figure 1 shows A robotic arm with labels. Thousands type of arm are available in the market and developed by different companies. Industrial use of the robotic arm is more than the domestic because at this time robot are not used for normal purpose; it's always used for specific purpose and in the industry some condition where humans are not able to work i.e. high temperature, polluted air zone, heavy weight lifting etc. Robotic arm also uses for high accuracy places where error not allowed. Robotic arm is set a task and perform it accurately in the various environment. A robotic arm is meant a set of rigid jointed bodies able to take different configuration, and to move between these configurations with prescribed limits on velocity and acceleration. Industrial robotic arm differs by the size of the fixed bodies, the type of joint, the sequence in which the joints are connected and the range of motion acceptable at each joint. The individual fixed bodies are called links. Robotic arms are manufactured by using different parameters like number of axis, degree of freedom, working envelope and working space that arm cover, kinematics, payload, speed and acceleration, accuracy and repeatability, motion control and drive of an arm etc. This survey papers to summarize the development in a robotic arm.

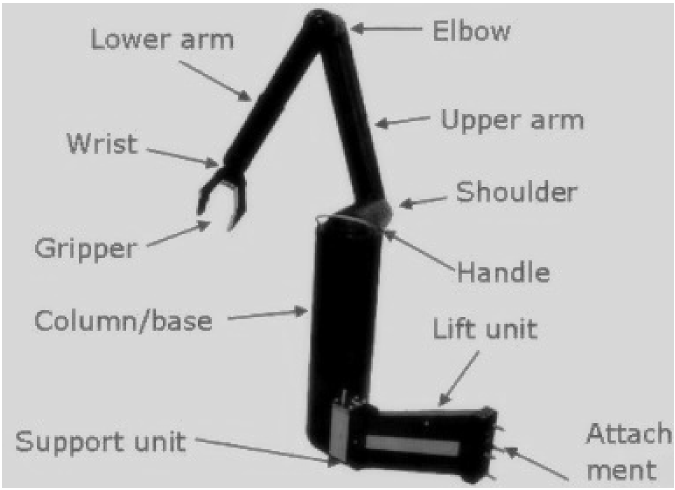

Figure 1. A robotic arm with labels [1]

II. LITERATURE REVIEW

In this survey, we studied papers according to the different parameter of a robotic arm.

A. Axis

Axis are used for movement indication, one use for a line, two for a plane and three for a point at anywhere in space. Roll pitch and yaw control are the main factors of a robotic arm axis, use for full control. Before 1987 robots robotic arms are working. In [2] 2-axis and 3-axis. But now there in [3] 4-axis, in [4] 5-axis, in [5] 6-axis and in [6] multi-axis robotic arms are available. Figure 2 shows a six axis- robotic arm. Freely moving are good for a three dimensions, rotating axis arm must be positive interactive for good stability. Mass of arm should be less for less force of inertia at different joints, lighter arm performs more dynamically than bulky arms at same stability level. Industrial robotic arms are using bulky tool and weight of arm also very high, use for big construction. Robots may become flexible and less in weight by using multiple axis arms.

B. Degrees of Freedom

Robotic arm control all points (directionally) using their degrees of freedom. A human arm control by seven degrees of freedom, articulated arms typically have up to six degree of freedom. [8] A robotic arm is made by using different solid part, join by n number of joint connected, each joints having

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one degree of freedom if there n number of the joint then arm have n degree of freedom (DOFs). Figure 3 show a seven joint robotic arm.

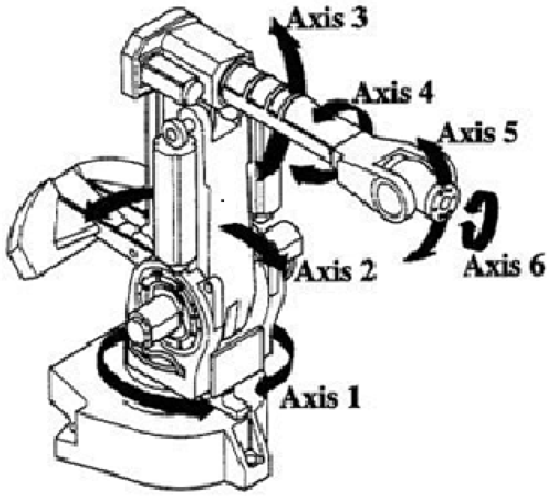

Figure 2. A six-axis-robotic arm [7]

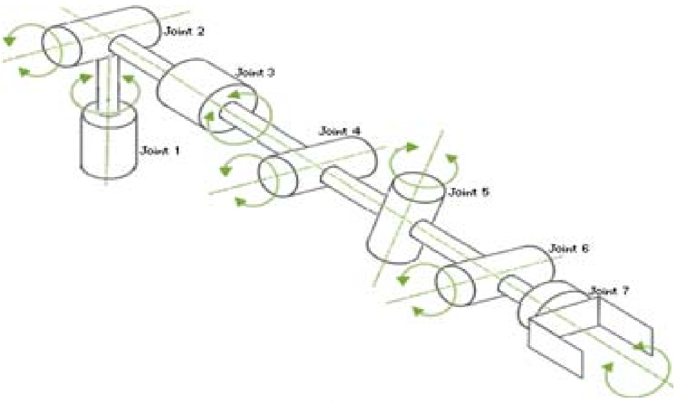

Figure 3. A seven joint robotic arm [9]

We can understand by n joint coordinates also known as internal coordinates. All coordinates depend on joints and describe the relative motion of beside links. In [10] robotic arm with three joint having 8 degrees of freedom and when we include five finger of hand then it became 17 degrees of freedom. In [11] a robotic arm mounted on wheelchair having 6 degrees of freedom and control by a color vision system for proper object finding, a force and torque sensor, driving by good user interface devices. In [12] 3D vision tracking of flight, an object is possible without making strong assumptions with 7 degrees of freedom arm. [13] Gives capturing Robot Workspace Structure with dual arm each having 7 degrees of freedom. [14] a robotic arm that behave like a human analog motion, this arm was designed with 7 degrees of freedom for increasing interactivity with humans, force sensor was attached to wrist sensor work in six axis and used calculating force apply at the arm. [15] A 7 degrees of freedom multipurpose arm light in weight (DLR LWR 3) used for ball catching robotic system. Ball catching is done by a

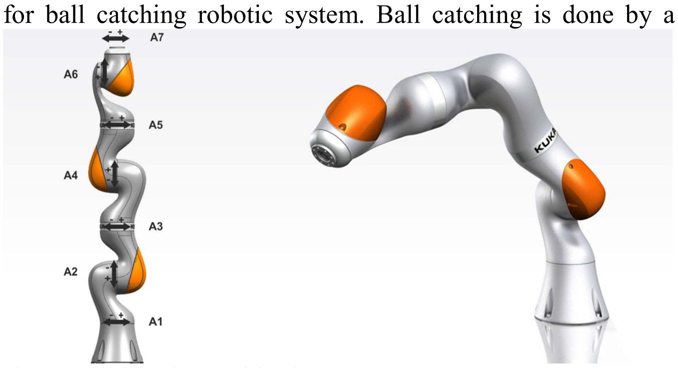

Figure 4. a kuka 7-degree-of-freedom arm [19]

four figure having 12 degrees of freedom (DLR hand 2). They also use a small basket with 7 degrees of freedom (DLR LWR 2) arm along with a camera and fast image processing system. [16] Two robotic arm mounted to a 7 degrees of freedom robot with four finger hand each having 12 degrees of freedom, lightweight robot and robotic arm used for dynamic performance. Robot use camera for tracking ball, both arm can catch simultaneously because its design for collision avoidance. In [17] robotic hand with high capabilities, robotic hand with 3 finger and 1 thumb each having 4 joint then total number of joint are 16 means each finger have 4 degree of freedom and hand working at 16 degree of freedom, size of hand is 1.5 times bigger than human normal hand this hand can be mounted over any good arm. In [18] a arm mounted over a table very flexible and lightweight KUKA LWR4+ arm used, arm having 7 degree of freedom connect with a catching hand and it can catch an empty and partially filled bottle, tennis racket, a cardboard box and a hammer etc. Figure 4 show a kuka 7-degree-offreedom arm.

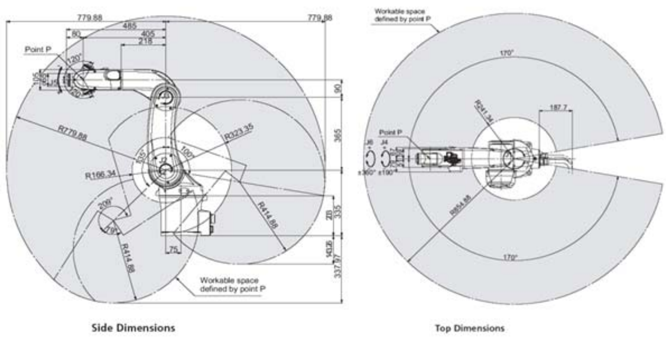

Figure 5. Side dimension working envelope and top dimension working envelope [25]

C. *Working Envelope and Working Space*

The robotic arm can cover circle in space is a working envelope of a robotic arm. Envelope means the range can cover by arm or range of movement. If we use the arm in different possible directions (forward and backward, up and down) then one 3D shape is an envelope, it depend on a robotic arm and number of axis, the axis can manipulate the range of motion. Figure 5 show Side dimension working envelope and top dimension working envelope. A robot can only work in their working envelope, but it's possible to design some flexible robotic arm they can change their envelope according to their requirement like a moving robot move with track and cover large envelope. In [20] combination of Roll, pitch and yaw controls are the main factor to improve target point and flexibility, the help in increasing robotic arm efficiency then working envelope also increased. In catching arm [12], [15], [16], [18], [21], [22], [23] and [24] working envelope cover half of sphere.

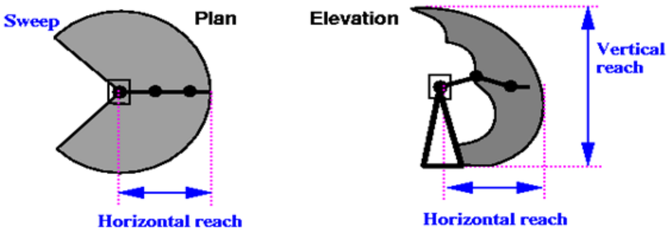

Figure 6. Workspace of a revolute robot [27]

The region where a robotic arm can fully work without any obstacles is a working space of that arm. Figure 6 show Workspace of a revolute robot it's same as space requires for their all efficient activities. [8] Working space of mounted arm is less. [26] Cover entire room for their working. [18] An arm mounted over table need half sphere of radius equal to a robotic arm.

D. Kinematics

Robotic arm have a different joint of Cartesian, articulated, spherical and parallel etc., we arrange them for controlling a motion of a robotic arm. Robot kinematics is use for finding the movement of multi-axis and multi-degree of freedom. A chain of kinematic is used for making structure of robot; Figure 7 show arm kinematics and motion planning. The priority of structure is different parts (rigid bodies) are properly connected at joint to provide excellent rotation, robotic kinematics use for know about velocity, acceleration and position of all rigid body part in the robotic system and decided all control movement. It also calculate exact force, torque, decide the role of motion, inertia and mass at every part of a robotic arm for making an efficient arm. [28] The kinematics having equation and transformation between working space and coordinates of Montana outlines formula, this method decide fixed body, motion and rate of change of connected coordinates. Its help to maintain arm and use for velocity analysis, it's limited to one analysis. [29] Non-redundant robot configuration solved kinematics problems, but it's difficult to solve accuracy and dynamic effect, this problems solved by redundancy. A redundant robot cannot work in a unique manner so it's difficult to define next move of redundant robot. This problem solves by real vision function monitor. [8] The distributed positioning is used for human arm motion, joint interfere measurement called kinematic fatigue this concept also known as integral kinematic involvement, in this work they discussed some support and results. In this paper, they give some new models for solving problems and proposed some local new redundancy solutions they help to control the movement of a robotic arm and modeled and controlled joints. [30] For solving trajectory planning they use inverse kinematics and get final position for desired goal, its first find out goal and predict the destination and then follow the trajectory for the goal, supplying both desired position and desired velocity. [13] Testing directions is much faster than inverse kinematics. It's used for determining direction vector location and use for reducing computation angles between the direction and the axis. [14] Fuzzy reasoning use for solving present inverse kinematic approach, different behavior for same coordinates and path like a pickup, writing etc., they try to develop different arms trajectory and proposed a structure of an arm that look like a human arm and also behave like a human arm. [31] They present an idea that is robot learn from human motion so the capability of learning and performing new motion is very high this type of learning called imitation learning, using kinematics maintain motion data and modified it time to time by capturing data from a human arm and there torque is minimum. [23] In this inverse kinematics used in an algorithm for hand catching point mapping, most of the time inverse kinematics works as a default frame of the robot system. But they added some change by mounting cameras and then it not work on a single fixed pre-decided model it change using vision and inverse kinematics.

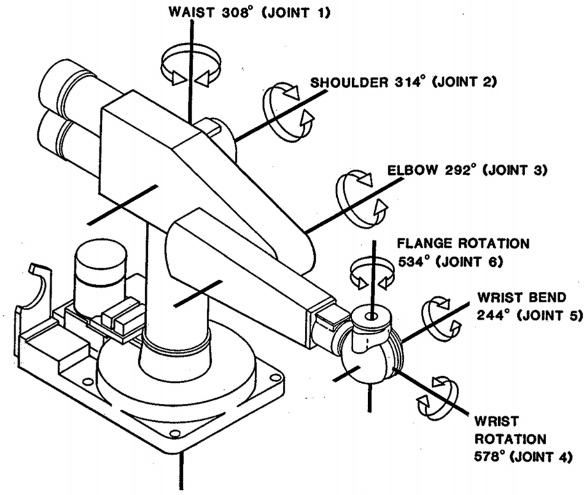

Figure 7. Arm kinematics and motion planning [32]

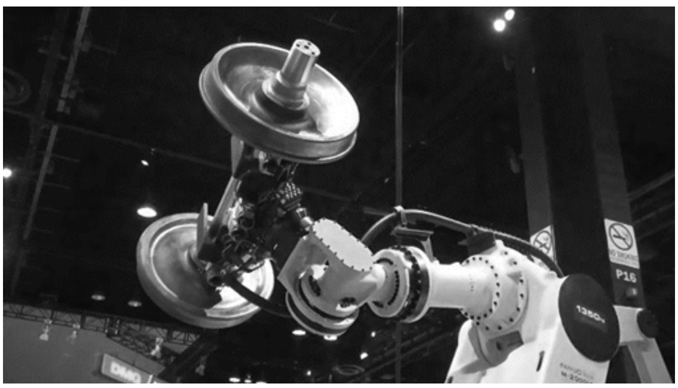

Figure 8. Weight lifting robotic arm [33]

E. Payload

A payload is a simply the weight that arm can be able to carry and movement possible with weight, Figure 8 show weight lifting robotic arm. It is important to maintain payload at the time of arms implementation and check how much weight arm can be lifted. It also includes weight of the entire arm with tools and dependent on a use of an arm in industries robotic arm use for heavy works so it should be high in industry arm and for normal use payload is 1 to 10 kg. range. Some tools are used for proper weight calculation. [11] The robotic arm have maximum payload 500gm., [12] the arm able up to maximum payload 7kg. industries arm having more payload than others.

F. Speed and Acceleration

It defines by each part and total, linear and angular movement. [34] In this paper flexible and active motion obtain by using a visual result of present task due to this perform real time high-speed catching, high-speed vision camera system and generate fast result during an experiment. [35] Robotic arm can be reached speed movement with a max velocity of 8m/s. [36] Robotic arm all joint can work at very high joint speed of 360degree/s, they make arm and finger high speed. [15] The closure of the fingers depend on the robot catches flying objects at different speed. The starting times for finger motion varies with the incoming object speed, i.e., approximately 33 ms (top) versus 50 ms (Bottom).

Acceleration changes speed at each degree and calculate regarding number of axis and degree of freedom, it decides final speed of an arm at any distance. [34] Robotic arm can be reached maximum acceleration upto 58m/s2. [35] This arm can help in reactive movement using acceleration and velocity of 13m/s. [15] its maximum acceleration for all the joints is 860degree/s2. [37] Robotic arm can change acceleration according to the situation with velocity 7m/s. [23] initial acceleration start at 0 to 9.81m/s2 and change according to camera results.

G. Accuracy and repeatability

Accuracy and repeatability are important factors in complete robotics performance depend on it, and accuracy of a task is needed for performing any task in exact time and a single attempt and repeatability is when we repeat the same task again and again and still got the same result, Figure 9 show Accuracy and repeatability over 10 measurements. [10] This arm working at distance measuring, working area 6300cm2 with an error of 10mm, for simple objects this accuracy is sufficient but for a complex object it's not good for preplanning methods, so this monitoring system have limited in accuracy, efficiency and repeatability. [38] In this robotic arm three laser sensors used for distance measuring, range of every laser between 80-180mm, it gives three accuracy value at three different times, 1ms with an accuracy of 1mm, 10ms with accuracy of 0.33mm and 100ms with an accuracy of 0.1mm. [12] One can observe the high accuracy less than 10cm achieved even for the early predictions, with the major error occurring in the X-axis direction of the throw. [39] Robot accuracy change with velocity and measuring distance it give error between 3 to 10 percent so accuracy and repeatability are not good. [14] Robot have excellent accuracy only 2mm error in 140mm work area, also have good repeatability. [15] Robotic hand can change estimating accuracy according to catch positions, also maintain the trajectory of ball and coordinates system. [21] This robot can improve accuracy according to distance and time, 12cm after 0.4 sec and improve according to time and reached to final accuracy about 0.5cm. It starts with a planning work so it little slow in a start. There is any fixed value for a catch success rate is not given. If any catch was performing by arm then result generate before 1.6-2sec and catch accuracy about 1.5cm, for any robotic arm for catching should have an accuracy of 2cm in 5ms. [40] This robot use all parts for tracking trajectory and performing with high accuracy. [18] The position and orientation accuracy of predictions encompassing 0.5 to 0.0 s. The repeatability of this LWR 4+ is 0.05 mm.

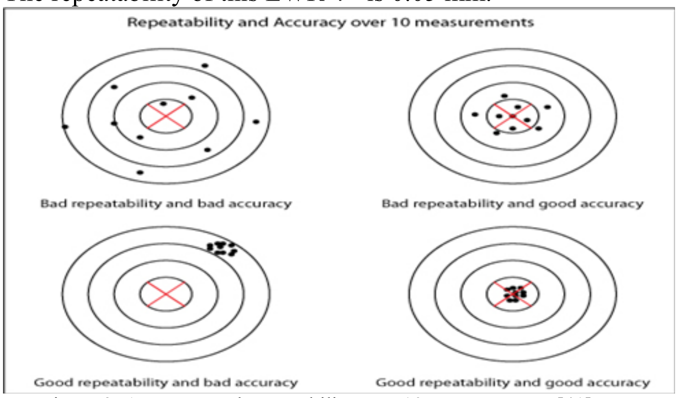

Figure 9. Accuracy and repeatability over 10 measurements [41]

H. Motion Control and drive

For any specific work arm may at any point in working space then this is not possible with a single movement, if all joint working then we reached all point. [10] Robotic hand design for holding an object like a human hand and typical deign of human finger also needs for specific motion. [11] Robotic arm having six joint and hand for controlling them they design multi-motion control functions. [42] Robotic system design with all advanced structure and new technologies like advanced computer vision control and multi-motion control. [14] Arms motion controller used for real-time trajectory planning.

Robots are derived by a different type of motors, according to the use of joint motor choice for joint. They connected by two type of connection first direct when motor direct connected at joint second indirect when motor connected single or multiple gears. [10] Robotic arm is very flexible and all joint connected by micro motors and human-like hand with

5 fingers all have 3 joints also connected with micro motors. [43] This robotic arm is testing in a laboratory all flexible joint connected with DC motors so that arm can work in different loads. [29] Robotic arm all joint connected by DC motor and wrist driven by high-speed DC motor. [35] Robotic arm was working at their developed mechanism, a mechanism is high-speed manipulator FALCON based and parallel driven. [36] Robotic arm consisting brushless DC motors the driven with the help of tooth belts and harmonic drive gears. [20] Robotic arm supported by a support bar, the driven by DC motor and rotate 360 degrees. Gears are also used to increase torque and to reduce speed as a controller. [40] Robotic arm electronic control system was working in both close loop as well as the open loop, it use 2ATMEGA16 L microcontroller and 7 L293D motor drivers. Each motor control 2 DC motor one is in anticlockwise and other is in clockwise all signals come from a microcontroller. [18] The predicted end-effector pose is mapped into the attractor of the DS based controller that drives the hand toward the target, its help in the predicted catching time and reached at the same time using timing control.

III. Research Gaps

We have discussed robotic arm using different parameters. Now we discuss research gaps using parameters - numbers of axes, degree of freedom, working envelope and working space, kinematics, payload, speed and acceleration, accuracy and repeatability, motion control and drive. There is an ongoing development in the field of number of axes but this field has experienced very little progress. Degree of freedom is a very important part of a robotic arm. In this field, every year, a new technology evolves for improving it, but there is a gap, because there were 6 DOF arms available in 1996 and now most of the arms work on 6 or 7 DOF. Working space and working envelope are getting better with time, it started with a half circle and now the arm can easily cover half of the sphere, but it's possible to cover more than 70 percent. Sphere. Kinematics is also have some gap, some paper was not clearly specifying about it. Payload is very important for industrial arms it should be between 1kg. To 1000kg. Vary according to use. Speed and acceleration may be improved by using effective use of motor and rigid links. Accuracy and repeatability was not much improving before 5 years then they improve continuously. Motion control may become much better in few years. These are main research gap.

IV. Strategy

We discussed robotic arm, now we discuss some strategy how to make it better, by covering its gap and issues. The general motive of our survey works to develop a number of new methods for new problems. We try to work in multiple axis robotic arm, by solving all issues related to this, then we try to increase degree of freedom of a robotic arm by increasing number of joints and use them efficiently. After this work we go for working envelope and working space, they also increase by increasing number of axis and DOF, also make an efferent pattern for the arm to cover more area. We also try to increase kinematics, accuracy, repeatability, payload, speed and acceleration, using simulation tool we care about all factors. We also notice motion control also important for a good robotic arm.

Conclusion

We presented a survey of 20-year papers. Discussed robotic arm and there different parameters. Understand which factor affect the performance of a robotic arm and how it change a robotic arm in work efficient arm. Know how multiple axis uses to change the mass of an arm, DOF increased by simply by adding joints, working envelope and space should decide according to the situation, kinematics improved movement of the robot, speed and acceleration vary in different works, accuracy and repeatability is the important factor for any robotic arm. Also, use diagrams for making proper understanding of robotic arm. Then discussed gaps in research and issues, its use as a guideline for future research work, at last give suggestions how we try to improve a robotic arm by working on effective algorithms and simulations.

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