Dual Arm Manipulation – Replacement or Step Ahead than Human Arm

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Abstract--- In today's scenario, Parallel Manipulators (PM) are widely used due to many important characteristics over the serial manipulator. Human arm motions which similar to double arom configuration of parallel manipulator are always lucrative for researchers, as it replaces human workers without major redesign of work-place in industries. Human have its own limitation of rotation of arms beyond which they can't work. Revolute joints in manipulator have virtually no mechanical limits so that the workspace can be maximized. It is therefore required to understand dual arm manipulation in humans and resulting knowledge can be used for robot control in industries. This review aims to summarize the dual arm planar and spatial manipulators used in various industrial applications and proposing planar configuration for different industrial applications.
Key words: Parallela manipulator, Double arm manipulator

I. INTRODUCTION

In general, industrial robot manipulators can be classified into two types according to their configurations. The robot manipulator of the first type is called a **serial manipulator** as shown in fig.1.

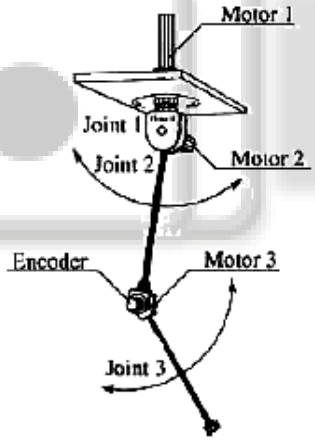


Fig. 1: Serial manipulator [1]

This type of manipulator consists of successive links, usually hinged at rotary joints which can be actuated in a coordinated fashion to position the end-effector. The other type of robot manipulator is called a parallel manipulator (Merlet [1], Tsai [2]). A parallel manipulator consists of two platforms, namely the base platform and the mobile platform. The base platform is fixed in space or attached to the end-effector of another robot. The mobile platform is movable with respect to the base platform as shown in fig.2. It is referred as close-loop manipulator because its end effectors are connected to the base by at least two independent kinematic chains.

Now a days, increasing trend of robots into environments originally designed for human use leads use of Double Arm Manipulator (DAM) i.e. anthropomorphic robots of human size that replace human workers without major redesigns of the workplace [3]. More advanced humanoid robots are expected to mimic human behaviours, act and manipulate objects in ways similar to humans. Recently, there have been several dual arm systems proposed for industrial use, with the motivation that dual arm systems occupy less space and have lower cost, as compared to two single arm units. Also the ability to replace human workers with robots without redesigning the workspace is used as a motivation.

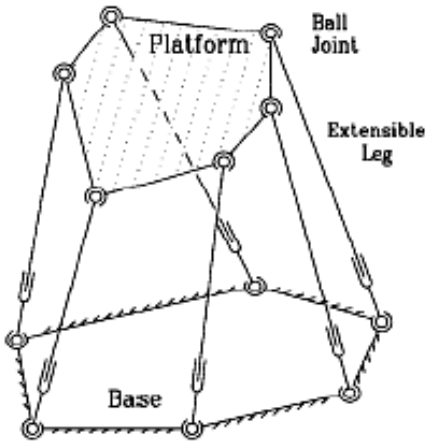


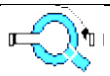
Fig. 2 Parallel manipulator [2]

In today's world, planar and spatial DAM are used in fields like: Medical robots, Military robots, Space robots, Robots in automobile industry, Ship building, Food and beverages, Ship building, Assembly operations, Pick and place operations, Machining plane surfaces etc. Planar manipulator means the links move in planes parallel to one another. While in spatial manipulator if at least one of the links of mechanism possesses a general spatial motion.

To do research in field of DAM, work is initiated for planar Double Arm Manipulator.

II. PLANAR AND SPATIAL DOUBLE ARM MANIPULATOR

Table 1 : Types of joints

Name	Representation	Description
Revolute		Allows relative rotation about one axis.
Cylindrical		Allows relative rotation and translation about one axis.
Prismatic		Allows relative translation about one axis.
Spherical		Allows three degrees of rotational freedom about the center of the joint. Also known as a ball-and-socket joint.
Planar		Allows relative translation on a plane and relative rotation about an axis perpendicular to the plane.

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As mentioned earlier, manipulator is a device for gripping and the controlled movement of objects. Robot manipulators are created from sequence of link and joints. The links are the rigid members connecting the joints. The joints are the movable components, which causes relative motion between adjoining links. The Joints, which are used to construct the manipulator, are of two plus three (i.e. total five) principal types [4]. The following table describes these five types of joints.

Planar DAM have 1, 2 or 3 DOFs while Spatial DAM have DOF > 3.

A. Planar double arm manipulator: From table describing types of joints, planar manipulator uses combination of revolute, prismatic and/or planar joints for manipulator modeling based on requirements. Table 1 describes that all these joints have 1 DOF.

Different configurations are possible for DAM using different combination of joint types available.

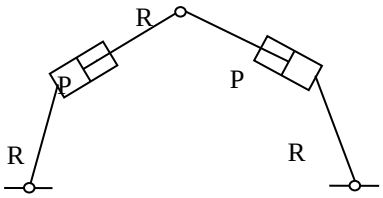

Fig. 3: 2DOF double arm manipulator with 3 R and 2 P joints

Fig.3 shows one of them. It consists of 3 revolute joints (R) and 2 prismatic joints (P).

Degree of freedom (DOF) indicates the number of independent relative motions (both translational & rotational) a pair can have. Total DOF of manipulator is calculated using Grumbler's criterion as follows:

$$DOF = 3(N-1) - 2J - H \quad (1)$$

Where,

DOF = degrees of freedom

N = Number of links

J = Number of joints having one DOF

H = Number of joint having two or more DOF

For proposed manipulator as shown in fig.3, degree of freedom is calculated as,

$$DOF = 3(5-1) - 2(3+2) - 0$$
$$= 2$$

Another possible configurations of planar double arm manipulator with use of revolute and prismatic joints are shown in fig. 2 and 3.

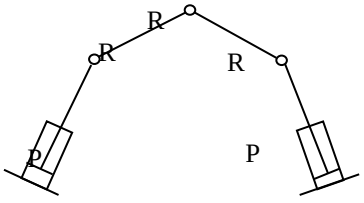

Fig. 4: 2DOF double arm manipulator with 2 P and 3 R joints

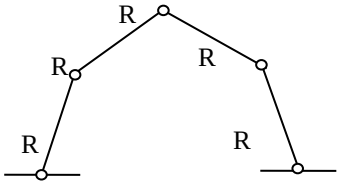

Fig. 5: 5R 2DOF double arm manipulator

Both configurations of fig.4 and 5, have 2DOF. In possible configurations shown earlier, prismatic joint (P) have 'to and fro' motion along particular direction. This limits movement of manipulator. And workspace one can get is less. In comparison to this, revolute joint (R) have fully rotational 360 degree movement and covers larger workspace compare to prismatic joint. Collision detection is required to check for revolute joints, as chances of link collision is high in this case. Even though collision is detected, by improving design of links, one can able to maximize workspace.

So, to cover maximum workspace, 5R DAM manipulators are best suited for applications like:

Fig. 6: construction work [5]

Machining plane surface

Assembly work

Fig. 7: Electronics and semiconductors [6]

Welding

Pick and place operation over plane surfaces

Fig 8 Food and beverages [6]

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B. Spatial double arm manipulator:

Limitation of planar manipulator is that it works only in a plane. But in some all applications may not require only planar configurations like bend metal parts, fold cartons into predetermined shape, gearbox assembly, car painting in industries as well as some household applications like folding laundry, dish washing. To work with these type of environment, spatial manipulator of human arm configuration is required.

Two types of joints that provides spatial configuration are spherical (S) and cylindrical. General spatial manipulator considered for applications like medical surgery, construction work, military robots, space robots, etc. similar to human arm.

Fig.9 shows this configuration with attached joint.

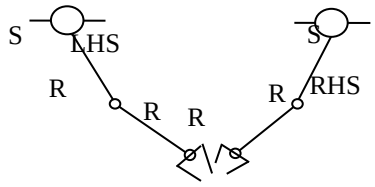

Fig. 9: Spatial double arm configuration

C. P.M. George et al. [4] has done optimization of

Description of figure says that spherical joints placed at base frame, improves workspace environment from 2D to 3D. Spherical joint allows three degrees of rotational freedom about the center of the joint.

DOF of special manipulator is generally higher than 3. For left or right limb of configuration shown in fig.9 DOF is calculated below.

$$DOF = 3(4-1) - 2(2) - 1$$
$$= 4$$

DOF 4 means the manipulator works in 2 more directions in addition to planar motion. The revolute joints of both limbs at location of end-effector can be combined to make it closed form manipulator. This closed form manipulator works in a way similar to human arm works for single operation. Applications of spatial manipulators involves: Medial robots

Fig. 10: medical robots helping in surgery [7]

Automobile industries
Ship building
Aircraft and Aerospace industries
Space robots

Other combinations are also possible for both planar and spatial configurations as per application required.

Fig. 11: Robot – welding automobile parts [5]

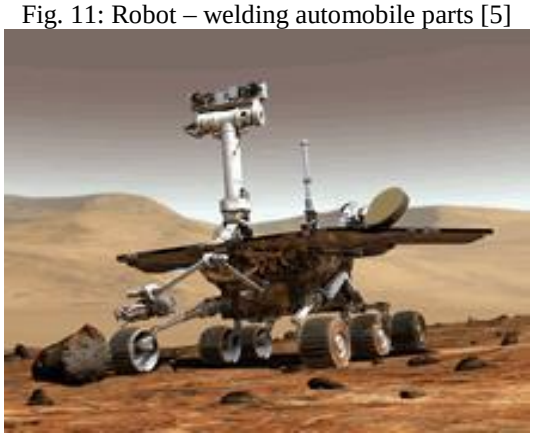

Fig. 12: Space robots [5]

III. SUMMARY

Future direction in robotic systems particularly in dual arm manipulation, will be the integration of elemental theory with tools of system using different methodologies. These will involve Trajectory planning and path planning for movement of parts, assembly operation, pick and place operation by avoiding obstacles. Motion planning for smooth movement of manipulators with desired velocity and acceleration with consideration of time. All these factors for dual arm manipulator helps in getting the desired objective of stated applications.

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