Perspectives in Science (2016) 8, 513—515

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Modelling and simulation of basic robotic configurations using D—H parameters based adaptive modules☆

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Received 20 February 2016; received in revised form 15 June 2016; accepted 15 June 2016
Available online 5 July 2016

KEYWORDS
Serial manipulators;
D—H parameters;
Adaptability

Summary Selection of a suitable robotic manipulator, out of the available conventional configurations, is one way to employ a robot. However, with the increasing applications of robotic assistance, the concept of task-oriented customised design for prescribed working locations in a given environment, has got attention of several researchers. One of the challenges in this direction is the realisation of specific designs, involving unconventional values of robotic parameters. This paper discusses the D—H parameters based adaptive modules, which can be adjusted according to the given values of robotic parameters. The modules are available in three types with similar architecture. The details of this basic length unit, adaptive twist unit and extended length unit are discussed. Focus of the work is to validate the adaptability of the proposed architecture through the modelling, simulation and development of standard configuration.

Introduction

Modularity add the concept of flexibility in fabrication process irrespective of the field it is used in i.e. in construction, nuclear plant, big structures, etc. In robotics also, it adds the dimension of flexibility and ease of transportation with onsite assembly. Researchers worked in area of robotics found out the way to design the reconfigurable and self-reconfigurable robots using modules. The modules are broadly divided into four categories: Chain systems, Lattice systems, Truss systems, and Free-Form Systems (Gilpin and Rus, 2010). Due to their capability of changing configurations autonomously and unmanned work conditions the module is heavily equipped with electronic components and has a very complex structure. Their mechanical performance is low, and is not advisable to use these for serial manipulators which have some load at its end effector. Therefore, researchers explored the area to design modules for industrial applications. Various robotics systems proposed by researchers which can attain different

☆ This article belongs to the special issue on Engineering and Material Sciences.

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http://dx.doi.org/10.1016/j.pisc.2016.06.006

configurations conventional manipulators (Acaccia et al., 2008). These configurations can do a set a tasks in a particular environmental constraints. If set of task space locations and environmental conditions changed, it may find a difficulty to perform the job in satisfactory manner. The manipulator has to be designed according to the task assigned. These task-based designs have such parameter values which are hard to map on hardware even using existing modules.

So it is important to design the modules in such a way that it can communicate the task-based design while fabricating manipulator. This work is an attempt to bridge the gap between task-based design and corresponding assembly of the manipulators through modularity involving D—H parameters. The next section describes the architecture of modules used in this work and ''Twist angle adjustment unit'' section illustrates the methodology used in this paper.

Parameters based modules

A hollow cylindrical body with bevel gears at its bottom end is the architectural arrangement of this first unit of module. The motor consisting an encoder and a gear box is fitted inside this unit. The important aspect of the gear box is the direction of motion transmission. With this arrangement, the power generated by the motor is used to rotate the link about an axis perpendicular to the hollow cylinder. Since, the actuator is fixed inside the link, the basic length of this unit needs to be equal to at least the length of the motor. The flange at the upper end is to be attached with the twist angle adjustment module. The cut section of this basic length unit is given in Fig. 1. The connectivity of the link with the other links needs the adjustment of twist angles and variations in link lengths. The other two components provide the corresponding variations.

Twist angle adjustment unit

The design of twist angle adjustment unit is suitable to integrate both types of twist angle arrangements. The basic length unit is attached to the flange of this unit. While assembling the two parts, the twist angle can be adjusted for the cases with successive axes of rotation in parallel planes, i.e. parallel or skew axes. Total number of holes designed on the flange decides the resolution of twist angle change i.e., if there are 36 holes on the flange, then the resolution is 10°. A gear box with a worm and a half spur gear is used to alter the successive axes of rotations which are not parallel. Another basic link unit is attached to the base of half spur gear. This self-locking gear mechanism is designed for specified number of modules. The module can be configured manually to incorporate the corresponding design outcome of the twist angle.

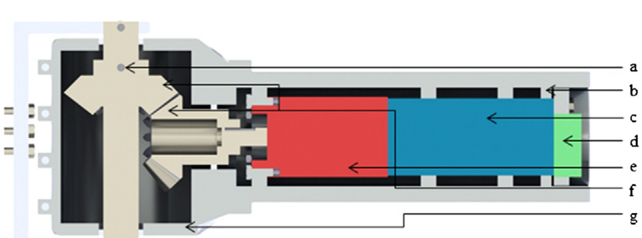

Figure 1 Modular component with architecture details. (a) Gear shaft, (b) motor casing, (c) motor, (d) encoder, (e) reduction gearbox, (f) bevel gears.

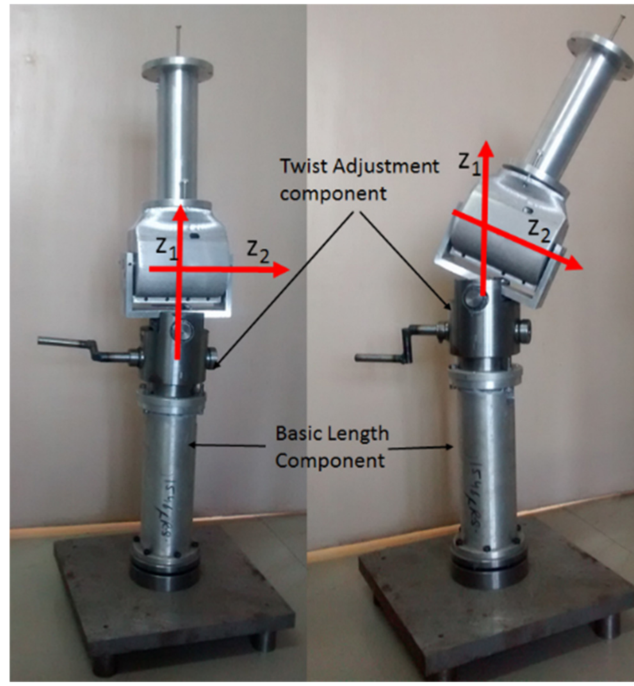

Figure 2 Variation in twist angles.

This module is used to adapt the twist angles between two successive axes of rotations. In conventional manipulator configurations, the values of twist angles are normally 0° or 90°. However, for larger solution space and thus, for better flexibility, no such constraint is defined in this design variables. The task-based design process can result into any allowable discrete value.

Fig. 2 shows the two variations in twist angle arrangement when the two successive axes of rotation are intersecting each other. The component has flexibility to adjust the twist angle in two different ways discussed in Singh and Singla (2015).

Case study

The modules discussed in the previous section have divided into three different types. Divisions of the modules are according to the actuator inserted in the basic length component and the strategy to select the actuators is not included in the work. The focus of the work is to validate the architectural design of the discussed modules. These various 3-R configurations discussed in the works of Ottaviano et al. (2007) and Zein et al. (2006). All the basic configurations have twist angle either 90° or 0°. But the twist angle adjustment component, discussed in the previous sections, provides the flexibility to develop the manipulator having twist angle other than 90° or 0° and that too in two different planes. Fig. 3 shows development of one of the basic configurations using modules and corresponding D—H parameters.

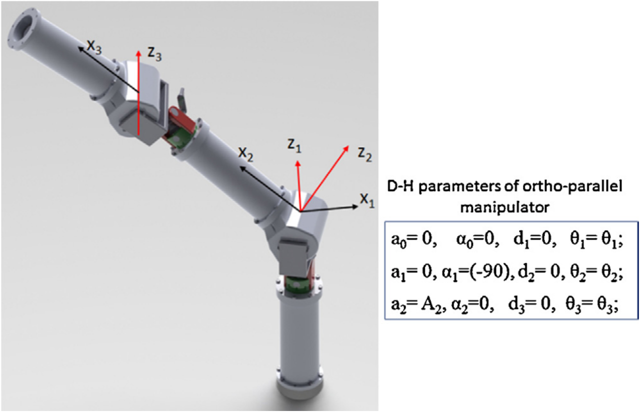

Figure 3 Basic 3-R configuration development using modules.

In this configuration, Z_1 and Z_2, two successive axes of rotations, are perpendicular while intersecting each other. Z_2 and Z_3 are parallel to each other. Using the twist adjustment component both the arrangement have successfully implemented. Similarly, the other basic configurations have been successfully developed. These modules have been utilised to realise the designs having in-conventional twist angle values.

Conclusion

This work illustrates the utilisation of modules while realisation manipulator configurations. The architecture of modules has been discussed and the flexibility of modules to accommodate un-conventional values of D—H parameters have been shown. A conventional configuration has been developed using the module library.

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