Computer Science 773

Robotics and Real-time Control

ROBOT GEOMETRY

LINKS AND JOINTS.

A robot's skeleton is constructed of rigid (usually) members called *links* which are connected by mobile connections called *joints*.

The links are usually rigid so that the robot can be controlled effectively. Flexible links would be good, because they're lighter and cheaper, but they are difficult to manage :

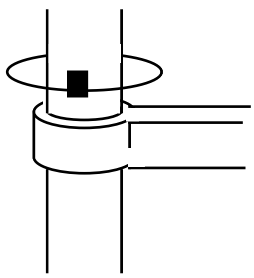
- They make the geometrical calculations much harder, because they bend, so the geometrical properties don't remain constant as the robot moves.

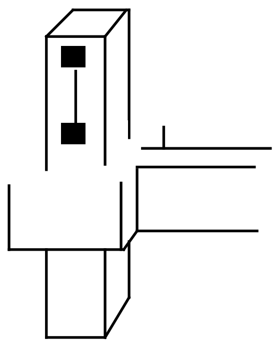
- Even worse, the bending depends on the weight of any load that the robot is carrying and on the instantaneous geometrical configuration (which changes bending moments), so it has to be recalculated continuously.

There is research in progress on how to use robots with flexible links, but so far it doesn't seem to have worked through into production.

Primitive joints are components with an axis and one degree of freedom. (More complicated joints with two degrees of freedom – such as ball-and-socket joints – can be built, but most robots can be described in terms of primitive joints.) There are two main types, differentiated by the relative directions of the axis and the motion.

- In a revolute joint, rotary motion occurs around the axis;
- In a prismatic joint, linear motion occurs along the axis.



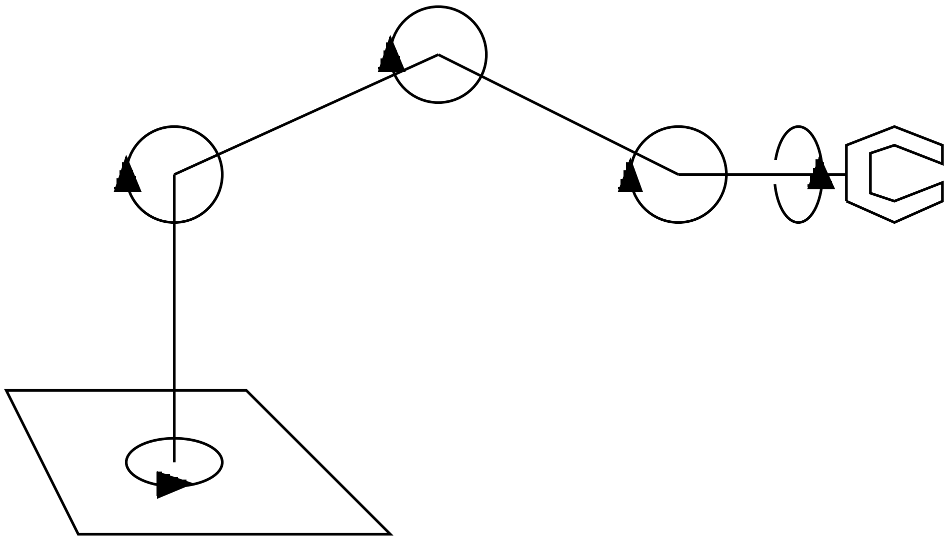


The state of each joint can be defined by giving a single coordinate, which measures the displacement (distance or angle) of the motion from some arbitrary standard position.

Other sorts of joint can be constructed by combining these elements in various ways (for example, as a screw), but these are the most important elementary joint types.

OPEN-CHAIN AND CLOSED-CHAIN ROBOTS.

Links and joints alternate in a robot's structure. The most common robot is constructed as a simple chain of links connected at revolute joints :



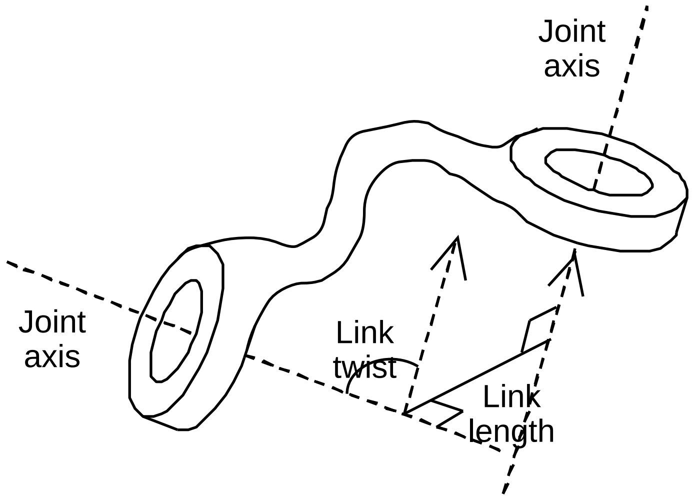
That robot has five degrees of freedom; some also provide means for varying the angle between the gripper axis and the final link in one or two directions (pitch and yaw).

The parameters of the joints in that diagram are all independent; you can change any one of them without changing any others. That structure is called a *simple kinematic chain*. Some robots are built with configurations of links and joints which have closed cycles in them; these are not so simple, and they are more difficult to treat mathematically. For any such robot, it is possible to define an equivalent (more or less, depending on what you want to discuss) open-chain robot, so we won't miss anything serious if we only consider open-chain systems. We'll do that.

DENAVIT-HARTENBERG PARAMETERS.

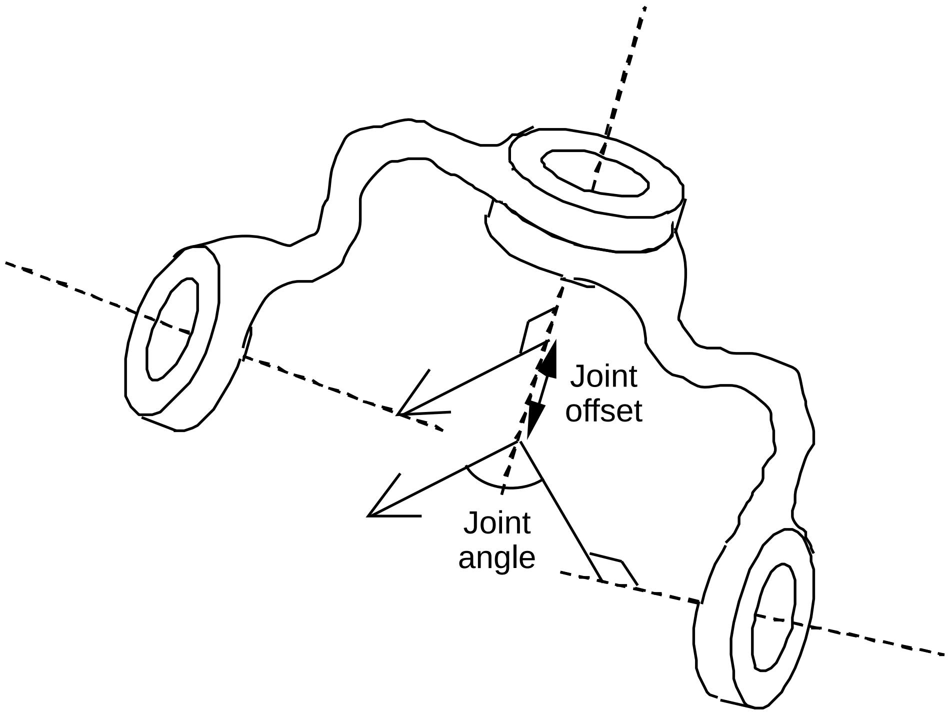
Using those ideas of links and joints, it's possible to define a rather neat set of parameters with which one can specify a robot's configuration. There are several ways to do that; I'll describe the Denavit-Hartenberg convention.

First consider the properties of a link. The diagram below shows an arbitrary link, drawn in an attempt to show that there need be nothing neat and tidy about links.



Notice that the two link parameters, link length and link twist, are independent of the curious shape of the link itself, and depend only on the relative position and orientation of the two joint axes which the link connects.

We can now use those definitions to construct corresponding definitions for the joints. The diagram below shows two similar links (to save me a lot of time) concatenated by sharing an axis, with the joint offset and joint angle defined in terms of the two mutual perpendiculars which define the link lengths. Notice that for a revolute joint, the angle will change while the offset remains fixed; for a prismatic joint, the angle is fixed but the offset changes.



The four parameters – link length and twist, and joint angle and offset – are sufficient to define the configuration of a simple kinematic chain. Knowing these parameters and the position and direction of the base of a robot, one can work along the chain through links and joints as they appear, and calculate the position of the end of the chain.

Alan Creak,
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