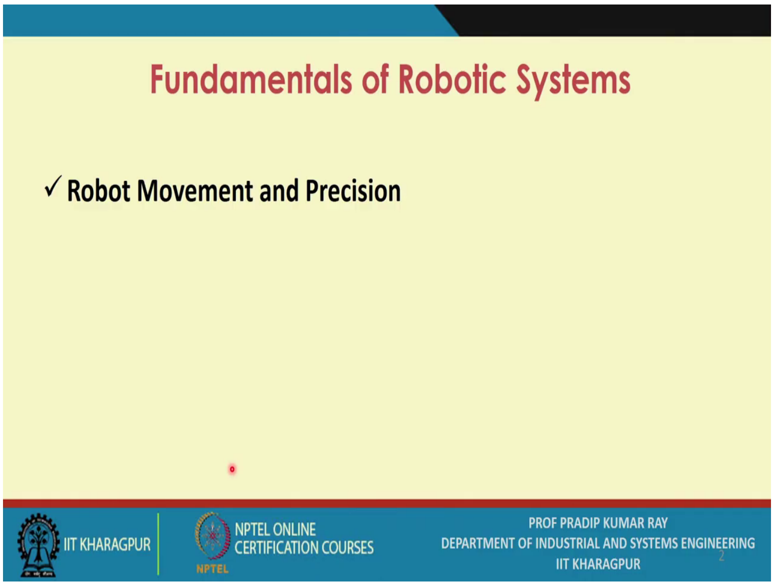
Automation in Production Systems and Management
Prof. Pradip Kumar Ray
Vinod Gupta School of Management
Department of Industrial and Systems Engineering
Indian Institute of Technology, Kharagpur

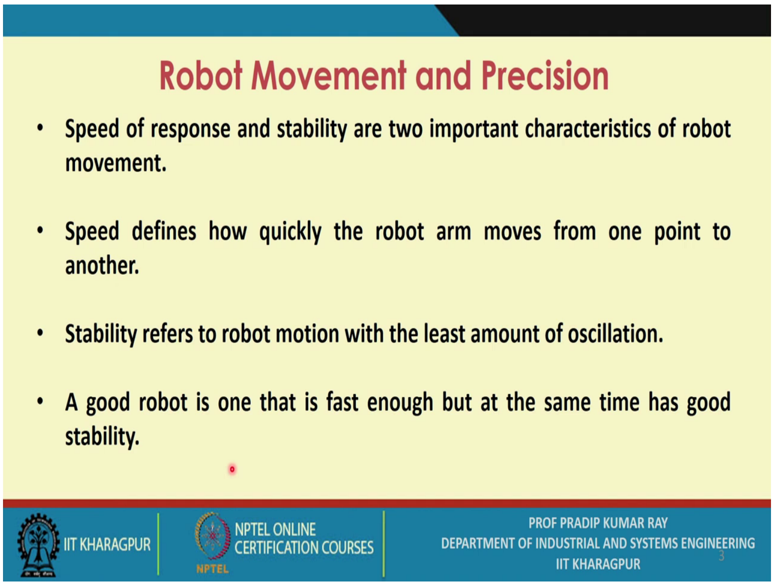
Fundamentals of Robotic Systems
Lecture - 47
Robot Movement and Precision

(Refer Slide Time: 00:22)



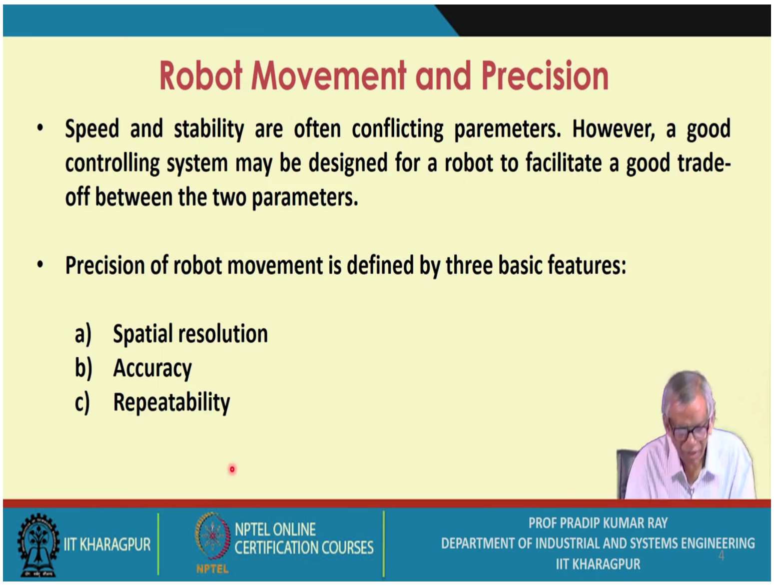
During this lecture session, I will be referring to one important aspect related to robotics that is Robot Movement and Precision.

(Refer Slide Time: 04:31)



Speed of response and stability are two important characteristics of robot movement. Speed defines how quickly the robot arm moves from one point to another. Stability refers to robot motion with the least amount of oscillation. A good robot is one that is fast enough but at the same time has good stability.

(Refer Slide Time: 07:15)



The speed and stability are often conflicting parameters, there is an inverse relationship. However, a good controlling system may be designed for a robot to facilitate a good tradeoff between the two parameters.

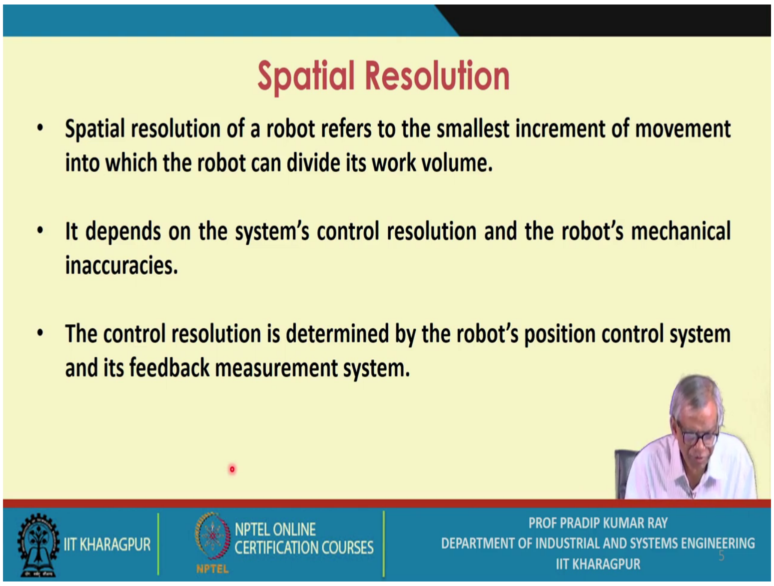
The precision of robot movement is defined by three basic features:

a) Spatial resolution

b) Accuracy

c) Repeatability

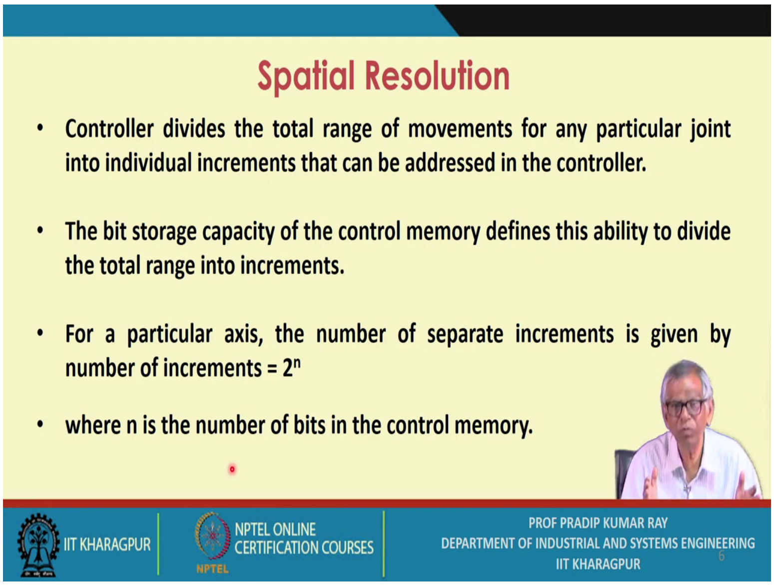
(Refer Slide Time: 11:49)



Now, I am going to explain all these three issues one after another.

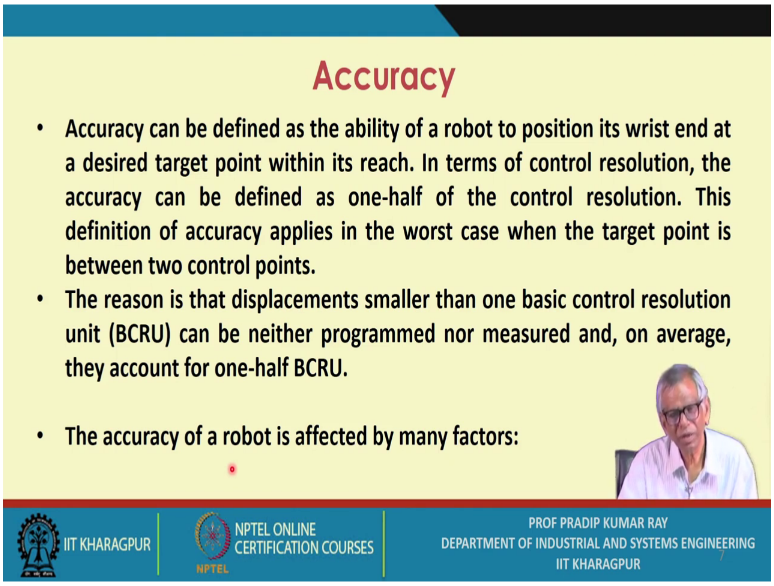
The spatial resolution of a robot is the smallest increment of movement into which the robot can divide its work volume. It depends on the system's control resolution and the robot's mechanical inaccuracies. The control resolution is determined by the robot's position control system and its feedback measurement system.

(Refer Slide Time: 13:55)



The controller divides the total range of movements for any particular joint into individual increments that can be addressed in the controller. The bit storage capacity of the control memory defines this ability to divide the total range into increments. For a particular axis, the number of separate increments is given by, number of increments = 2^n where n is the number of bits in the control memory.

(Refer Slide Time: 15:38)

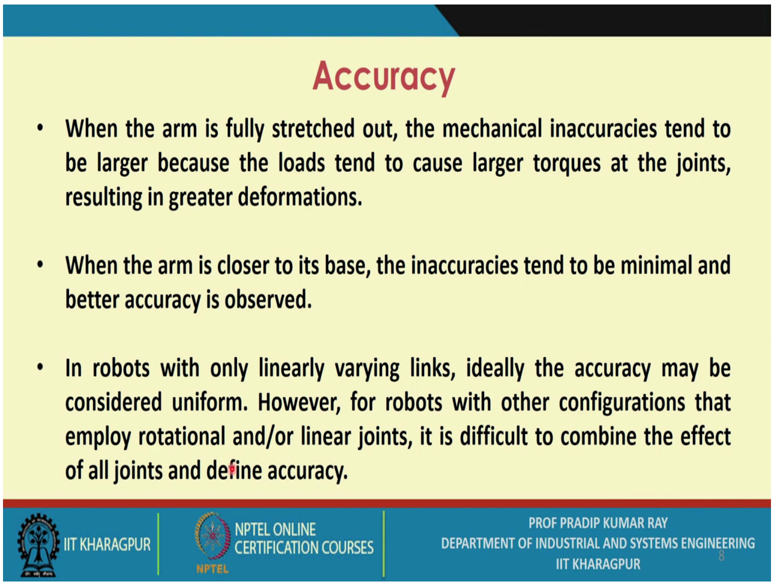


Second important aspect is the accuracy.

Accuracy can be defined as the ability of a robot to position its wrist end at a desired target point within its reach. In terms of control resolution, the accuracy can be defined as one-half of the control resolution. This definition of accuracy applies in the worst case when the target point is between two control points.

The reason is that displacements smaller than one basic control resolution unit (BCRU) can be neither programmed nor measured and, on average, they account for one-half BCRU. The accuracy of a robot is affected by many factors:

(Refer Slide Time: 19:40)

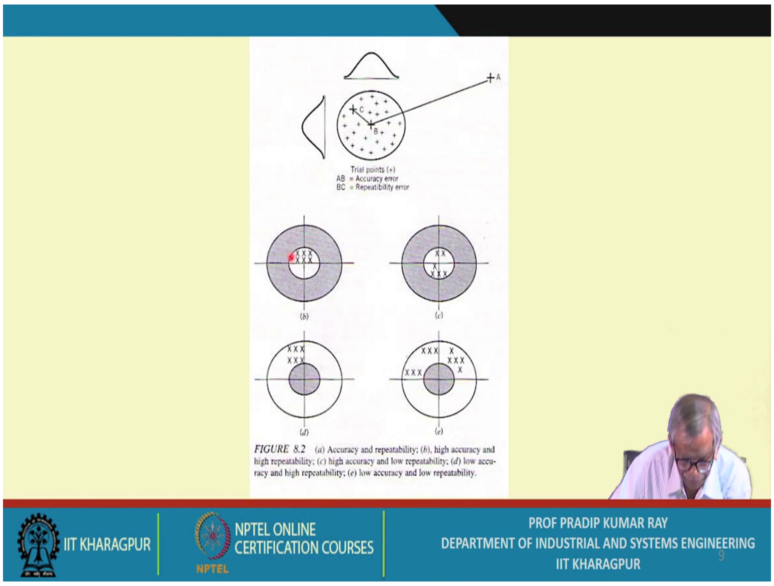


When the arm is fully stretched out, the mechanical inaccuracies tend to be larger because the loads tend to cause larger torques at the joints, resulting in greater deformations.

When the arm is closer to its base, the inaccuracies tend to be minimal and better accuracy is observed.

In robots with only linearly varying links, ideally the accuracy may be considered uniform. However, for robots with other configurations that employ rotational and/or linear joints, it is difficult to combine the effect of all joints and define accuracy.

(Refer Slide Time: 22:58)



This is the example. This condition shows that accuracy is very high and also the repeatability. The second condition is this one; it is like the bull's eye. You hit at the target, the inner circle is your target. It is the inner circle and the diameter is small and this is a large diameter; there is the outer circle.

This is accurate when you hit the target bull's eye, but among the points the difference is more. If you calculate the standard deviation, the standard deviation is more whereas, here this standard deviation is very less. Like here all these points are very near to one another the precision is very high, but it is off the target that is why it is inaccurate. This one is neither accurate nor precise.

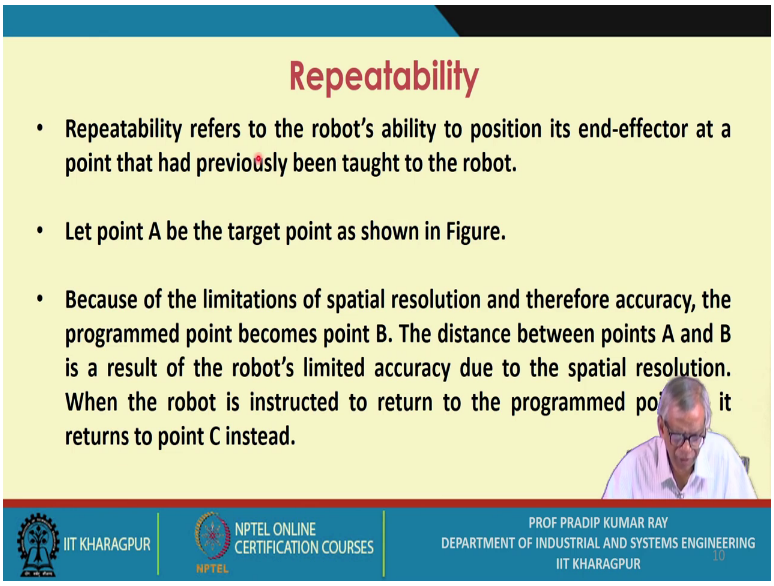
This one; you want to reach point C. You have reached B with the robot arm. But you are supposed to reach C. You are off the target. Difference is BC, it is basically the repeatability error.

How many points you get? Several points, and there must be a distribution. On one direction is another axis the distribution is this one x-y direction. The assumption is variability is occurring due to some common causes and the common causes are basically a part of the system.

You have designed the robot and there are certain levels of limitations as far as its repeatability is concerned. It just cannot be 100% precision. Yes, there is a variability as far as precision is concerned, but it is acceptable and there are common causes; that means it is a part of the system as such there is no assignable cause.

The first time you reach B, the next time you may not reach B, you may reach some other points. You may also reach certain points, you may reach C also, but that could be a random occurrence.

(Refer Slide Time: 27:49)

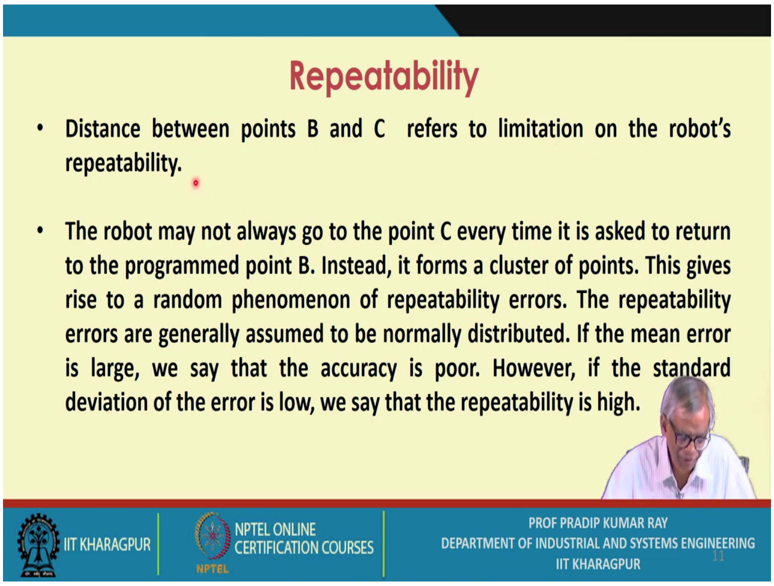


Repeatability refers to the robot's ability to position its end-effector at a point that had previously been taught to the robot.

Let point A be the target point as shown in Figure 8.2a.

Because of the limitations of spatial resolution and therefore accuracy, the programmed point becomes point B. The distance between points A and B is a result of the robot's limited accuracy due to the spatial resolution. When the robot is instructed to return to the programmed point B, it returns to point C instead.

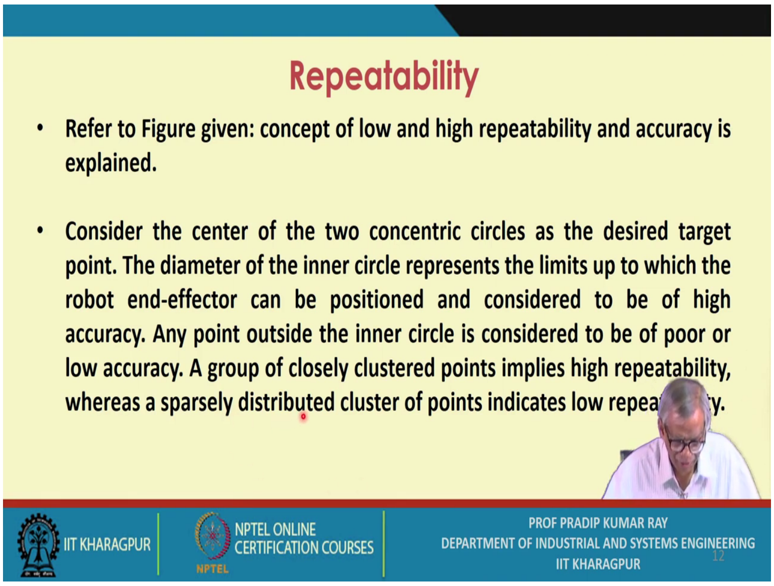
(Refer Slide Time: 28:50)



The distance between points B and C is the result of limitations on the robot's repeatability.

However, the robot does not always go to the point C every time; it is asked to return to the programmed point B. Instead, it forms a cluster of points. This gives rise to a random phenomenon of repeatability errors. The repeatability errors are generally assumed to be normally distributed. If the mean error is large, we say that the accuracy is poor. However, if the standard deviation of the error is low, we say that the repeatability is high.

(Refer Slide Time: 30:01)



We pictorially represent the concept of low and high repeatability as well as accuracy in Figure 8.2b, c, d, and e.

Consider the center of the two concentric circles as the desired target point. The diameter of the inner circle represents the limits up to which the robot end-effector can be positioned and considered to be of high accuracy. Any point outside the inner circle is considered to be of poor or low accuracy. A group of closely clustered points implies high repeatability, whereas a sparsely distributed cluster of points indicates low repeatability.

(Refer Slide Time: 30:28)