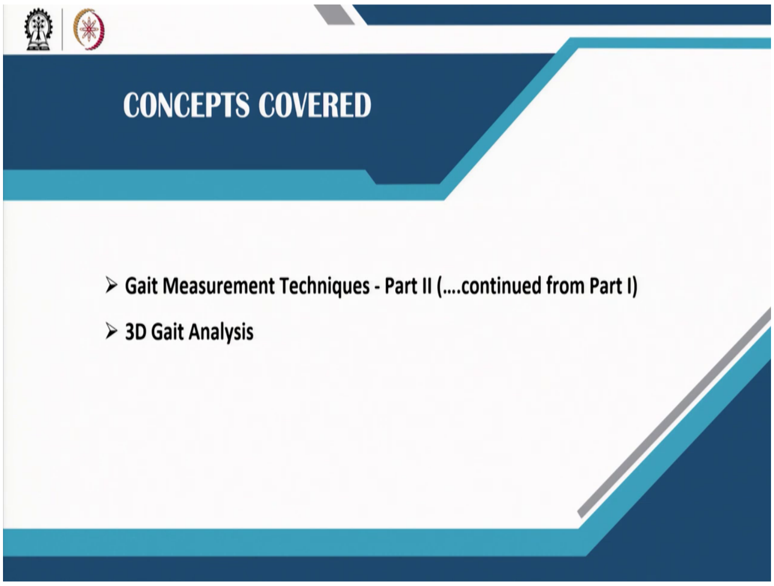
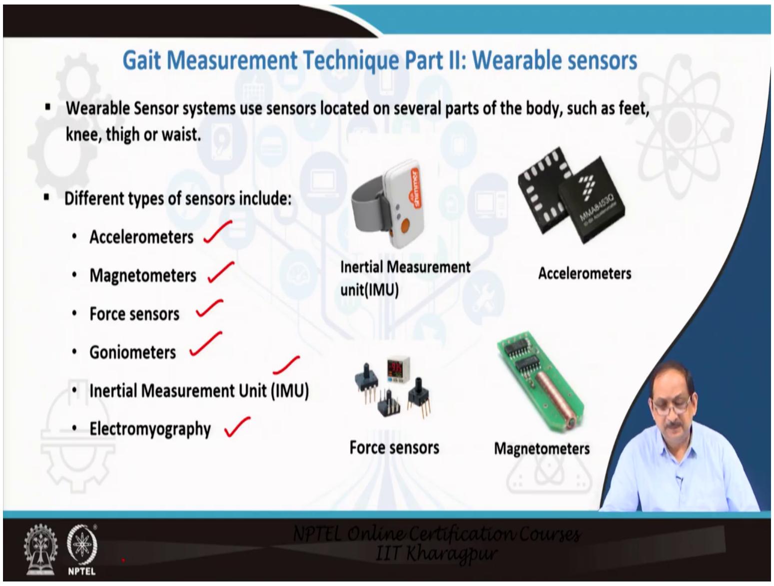
Biomechanics of Joints and Orthopaedic Implants
Professor Sanjay Gupta
Department of Mechanical Engineering
Indian Institute of Technology, Kharagpur
Lecture 17
Measurement Techniques of Gait Analysis Part II

(Refer Slide Time: 00:34)



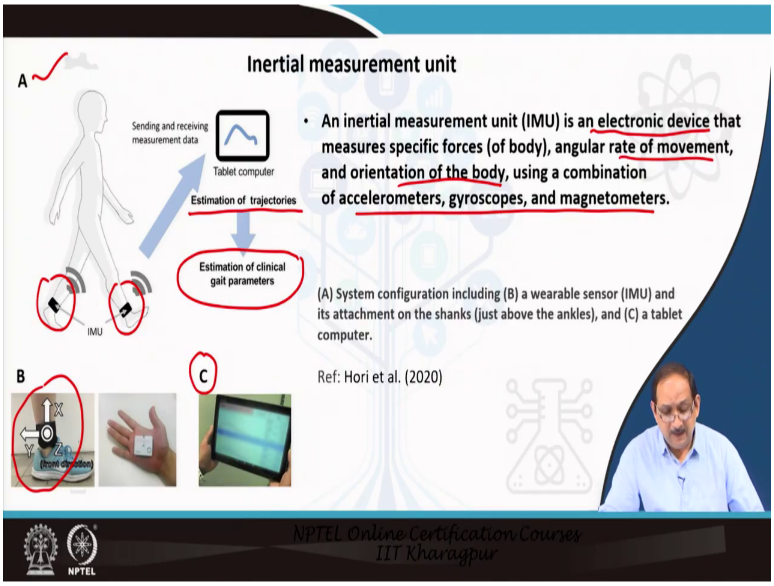
Good afternoon everybody. Welcome to the part 2 of the lecture on Measurement Techniques of Gait Analysis. In this lecture, we will be discussing about the gait measurement techniques in continuation to part 1. So, this is part 2 of the lecture and the second topic of discussion would be on 3D Gait Analysis.

(Refer Slide Time: 01:00)



We will be continuing our lecture on the objective measurement techniques for gait analysis in continuation to part one of the lecture, but in this lecture, we will be focusing on wearable sensors. Wearable sensor systems use sensors located on several parts of the body such as feet, knee, thigh, or waist. Different types of sensors include accelerometers, magnetometers, force sensors, goniometers, Inertial Measurement Unit, and electromyography or EMG. Some of these sensors are shown here in this figure.

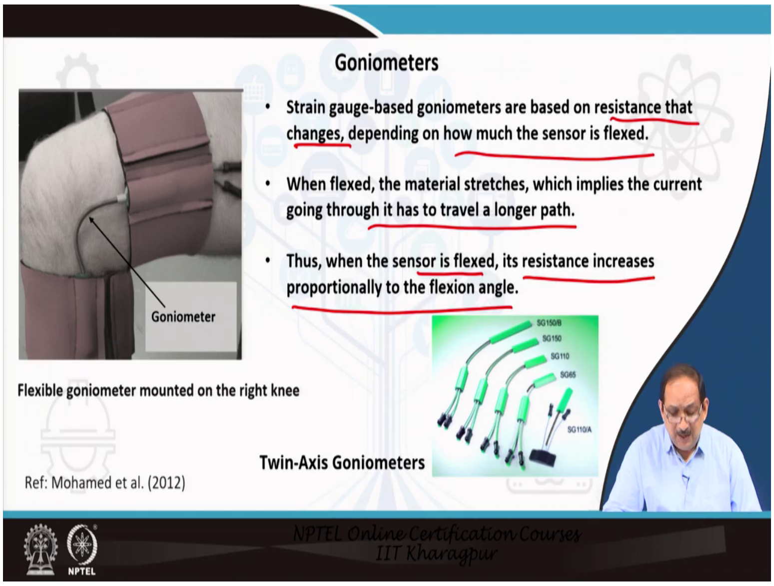
(Refer Slide Time: 01:59)



The Inertial Measurement Unit is an electronic device that measures specific forces of the body, angular rate of movement, and orientation of the body using a combination of accelerometers, gyroscopes, and magnetometers. Now, in the figure presented here, we see the system configuration of the inertial measurement unit that includes wearable sensors as indicated in the figure and its attachment to the shanks.

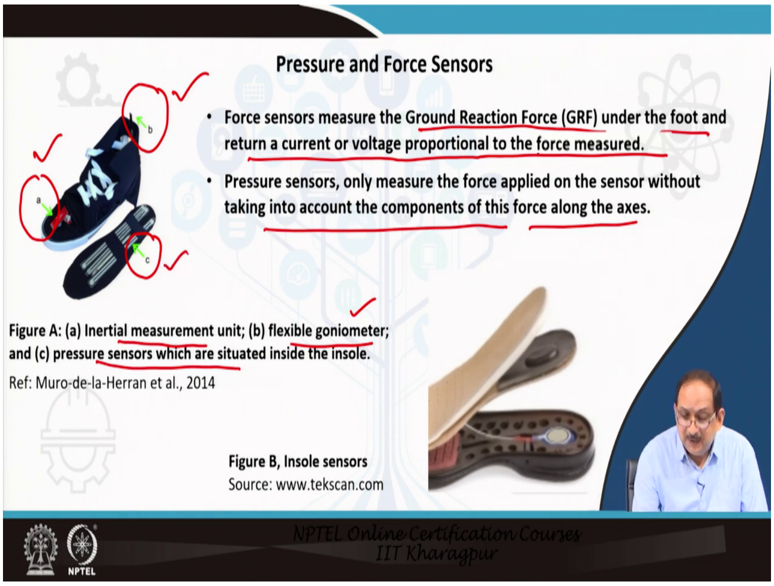
As you can see here in figure B, just above the ankle and the tablet in figure C. So, the IMU interacts with the tablet by sending and receiving measurement data, which is later used for estimation of trajectories and finally to evaluate clinical gait parameters. The Inertial Measurement Unit measures the angular rate of movement and acceleration data.

(Refer Slide Time: 03:37)



Goniometers are used to measure joint angles. Strain gauge-based goniometers are based on resistance that changes depending on how much the sensor is flexed. So, when it is flexed, the material stretches, which implies the current going through it has to travel a longer path. Therefore, when the sensor is flexed, its resistance increases proportionally to the flexion angle. On the left, you can see a goniometer fixed in a knee joint. So, a flexible goniometer mounted on the right knee is shown in the figure. Twin-Axis goniometers are also available, and they simultaneously measure joint angles in up to two planes of movement.

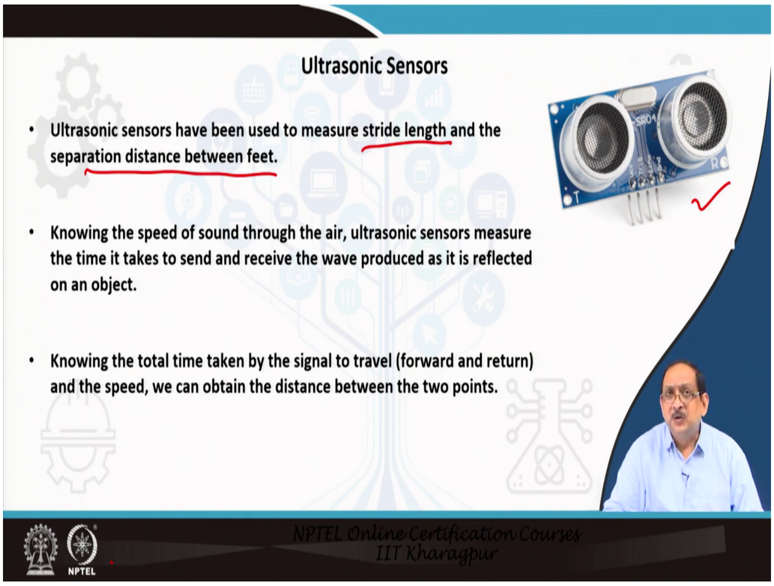
(Refer Slide Time: 04:53)



Now, pressure and force sensors are wearable sensors, and the force sensor measures ground reaction force under the foot and return a current or voltage proportional to the force measured, whereas pressure measures only measure the force applied on the sensor without taking into account the components of the forces along the axis.

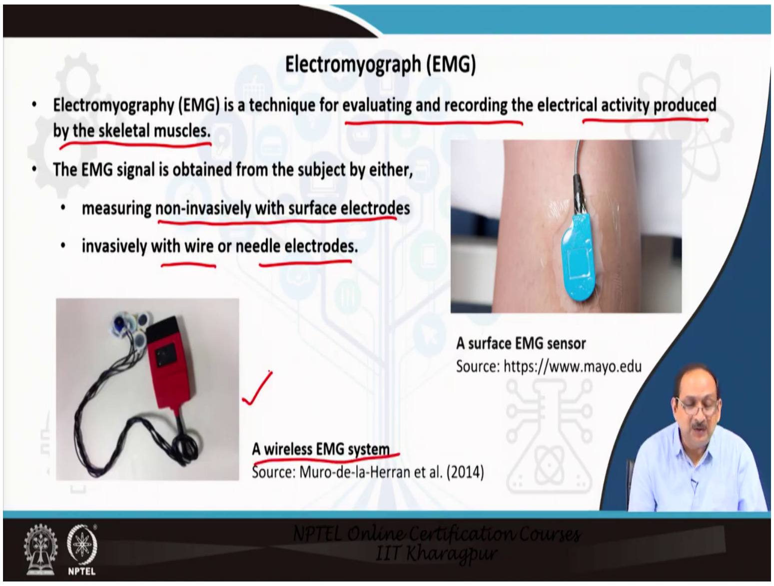
So, in figure A, we can see that there is an Inertial Measurement Unit mounted on the shoe. There is a flexible goniometer mounted on the backside of the shoe, and a pressure sensor is situated inside the shoe that is C. So, A is an Inertial Measurement Unit, B is a flexible goniometer, and C is a pressure sensor. A more detailed arrangement of the insole sensor can be seen embedded within the sole.

(Refer Slide Time: 06:21)



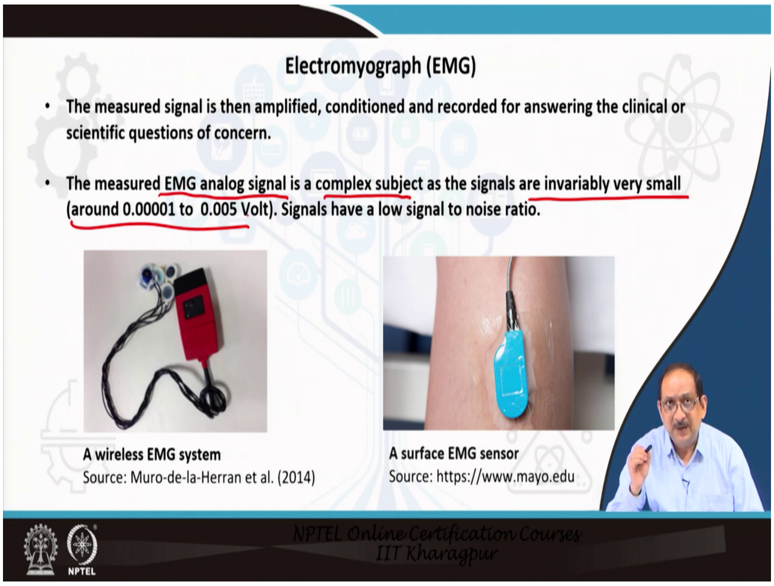
Ultrasonic sensors have been used to measure stride length and the separation distance between feet. On the right, you can see an ultrasonic sensor. Knowing the speed of sound through air, ultrasonic sensors measure the time it takes to send and receive the wave produced as it is reflected on an object. Knowing the total time taken by the signal to travel forward and return and the speed, we can obtain the distance between the two points.

(Refer Slide Time: 07:07)



Electromyography or EMG is a technique for evaluating and recording the electrical activity produced by the skeletal muscles. The EMG signal is obtained from the subject by either measuring non-invasively with surface electrodes or invasively with wires or needle electrodes. So, typically wireless EMG system is shown here on the left, and a surface EMG sensor figure is given on the right.

(Refer Slide Time: 08:00)

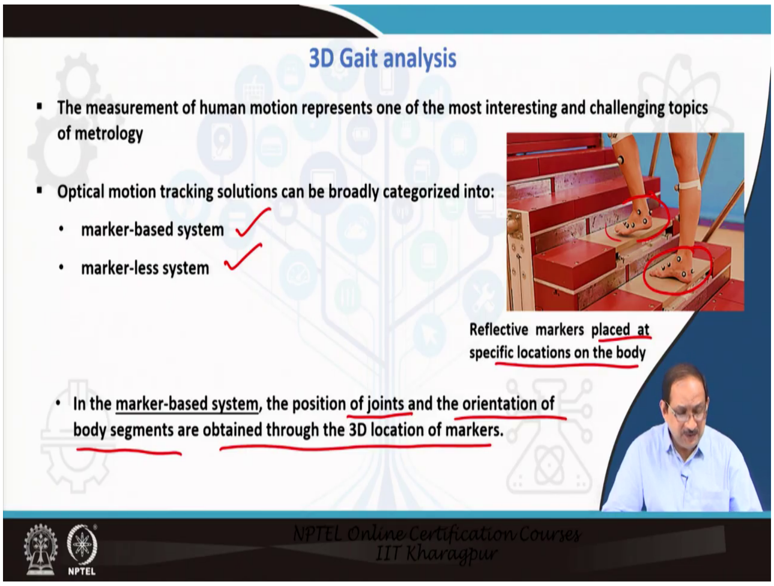


The measured signal is then amplified, conditioned and recorded for answering clinical and scientific questions of concern. The measured EMG analog signal is a complex subject, and the signals are invariably very small in microvolts or even less. So, the signals have a very low signal to noise ratio.

(Refer Slide Time: 08:37)

A commercially available wearable sensor system is presented in this slide, as you can see, and it is based on inertial sensors.

(Refer Slide Time: 08:54)

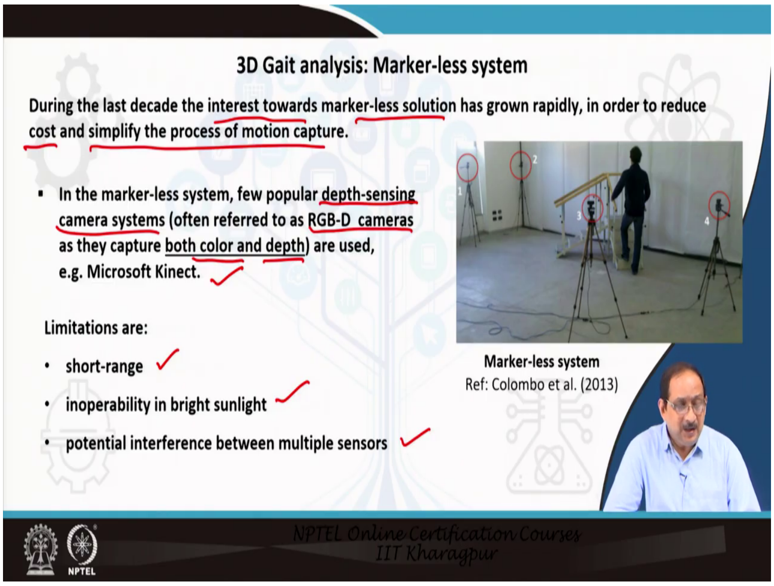


Now, let us move to the second part of the lecture or the second topic in this lecture, the 3-D gait analysis. Measurement of human motion represents one of the most interesting but challenging topic of metrology. The optical motion tracking solutions can be broadly categorized into marker-based systems and marker-less systems. These markers are fixed on the subject's body, and the motion is captured by a calibrated multi camera system.

So, you can see the reflective markers here placed at specific locations on the body. Now, instead of directly tracking a body posture, these systems work by identifying common marker features in consecutive images. So, it identifies common marker features in consecutive images, which are used to track the motion of the body.

Owing to the cost, complexity, and the necessary technical skill of personnel to run the recording, the markers are placed, preferably at specific anatomical landmarks. In the marker-based system, the position of the joints and the orientation of the body segments are obtained through the 3-D location of the markers. Therefore, marker-based systems are mainly used in specialized laboratories for clinical rehabilitation and other specific applications.

(Refer Slide Time: 11:19)

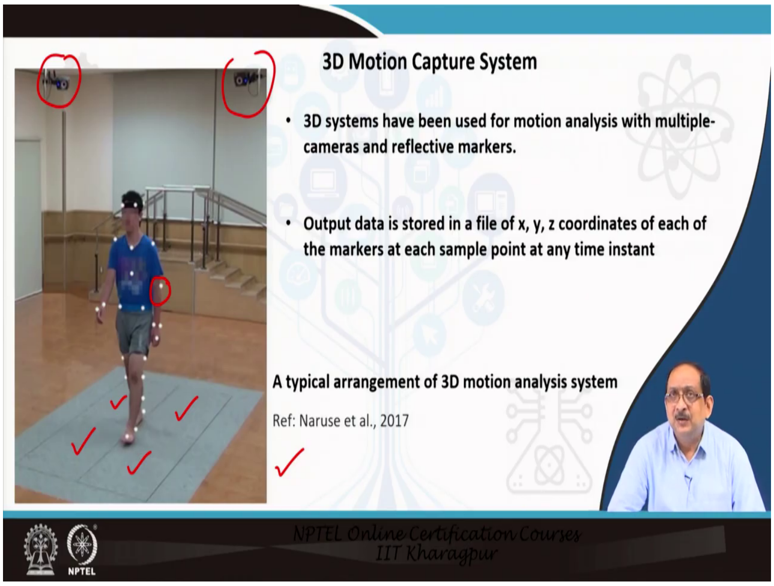


Now, let us discuss about the marker-less system. During the last decade, considerable interest has been shown towards marker-less solutions, in order to reduce the costs involved in marker-based systems and to simplify the process of motion capture systems. On the right, you can see a marker-less system with the four cameras shown in the figure.

In the marker-less system, few popular depth sensing camera systems are used. They are often referred to as RGB-D cameras since they can capture both color and depth of the object. A typical example of such a camera is Microsoft Kinect that we had discussed in the last lecture.

Although marker-less system finds wide application in clinical and biomechanical research, it suffers from the following limitations. It has a short range of measurement, its inoperability in bright sunlight, and potential interference between multiple sensors are the three important limitations of the marker less system. Most importantly, however, the accuracy and precision of motion tracking is still lower than the marker-based system, which remain the gold standard of 3D gait measurement.

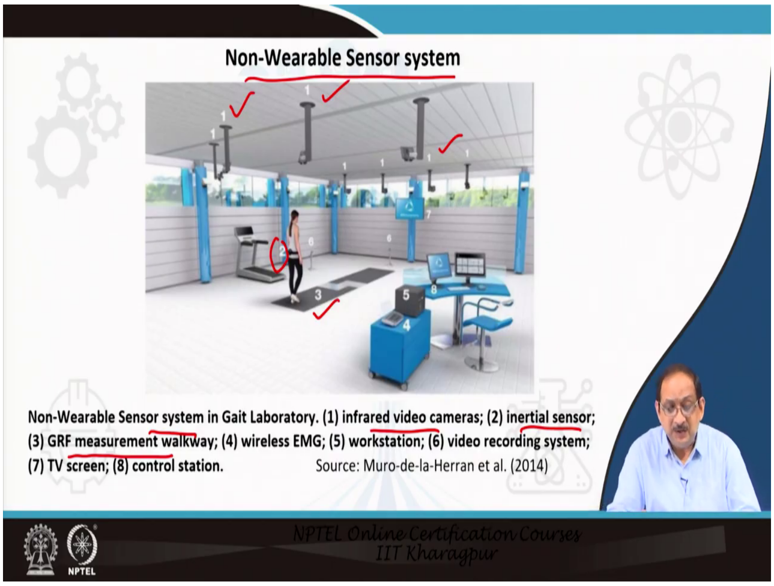
(Refer Slide Time: 13:38)



Let me now present to you a 3D motion capture system. A typical arrangement of the three-dimensional motion analysis system is presented in the figure. The system comprises ten cameras, but we can see only two here mounted from the ceiling. There are four force plates forming a walkway. So, the force plates are mounted on the floor in the middle of the walkway.

And there are reflective markers which is represented here as white circles. There are 14-millimetre reflective markers. So, the 3D motion capture system used for motion analysis consists of multiple cameras, reflective markers, as well as the force platform or the instrumented walkway. The output data is stored in a file of x, y, z coordinates of each of the markers at each sample point at any instant of time.

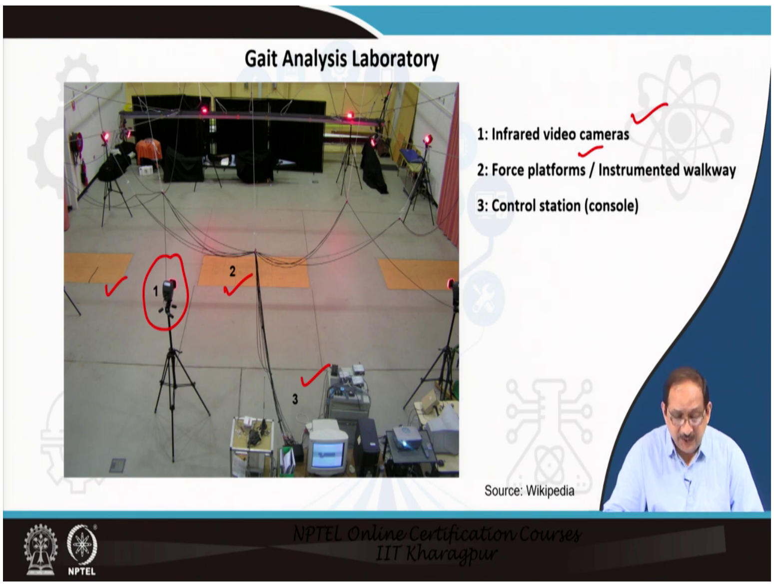
(Refer Slide Time: 15:08)



Let me now present to you a schematic diagram of a non-wearable sensor system. We had discussed about the non-wearable sensor system earlier in part one of the lecture, and it may be recalled that the non-wearable sensor system is restricted within the domain of the gait laboratory.

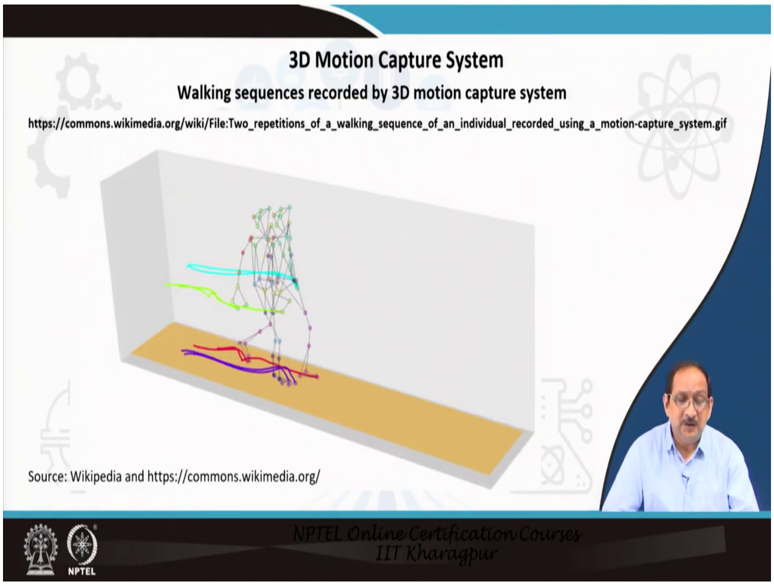
So, the system consists of infrared video cameras mounted from the ceiling, inertial sensors mounted on the waist of the subject, ground reaction force measurement walkway, wireless EMGs, workstation, video recording system, TV screen, and finally, the control station on the right.

(Refer Slide Time: 16:12)



Now, let us visit a gait analysis laboratory, not a schematic diagram but a real gait analysis laboratory consisting of infrared video cameras, force platforms, instrumented walkway, and control station. So, the video cameras, quite a few of them can be seen in this photo. So, the laboratory is equipped with multiple force platforms, as you can see in the figure and multiple infrared cameras that can capture motion based on the marker-based technique.

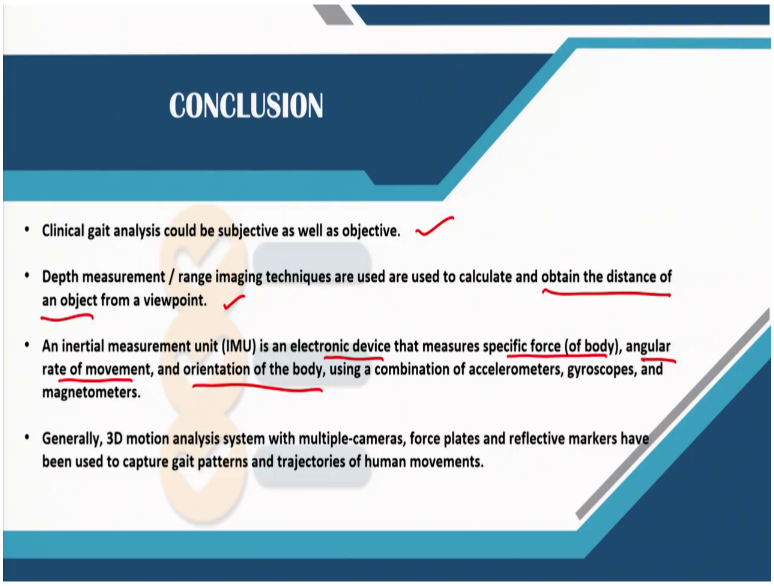
(Refer Slide Time: 17:06)



Let me come to the final slide. A very interesting slide on the 3D motion capture system. Herein walking sequences recorded by a 3D motion capture system have been presented, and the animation that you can see shows the recorded trajectory of the markers. So, there is no subject or human being in this walking sequence.

It is the recorded trajectory of the markers that is very clearly represented in this animation. After data acquisition and processing of the motion capture system, the recorded trajectory of the markers during the walking sequence is available for interpretation. It could be further used for the diagnosis of gait disorders and study of joint kinematics and kinetics.

(Refer Slide Time: 18:18)



Let us now conclude together on part one, and part two of this lecture on Measurement Techniques for Gait Analysis. Clinical gait analysis could be subjective as well as objective. Depth measurement or range imaging techniques are used to calculate and obtain the distance of an object from a viewpoint.

An inertial measurement unit IMU is an electronic device that measures specific forces of the body, angular rate of movement, orientation of the body using a combination of accelerometers, gyroscopes, and magnetometers. Generally, 3-D motion analysis system with multiple cameras, force plates, and reflective markers has been used to capture gait patterns and trajectories of human movements.

(Refer Slide Time: 19:28)

The references are mentioned in two slides based on which the lecture has been prepared. Thank you for listening.