Biomechanics of Joints and Orthopaedic Implants
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Lecture 16
Measurement Techniques of Gait Analysis – Part I

Good morning everybody. Welcome to the lecture on measurement techniques of gait analysis part one and belongs to module three of the NPTEL online certification course on Biomechanics of Joints and Orthopedic Implants.

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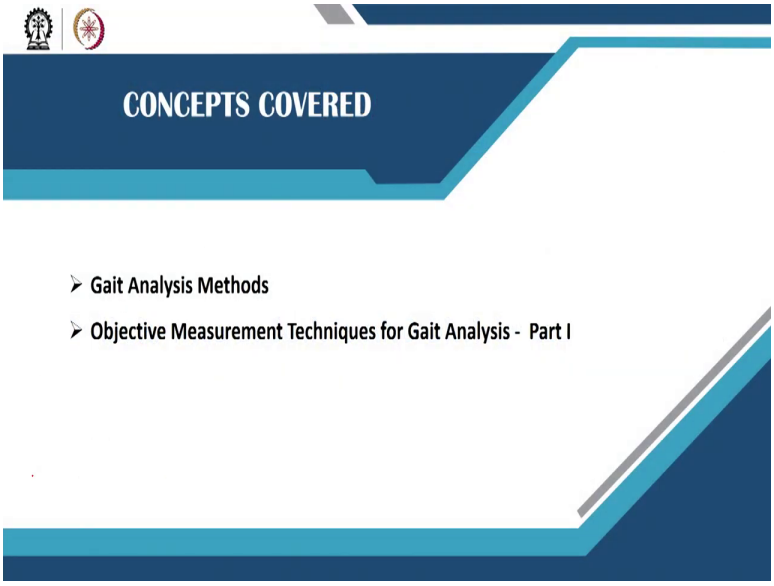

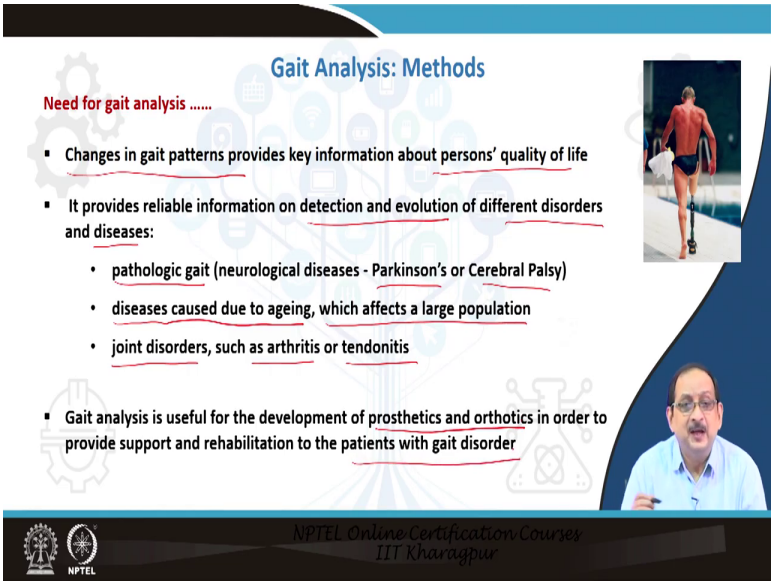

The concepts covered in this course are the methods for gait analysis and the second topic is on objective measurements for gait analysis. We will be discussing part one of the lecture here, followed by part two of the lecture in the next presentation. Before we discuss about the methods of gait analysis, we need to justify gait analysis. Gait analysis helps to figure out changes in gait patterns and provides key information about the person's quality of life.

It provides reliable information on detection and evolution of different disorders and diseases, such as pathologic gait, pathologic gait are gait abnormalities. There are eight basic types of pathological gaits that can be attributed to neurological conditions, such as Parkinson's or cerebral palsy, spastic, neuropathic, myopathic, and other neurological diseases. Apart from that, the gait analysis provides reliable information on diseases caused due to aging, which actually affects a large population.

It provides important information on joint disorders such as arthritis, osteoarthritis and rheumatoid arthritis, as well as tendonitis. Observation of these gaits is essential aspect of diagnosis that may provide information about several musculoskeletal and neurological problems. Gait analysis is useful for the development of prosthetics and orthotics in order to provide support and rehabilitation to the patient with gait disorders.

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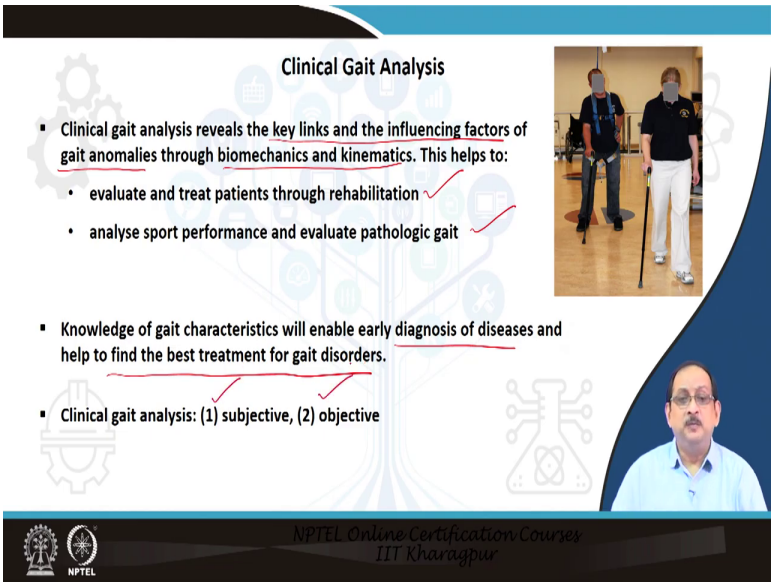

Let us discuss about the clinical gait analysis. The clinical gait analysis reveals key links and the influencing factors of gait anomalies that are deviations from the normal gait through biomechanics and kinematics. This helps to evaluate and treat patients through rehabilitation and to analyze sports performance and evaluate pathologic gait.

Knowledge of gait characteristics will enable early diagnosis of the disease and help to find out the best treatment for the gait disorders. Clinical gait analysis can be of two types broadly speaking, one is the subjective type, another is the objective type.

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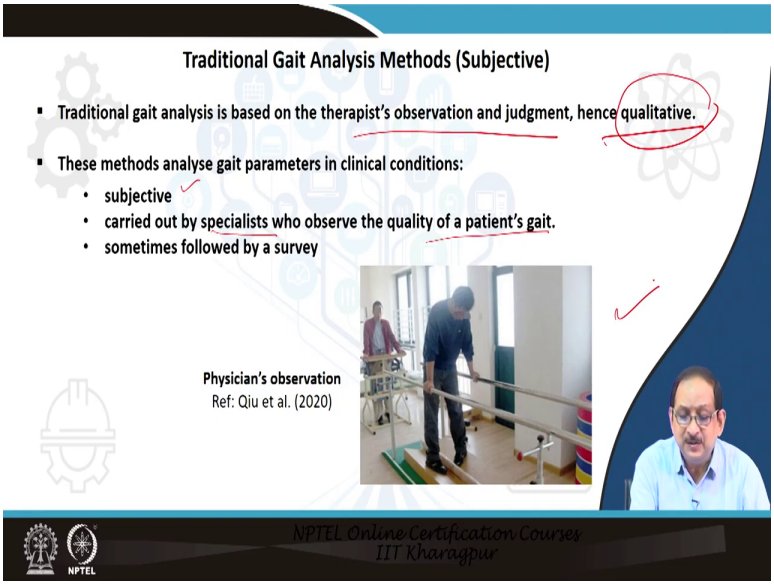

Let us discuss about the traditional gait analysis methods which are subjective in nature. The traditional gait analysis is based on therapists observation and judgment. Hence, it is qualitative in nature. These methods actually analyze gait parameters in clinical conditions. So, it is a subjective observation, it is carried out by specialists who observe the quality of a patient's gait as indicated in the figure, and it is sometimes followed by a survey.

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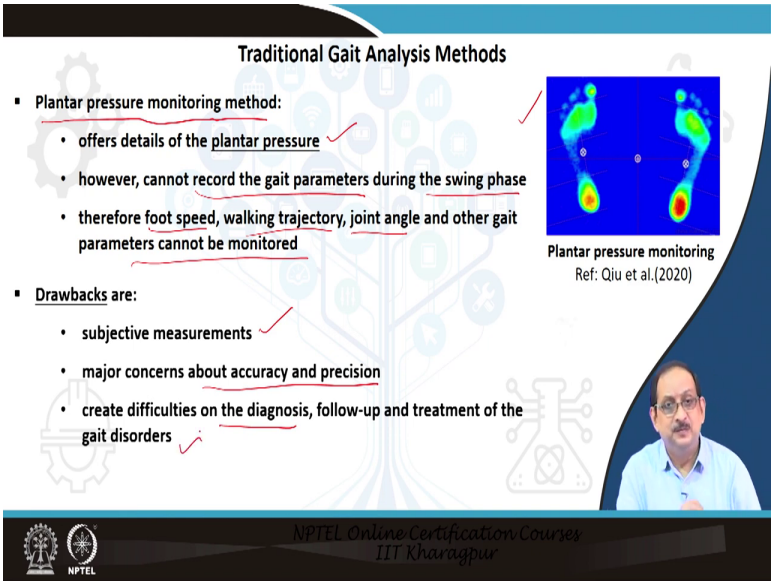

The other type of traditional method is a plantar pressure monitoring method. You can see the figure on the right, which is actually giving us plantar pressure distribution. So, it offers details about the plantar pressure, foot pressure, basically foot pressure measurement. However, it cannot record the gait parameters during the swing phase. Why? Because during the swing phase, the foot is not in contact with the ground. So, we cannot actually monitor plantar pressure during the swing phase.

Therefore, gait parameters like foot speed, walking trajectory, joint angle and other parameters cannot be monitored by this process. Let us come to the drawbacks of this plantar pressure monitoring method. It is a purely subjective measurement which raises major concerns about the accuracy and precision, and it creates difficulties in precise diagnosis follow up and treatment of gait disorders.

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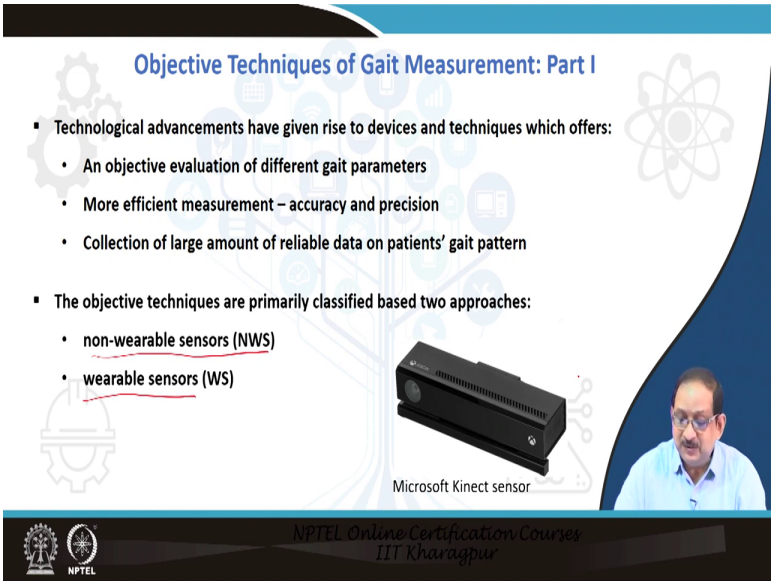

Let us now come to the second part of the lecture: the topic on objective techniques of gait measurements part one, as I told you earlier, part two will be covered in the next lecture. So, let us concentrate on part one of this lecture on objective techniques of gait measurement. Now, as you all know, technological advancements have given rise to devices and techniques, which offer an objective evaluation of different gait parameters. The gait parameters have been discussed earlier in the lectures on gait cycle and gait analysis.

These techniques are more efficient in terms of measurement accuracy and precision. It gives rise to the collection of a large amount of reliable data on patient's gait patterns. We actually have a large amount of data at our disposal for different purposes like diagnosis and evolution of gait abnormalities. The objective techniques are primarily classified based on two approaches.

One is the non-wearable sensors, the other is based on wearable sensors. On the right, you can see a Kinect sensor which belongs to the class of image processing system under non-wearable sensors.

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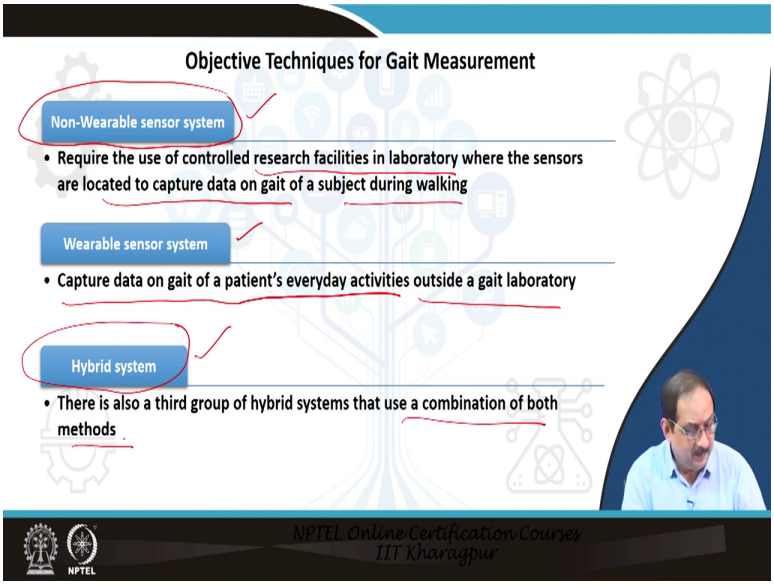

The objective techniques for gait measurements are briefly presented in this slide. So, we start with non-wearable system. This system requires the use of controlled research facilities in the laboratory where the sensors are located to capture data on the gait of a subject during walking. So, it requires a laboratory setup to capture data on gait. Wearable sensor systems capture data on the gait of a patient's everyday activities outside a gait laboratory. Therefore, it can be anywhere outside the gait laboratory.

The data can be recorded and later analyzed for different purposes. This can be done when we rely on wearable sensor systems. There is also a third type which is called the hybrid system that uses a combination of both non-wearable sensor and wearable sensors.

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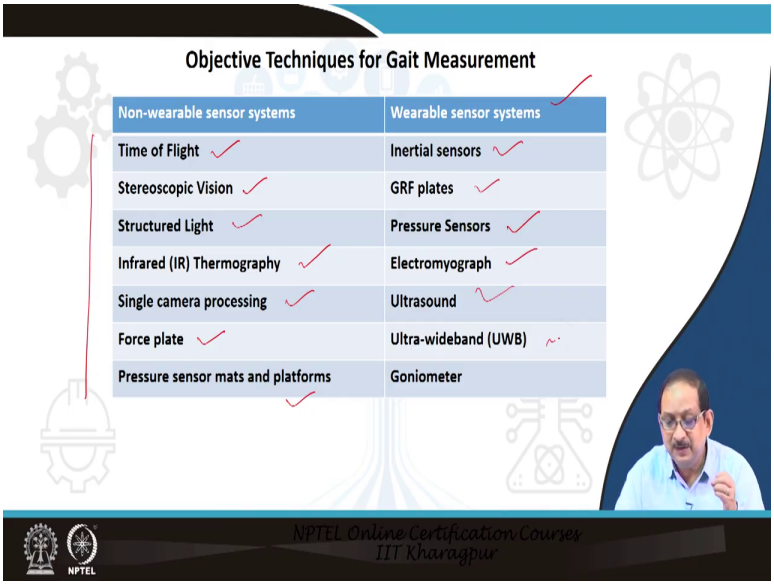

The objective techniques of gait measurements are summarized in a tabular form in this slide. The wearable sensor systems can be of different types: time of flight, stereoscopic vision, structured light, infrared thermography, single camera processing, force plate, and pressure sensor mats or platforms. So, in this category of non-wearable sensors, there is no need to wear a sensor on any body part in order to do gait analysis.

However, in the case of wearable sensor system, there is a need to wear a sensor on a patient's body, and these systems can be inertial sensors, ground reaction force plates, pressure sensors, electromyography, ultrasound, ultra-wideband, and goniometer.

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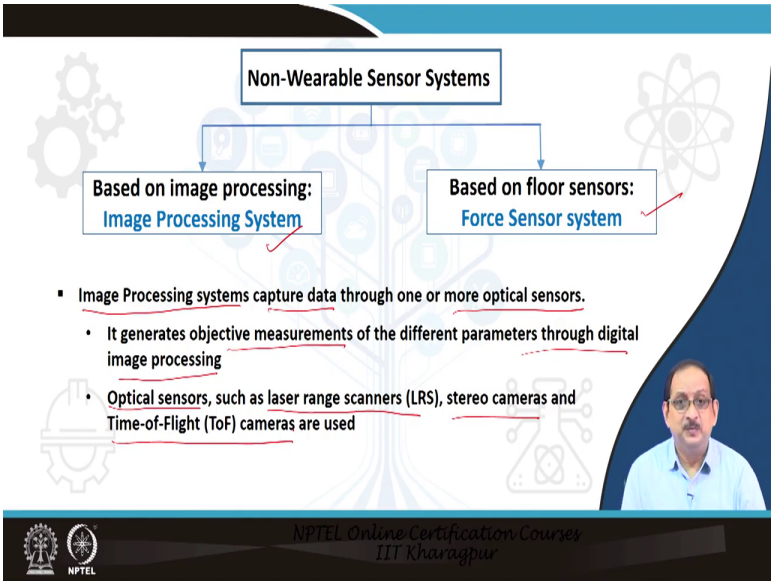

In this lecture, we will be focusing our discussion on non-wearable sensor systems, which can be based on the image processing system or can be based on floor sensors, where there are force sensors. The image processing system actually captures data through one or more optical sensors. It generates objective measurements of different parameters through digital image processing.

As from the definition of the system, the image processing system, you can understand that it generates objective measurements of different parameters through digital image processing. It can get information from optical sensors such as laser range scanners, stereo cameras, and time-of-flight cameras which are used as optical sensors.

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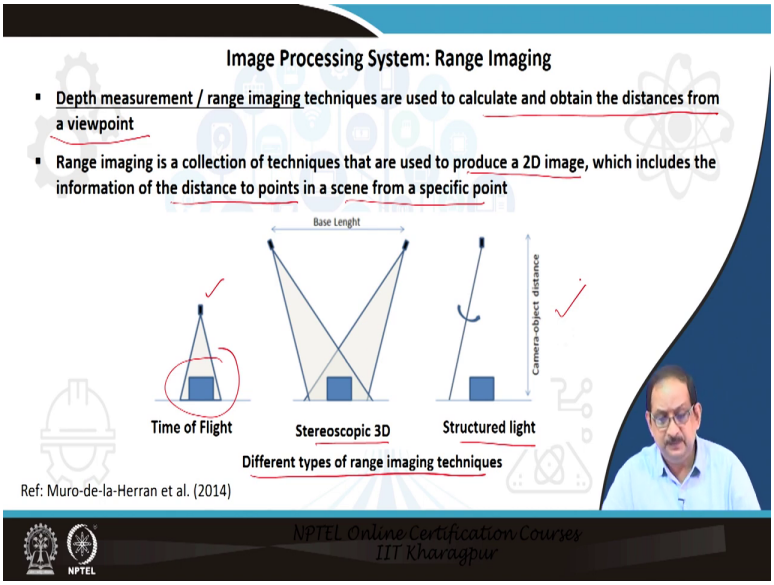

Now, let us come to one of the imaging systems: the range imaging system. It is basically a depth measurement range imaging technique. This technique is used to calculate and obtain the distances from a viewpoint. So, range imaging is a collection of techniques that are used to produce a 2d object which includes information of the distance to points in a scene from a specific point. So, as you can see, that it actually measures the distance from a viewpoint by using different types of methods like time of flight, stereoscopic 3D system or structured light system.

So, these are different types of range imaging techniques, stereoscopic 3D, and structured light system which actually measures the distance of the object from a viewpoint.

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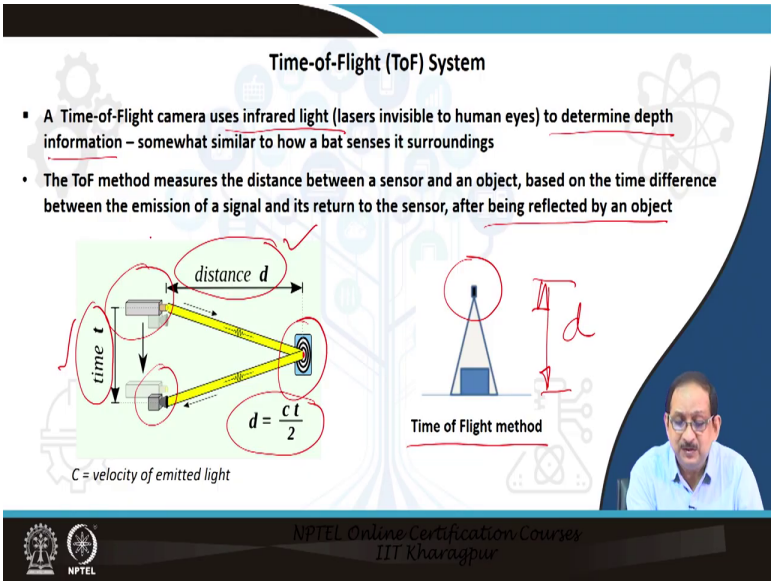

Let us come to time-of-flight system. A time-of-flight camera uses infrared light. It uses infrared light to determine the depth information. It determines the depth information, somewhat similar to how a bat senses its surroundings. So, the time-of-flight method measures the distance between a sensor and an object, as you can see here, based on the time difference between the emissions of a signal. So, it measures the time difference between the emission of a signal and its return to the sensor after being reflected by the object.

So, the infrared light travels from the camera hits the object and the sensor, and returns to the sensor or the sensor sense the return of this infrared light after being reflected by the object. So, the distance is calculated as a function of the velocity of the emitted light and the time of travel, the time difference between the emission of this signal and its return to the sensor.

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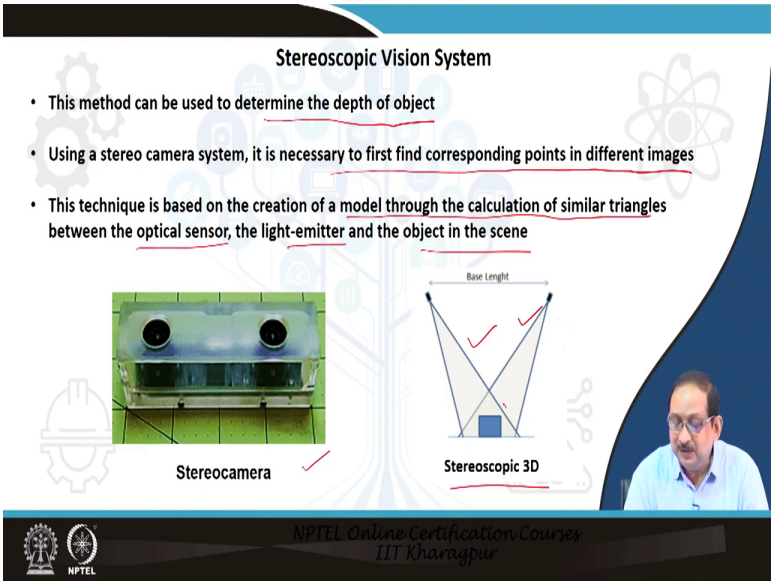

Let us discuss about the stereoscopic vision system. So, this system is used to determine the depth of the object using a stereo camera system. It is necessary to first find the corresponding points in different images. You can see a stereo camera has two or more image sensors.

This allows the camera to simulate human binocular vision and therefore provides the ability to perceive depth. So, this technique is based on the creation of a model through calculation of similar triangles, as you can see in the figure, between the optical sensor and the light emitter and the object in the scene.

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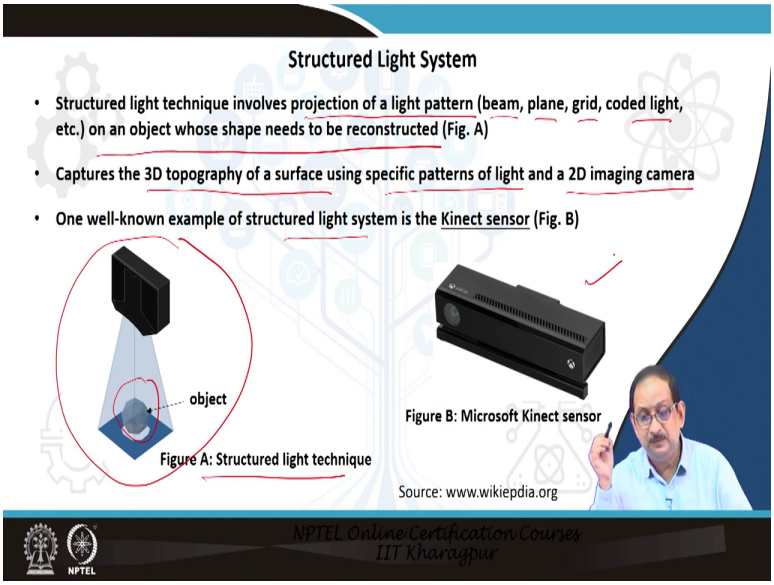

Structured light system involves the projection of a light pattern. As you can see in the figure here, a projection of a light pattern in the form of a beam, plane, grid, coded light, etc., on an object whose shape needs to be reconstructed as shown in figure A. So, the object is here, and we need to reconstruct the shape of the object as far as possible. It actually captures the 3D topography of the surface using the specific patterns of light and a 2D imaging camera.

So, a well-known example of a structured light system is the Microsoft Kinect sensor, which actually can be used to reconstruct the shape of the object using 3D topography of the surface of the object.

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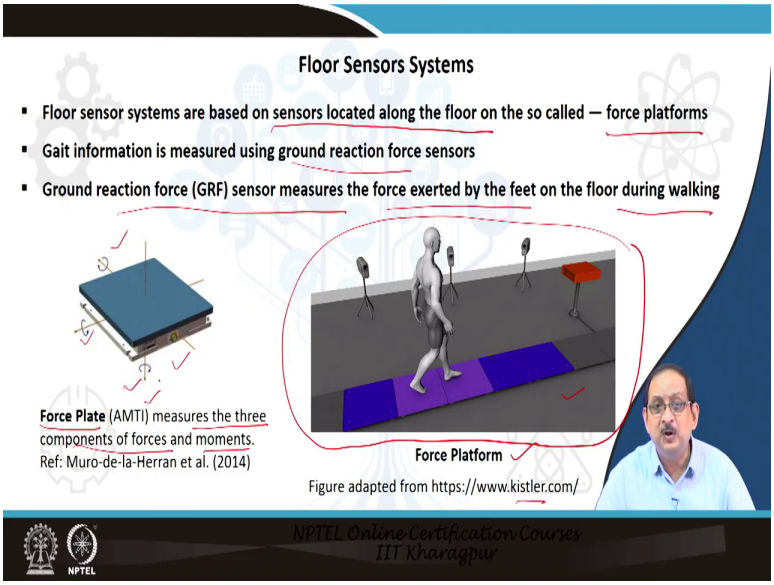

Let us come to the floor sensor system. The floor sensor systems are based on sensors located along the floor. So, these sensors are embedded in the floor in the form of force plates. A collection of force plates can give rise to a force platform, as you can see from the figure, and these are sensors that actually can give you measurement on the ground reaction force.

The ground reaction force sensors measure the forces exerted by the feet basically when the feet are coming in contact with the floor. The reaction force that is the ground reaction force is the reaction force from the ground on the foot during walking, which is basically opposite in direction but equal in magnitude to the force exerted by the foot on the floor during walking.

So, on the left, we can see a force plate that measures three components of forces and moments. So, along the axis are directions x y z. So, these are the moments, and one can also get the forces, and this is a typical example of a force platform, and one of the prime manufacturers of force platform are Kistler, for example. AMTI is a prime manufacturer of force plates.

So, this is the setup of the force platform on which a subject can walk. It will actually give us direct measurements of the forces and moments at different instances of the gait cycle. But it is important that this force platform needs to be embedded on the floor. So, that it is easy to walk on, it cannot be on a raised platform.

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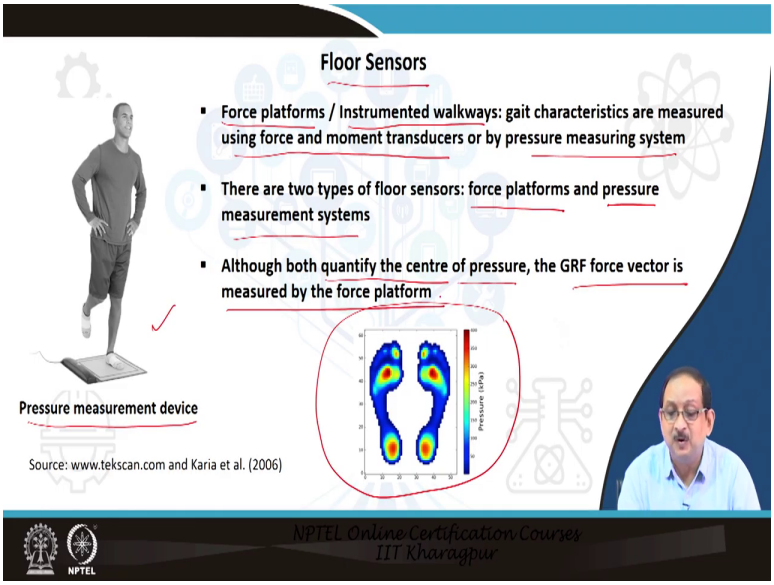

Let us discuss in general about the floor sensors. Floor sensors, as already discussed, can be forced platform or instrumented walkway. So, these sensors can measure gait characteristics and using force and moment transducers or by pressure measuring system. So, the pressure measuring system is indicated here, this is also a floor sensor. There are two types of floor sensors; one is forced platforms, the other is a pressure measurement system.

This figure on the right is an example of the pressure measurement system. It gives us a distribution of foot pressure. As you can see, quantitative measurement of foot pressure across the foot when it is coming in contact with the ground; different instances of the gait cycle, of course, only during the stance phase because in the swing phase, the foot is not in contact with the ground. Although both these sensors quantify the center of pressure, the ground reaction force vector is only measured by the force platform and not by the pressure measurement system.

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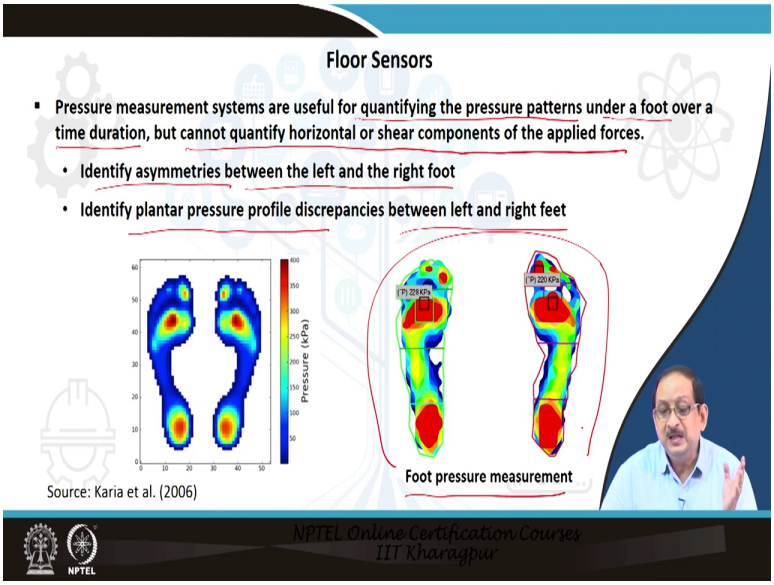

Now, let us come to the pressure measurement systems. So, the system is useful for quantifying pressure patterns under a foot over a time duration. It can actually measure pressure distribution during a time interval but cannot quantify the horizontal or shear components of the applied forces.

So, it is basically a pressure measuring system and does not give me any information on the forces. It can be used to identify asymmetries between the left and the right foot, and it can help to identify plantar pressure profile discrepancies between the left and the right foot. So, it is a foot pressure measurement system that can give important information on the pressure distributions in the left and right feet.

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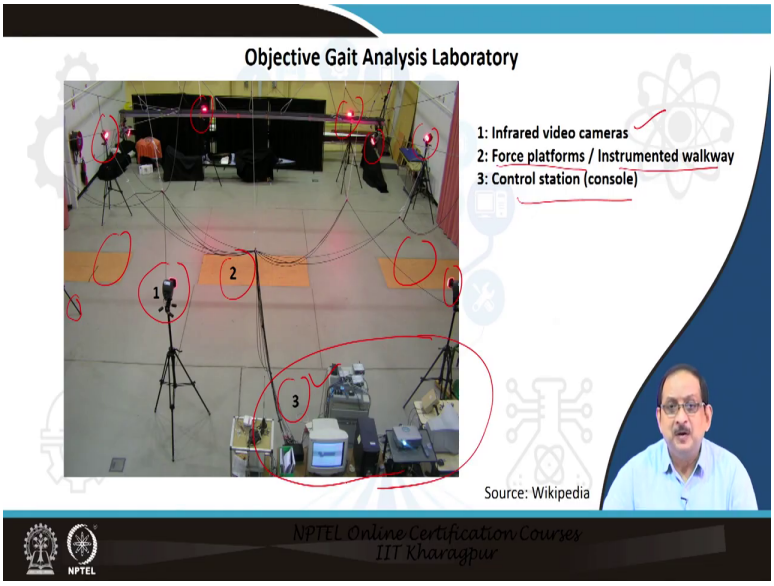

Let us come to the final slide of this lecture on the objective gait analysis laboratory as a whole so, as you can see in this figure that the laboratory is equipped with infrared video cameras. So, there are quite a few video cameras in different positions of the laboratory. So, this is another one that is not included in the picture; only the stand is visible.

So, this laboratory is equipped with force platforms or instrumented walkway, seen here in yellow color, embedded in the floor at the floor level. So, it has to be embedded on the floor level so that a person can walk over it and the data can be measured for the duration of the gait cycle. It also has a control station or console.

So, this is the console unit or the control station, which actually records all the information from the gait analysis. So, the gait laboratory equipped with multiple force platforms, multiple infrared motion capture cameras is shown in this figure. A discussion on the wearable sensors will be taken up in the next lecture, part two.

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The list of references is indicated here based on which the lecture has been prepared. There are other references as well. Thank you for listening.