KAPITEL 6 / *CHAPTER 6* [6]
BODY SCANNERS FOR THE FORMATION OF THREE-DIMENSIONAL IMAGES OF THE EXTERNAL SURFACES OF OBJECTS

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Introduction

Three-dimensional modeling is the process of creating virtual three-dimensional objects in computer space using special software. It is an important technology that finds application in many fields such as engineering, architecture, medicine, gaming industry, advertising and many others.

Fields of use

3D body scanners are used in a variety of industries, including medicine, fitness, fashion, and more. In the medical field, 3D body scanners can be used to create accurate 3D models of the external parts of the human body. It can be useful for plastic surgery, dermatology, orthopedics and other specialties where it is important to have a detailed idea of the shape and structure of the body. In fitness and nutrition, 3D body scanners are used to analyze body composition, measure body volumes, and track changes in physical form over time. This allows customers to see more than just the weight on the scale, but a detailed picture of how their body is changing, including muscle mass, body fat and other parameters. In the fashion industry, 3D body scanning can be used to create clothes that perfectly fit specific measurements of a person. This allows designers and clothing manufacturers to create more personalized products.

3D scanning technologies

3D scanning technology works by using a variety of techniques to capture the shape of an object from all sides, and then create an accurate 3D model. Methods may include laser scanning, structured light, photogrammetry, and others. The result is a highly detailed three-dimensional image that can be used for a variety of purposes.

With structured lighting, the scanner projects specially structured light (often in the form of lines or patterns) onto the object.

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The projection system generates a light pattern, which can be in the form of a grid, stripes, dots or any other geometric shape. This template can be modified depending on the needs of the application. The created light pattern is projected onto the surface of the object being scanned. During design, the shape and size of the object, as well as the distance and angle of projection are taken into account. A light pattern is displayed on the surface of the object, depending on the shape and depth. A camera or other sensor located next to the projector registers the deformation of the projected light pattern on the surface.: The received data on the deformation of the light pattern is analyzed by the data processing system. With the help of these data, the surface of the object is reconstructed, including the definition of shape, depth and textures. Based on data analysis, the system creates a three-dimensional image of the surface of the object. This image can be used for further analysis, modeling, visualization or other purposes depending on the application of the scanner.

Patterns can be used in structured light: grids, stripes, code labels, phase masks. A grid pattern can be used to create an evenly distributed pattern of light on the surface of an object. This allows for uniform coverage of depth and shape information. A stripe pattern can consist of parallel stripes that pass through the object at different angles. This can help increase resolution and improve scanning accuracy. Some systems use special code labels or markings placed on the surface of the object. These labels can contain unique information that helps the system determine the position and orientation of the object in space.

The body scanner can use a laser beam light that scans the surface of the object. A laser can move or have a fixed position, but its beam is usually used to create structured illumination on the surface of an object.

The principle of operation of laser light in body scanners is based on the analysis of the deformation of the laser beam on the surface of the object. Here is the general principle of this process. The laser generates a thin, narrow beam of light that can be directed at the surface of the object at various angles or in the form of a line, grid, etc. This structured light is used to illuminate the object accordingly. The beam reflects off the surface of the object, changing its shape or position depending on the depth and

shape of the object. For example, on a flat surface it may remain straight, but on an uneven surface it will deform. A camera or other sensor located next to the laser source registers the deformation of the laser beam on the surface of the object. This information is transferred to the data processing system.

The system processes data on the deformation of the laser beam, taking into account the known parameters of the projection of laser light onto the surface. With the help of these data, you can determine the shape and depth of the object, build a three-dimensional representation of its surface. Based on data analysis, the system constructs a three-dimensional image of the surface of the object. This image can be used for further analysis, modeling, visualization or other purposes depending on the application of the scanner.

LED lighting is often used to create structured light. LED can be located in a special array, which allows you to create different patterns or patterns of light on the surface of the object.

An LED projector consists of a matrix of LEDs that emit light in a given pattern. By controlling the intensity and duration of each LED, different light structures such as grids, stripes or dots can be created. Structured light created by LEDs is projected onto the surface of the object being scanned. This can be achieved with the help of optical systems that direct the light flux to the object.

A camera or other sensors register the reflected structured light on the surface of the object. The deformation of this light caused by the surface relief gives information about the depth and shape of the object. The received data on the deformation of the light pattern are analyzed and processed by the data processing system. These data are used to restore a three-dimensional image of the surface of the object. Based on data analysis, the system constructs a three-dimensional image of the surface of the object. This can be visualized on a computer screen or used for further analysis or simulation.

LED projection in the body of scanners provides many advantages, such as high scanning speed, low cost and compact equipment, as well as the ability to work in different lighting conditions.

A typical scanning application can only capture a 2D image of the object being

scanned. However, if you add depth cameras to this, they add an additional layer of information - depth information. This allows you to create three-dimensional models of objects in higher detail and with more accurate dimensions.

Depth cameras help in measuring distances to objects in the field of view. This allows you to know how far individual points on the object are from the camera, which makes it possible to create more accurate three-dimensional models. Depth data allows you to separate the object from the background with high accuracy. This creates the possibility of automatic image processing, such as removing the background or separating individual objects from their surroundings.

Depth data can be used to measure the size of objects because they provide information about actual distances. This can be useful for object geometry analysis, defect detection, or quality control.

In general, the use of depth cameras allows you to more accurately capture the shape and depth of the objects being scanned, which makes the scanning process more accurate and efficient.

Let's consider the general characteristics of body scanners

Resolution is an important characteristic that determines the level of detail in the images that the scanner can provide. The higher the resolution, the more accurate the images will be. Scan time is the time it takes to complete one scan. Scanning speed can be important for medical research as well as patient convenience. For scanners that use X-ray or ultrasound radiation, the maximum depth of tissue penetration can be an important characteristic. Radiation energy is a parameter that indicates the power of radiation that is used for the scan. It is important to ensure a safe level of radiation for patients and staff. The size of the scanning area is a characteristic to ensure the possibility of scanning different parts of the body or objects of different sizes. Maximum patient load - the maximum weight or size of the patient that can be handled by the scanner.

Today, handheld 3D scanners occupy a large share of the 3D scanning market. Portable, versatile and accurate enough for many professional applications, handheld scanners have advantages over static solutions such as desktop scanners and

photogrammetry systems.

Since handheld 3D scanners can be moved to different positions around the object being scanned, they can be used to scan both large and small objects, hard-to-reach objects, and even objects that are outdoors. And while these benefits come at the expense of some accuracy - manual movement during manual scanning can adversely affect point cloud data - many users find manual scanning to be the ideal option for their professional needs. In today's market, most scanners use structured light technology. They project lines of light onto the scanned object and use cameras to see how those lines of light deform on the surface of the object. By measuring these deformations, the device can understand the three-dimensional shape of the object. Other scanners use laser scanning technology, in which a laser shines on an object and sensors measure the distance between the scanner and the object.

One of the most important characteristics of a 3D scanner is its resolution, which can be defined as the distance between points in the data cloud. Although the resolution is not the main parameter of the scan, many users choose a 3D scanner based on its resolution: a high-resolution scan gives a more accurate and clear image of the scanned object than a low-resolution scan, and especially useful for small objects with fine details.

When scanning large objects such as furniture and cars, users are more concerned with scanning speed than resolution. Scanning speed is usually expressed in dots per second and is equally important for applications such as human body scanning, where the scanned object cannot remain stationary for too long, and for time-sensitive projects such as outdoor scanning in poor light weather conditions. Another factor to consider when buying a handheld 3D scanner is its accuracy. Accuracy can be defined as the closeness of the measured image to the true, real measurement. Accuracy is critical in scanner applications such as quality control and reverse engineering, where millimeter inaccuracies can lead to problems down the road.

Scanning the human body in 3D has proven to be a challenging task for developers and users of scanning technology. First, it is difficult for a person to maintain complete integrity during the entire scan time, which can lead to violations

in the scan data. Second, human hair - with its unusual texture, shine and variety of colors - is notoriously difficult to scan.

In many cases, large stationary scanners with multiple cameras or rotating platforms are used for body scanning, but portable devices can also provide good results. One such 3D scanner is the EinScan H2, a full-color hand-held scanner that uses both LED light projection and infrared rays to scan bodies and other objects at high speed.

EinScan H2 is equipped with features that make body scanning easier. For example, the infrared beam used in the face scanning mode causes less discomfort to the eyes than a sequence of bright, flashing light signals. Meanwhile, the optimized inflexible alignment algorithm in the body scan mode allows you to smoothly capture the body even with slight movements.

These features, combined with a scan rate of 1.2 million dots per second (white light mode) and 1.06 million dots per second (IR mode), make the H2 excellent for 3D modeling, virtual reality and gaming applications.

Body scanner software includes a variety of components that help manage the scanning process, process data, and display results. Control software is the main software that controls the operation of the body scanner as a whole. It is responsible for controlling the movement of the scanner, adjusting the scanning parameters and collecting data. Processing software is responsible for processing the received data received from the detector or sensors. This may include data filtering, artefact correction and computation of the resulting images. Imaging software displays the acquired images on a monitor for review and analysis by medical personnel. It can allow you to vary the level of magnification, adjust the contrast and brightness of the image. Analytical software is used for automated analysis of received data in order to detect anomalies or determine parameters that help in diagnosis. System software is responsible for ensuring the correct operation of the equipment as a whole, including interaction with the operating system and device drivers. The Software may also include privacy, authentication and access control features.

Body scanners for 3D modeling in medicine are used to obtain detailed 3D images

of the internal organs and structures of the human body without the need for invasive procedures such as surgery.

Body scanners allow obtaining detailed three-dimensional models of organs and tissues, which helps doctors accurately diagnose various diseases and pathologies. For example, in oncology, body scanners can be used to assess the size and location of tumors before surgery or radiotherapy. Before complex surgical operations, body scanners allow the creation of three-dimensional models of patients, which help surgeons carefully plan each step of the procedure. This allows you to reduce the risk of complications and improve the results of operations. The use of body scanners in medical education allows students and junior doctors to study anatomy and pathology on realistic 3D models without the need to use real tissues or patients. Also, they can be used for research into new methods of treatment and diagnosis.

Body scanners make it possible to obtain accurate three-dimensional models of the individual anatomical features of each patient. This allows for the development of individual medical devices, such as prostheses, orthoses and other means of rehabilitation, which meet the needs of a particular patient as much as possible.

After starting treatment, body scanners can be used to regularly monitor changes in the patient's health and the effectiveness of treatment. 3D models can help doctors detect any changes in time and adapt therapy based on these changes.

The use of body scanners in medicine is extremely important because they allow doctors to obtain detailed information about patients without the need for invasive procedures, which allows to reduce risks and improve treatment outcomes.

Facial diagnosis, also known as face analysis, is used to determine various aspects of a patient's health, mental state, and other parameters based on their face. Image processing and artificial intelligence technologies have become very powerful in recent years, which allows for the development and improvement of diagnostic methods using the face.

Facial analysis can reveal physical signs that indicate the presence of genetic diseases or syndromes. For example, specific facial features may be associated with diseases such as Down syndrome or Williams syndrome.

Processing facial images can reveal signs of neurological disorders such as paralysis, tremors, or other motor disorders. Some studies have shown that facial analysis can help in the early diagnosis of Parkinson's disease or autism spectrum disorders.

Emotional state and mental health can be reflected on the face. Facial analysis technologies can detect signs of stress, depression or other mental disorders, helping to provide early intervention and support for patients.

Facial analysis can help in choosing the optimal approach to treatment. For example, individual features of the face can affect the effectiveness of some medications or therapy methods.

The use of face analysis can also provide an effective method of biometric personal identification, which will be needed in many areas, including medical patient identification systems and security systems.

Body scanners for three-dimensional modeling can also be used to diagnose genetic diseases. Body scanners make it possible to obtain three-dimensional models of organs and tissues, which can help identify abnormalities in their development that may be associated with genetic diseases. For example, abnormalities of the skeleton, heart, or nervous system can be detected using three-dimensional modeling.

Three-dimensional models of organs and tissues created using body scanners can help detect specific signs of genetic diseases, such as deformities or developmental disorders. This may be particularly useful for early diagnosis of genetic diseases in children.

On the basis of three-dimensional models of organs and tissues obtained from body scanners, it is possible to carefully plan the treatment of genetic diseases. This allows doctors to choose the most effective methods of therapy and minimize the risks of complications. During the treatment of genetic diseases, body scanners can be used to regularly monitor changes in the condition of the patient's organs and tissues. This allows doctors to detect any deterioration in time and adjust therapy according to these changes.

Overall, body scanners for 3D modeling can be a useful tool for the diagnosis and

treatment of genetic diseases, helping doctors obtain detailed information about patients' organs and tissues without the need for invasive procedures.

In 2023, 730 million people worldwide suffered from low back (lumbar) pain, and by 2050, mainly due to population growth and aging, this number is expected to increase to 843 million (1).

Low back pain is the leading cause of physical disability worldwide, and low back pain rehabilitation can improve the lives of the greatest number of people.

A 3D scan of the back can provide doctors with detailed information about the structure of the spine and spinal cord, aiding in accurate diagnosis and treatment planning for various diseases and injuries. A three-dimensional examination of the back can help identify various diseases and lesions that affect this area of the body. A three-dimensional scan can detect changes in the structure of the spine, such as a decrease in the height of the intervertebral discs, the formation of osteophytes (bone growths) and other changes that indicate osteochondrosis. **C** scanning can help identify abnormalities in the shape and structure of the spine, such as scoliosis (lateral deviation), kyphosis (increased curvature in the anterior-posterior direction), and lordosis (increased curvature in the posterior concave direction). A 3D scan can detect prolapsed or ruptured intervertebral discs, which can compress the spinal cord or nerve roots, causing pain and other symptoms.

The scan can help detect tumors or neoplasms in the spine and extra-vertebral tissues, such as cancer metastases, myeloma, hemangiomas, and others. A 3D scan can detect congenital abnormalities and deformities of the spine, such as hiatus hernia, missing or fused vertebrae, rib deformities, and more.

The technology of the first light-optical analysis of the spine and posture in 3D/4D is promising. DIERS formetric is a light-optical scanning method based on video-raster stereography (VRS). Accordingly, the system consists of a light projector that projects a linear grid onto the patient's back, which is recorded by the imaging unit. Computer software analyzes the curvature of the lines and generates a three-dimensional model of the surface, similar to a plaster cast, from them using the photogrammetry method. Unlike an X-ray, DIERS formetric provides comprehensive information on body

statics and posture in a single measurement process, such as spinal curvature (lateral and frontal), vertebral rotation, and pelvic position. Even muscle imbalances can be detected based on the image of the curvature of the back surface.

Unlike other systems, DIERS formetric also provides three-dimensional reconstruction of the spine without the use of reflective marker points. Using automatic detection of anatomical landmarks and a scientifically based correlation model (developed by Turner-Smith and Drerup) that describes the relationship between surface curvature and vertebral orientation, it is possible to reproduce the curvature of the spine and the position of the pelvis

Observing changes in the spine and spinal cord can help identify exacerbations of chronic inflammatory diseases such as rheumatoid arthritis.

A number of computer programs are used for three-dimensional modeling using body scanners.

3D Slicer is an open source software for visualization and processing of medical images. 3D Slicer allows users to visualize medical images in various modes, including 3D visualization and MPR (Multi-Planar Reconstruction) viewing. This allows users to get a complete picture of anatomy and pathology. 3D Slicer has medical image segmentation tools that allow users to highlight individual structures or regions in an image. This can be useful for surgical planning, data analysis and research. After segmentation, 3D Slicer allows users to perform various operations on regions and structures, such as dimension measurement, intensity analysis, and more. The program has options for registration (alignment) of various medical images. This allows you to combine data from different sources or from different equipment to obtain a comprehensive analysis.

OsiriX is another medical image visualization software, particularly for working with CT and MRI images. OsiriX has a friendly interface that makes it easy for the user to interact with medical images. The interface is designed taking into account the needs of medical professionals and simplifies the process of data visualization and analysis. OsiriX provides the ability to display medical images in three-dimensional space, allowing users to gain a deeper understanding of anatomy and pathology. Similar to

3D Slicer, OsiriX allows users to perform segmentation of medical images to highlight individual structures or regions and further process this data.

OsiriX is widely used in medical practice and research where high-quality visualization and processing of medical images is required.

3DsizeME is a software designed to create accurate three-dimensional models of the human body using stereophotogrammetry. It enables fast and accurate scanning of various body parts for use in medical, fitness and fashion applications.

Artec Studio allows users to use a variety of scanning methods, such as structured light, photogrammetry or laser scanning, to capture the surface of objects as data points. After scanning, the program allows you to perform data processing, including cleaning, alignment and combining scans into one complex 3D model.

Artec Studio also has a number of tools for editing and improving 3D models, such as removing redundant elements, retopology, texturing and others. It is a powerful software that allows users to create detailed 3D models with great accuracy and quality.

3D Slicer is open source software used in medical research and diagnostics. It has an advanced set of tools for processing medical images, including the ability to create 3D body models for medical purposes.

These programs are known for their ability to accurately scan the body and process 3D models of the human appearance, providing users with a wide range of applications in various fields, including medicine, fashion, fitness and forensics.

Artec ScanApp is often used in situations where you need to quickly create a 3D model of a person or object without the need for extensive training or the use of specialized equipment.

3DMD Patient is software used to analyze and visualize 3D data obtained from 3D scanning systems such as 3DMD (3D Multi-Dimensional Capture). This system is often used in medical research, dentistry, orthodontics, and other medical fields to obtain accurate 3D models of a patient's face and head. The software allows you to receive data from three-dimensional scanners that capture the shape of the patient's face and head with high accuracy. 3DMD Patient may provide tools for analyzing 3D models, such as measuring dimensions, detecting asymmetry, or other characteristics.

The program allows you to display three-dimensional models of the patient's face and head in an easy-to-understand format.

The prospects for the development of body scanners for medical applications are very encouraging, given the constant technological innovations and the growing demand for highly accurate and non-invasive diagnostic methods

The use of machine learning algorithms and artificial intelligence to analyze 3D images can significantly improve the accuracy of diagnostic conclusions, automate the processes of identification of pathologies and provide personalized recommendations for treatment. The development of more portable and economical models of body scanners will allow their use not only in hospitals and clinics, but also in remote or resource-limited regions.

Integration with other imaging modalities, such as ultrasound, MRI, and CT, can produce comprehensive multimodal images that provide more information and aid in disease detection and treatment.

Using virtual and augmented reality to view and analyze 3D images of the body can provide physicians with a more intuitive and in-depth means of studying anatomical structures and planning therapeutic interventions.

The development of nanotechnology may allow the creation of scanning devices capable of detecting and visualizing structures at the microscopic level. This will open opportunities for early detection of diseases at the cellular level, allowing detection of pathologies even before they become visible at the macroscopic level.

The development of algorithms and systems that can adapt to the individual anatomical and physiological characteristics of each patient will allow creating more accurate and effective treatment plans.

The development of more powerful and efficient algorithms for processing data and creating 3D models will be able to significantly reduce the time of image processing and improve their quality, making the scanning process faster and more affordable.

Integrating 3D scanning directly into the surgical process, with the ability to reproduce detailed anatomical structures in real time, can significantly improve the

accuracy of surgical interventions and reduce the risk of complications.

These innovations will not only improve the quality and availability of medical imaging for patients, but will also contribute to the development of new diagnostic and therapeutic techniques, making medical care more personalized and efficient. As technology continues to advance, we can expect to see more and more innovative applications of body scanners in medicine.

Body scanners are used in forensics to investigate crimes and gather evidence. Body scanners can be used to obtain detailed images of a person's appearance in order to identify or analyze marks on the body such as wounds, scars or other characteristics. This can be useful in the investigation of crimes, where it is important to establish the identity, physical condition or other signs that will help to solve the case. Such scanners can be one of the tools of forensics to gather evidence and solve crimes.

Body scanners can help identify a person based on their external features, such as physical features, tattoos or other unique characteristics. Images captured by body scanners can be used to analyze marks on a victim's or suspect's body, such as wounds, bruises, or scars. This can help in the investigation of crimes, for example, establishing the circumstances of an assault or battery.

Body scanners can detect hidden objects on a person's body, such as weapons, drugs, or other evidence that may be important to a crime investigation. Information obtained with the help of body scanners can be used as part of the evidence base in criminal cases, helping law enforcement agencies to solve crimes and bring perpetrators to justice.

Today, there are several well-known applications and technologies that use body scanners for various forensic and security purposes. The Rapiscan Secure 1000 uses body scanning technology to detect hidden objects under clothing, such as weapons, explosives or drugs. Another prominent L3 ProVision ATD application uses body scanners for security in transportation such as airports and train stations to detect dangerous objects or materials. Smiths Detection develops a variety of body scanners and technologies for use in forensics and security, including the detection of contraband, prohibited items or illegal substances. The Chinese company Nuctech

Company Limited also specializes in the development and production of body scanners and other technologies for security and forensics.

The use of body scanners for clothing selection is an innovative technology that allows customers to receive personalized recommendations regarding the size and style of clothing. Body scanners use 3D scanning technology to create an accurate model of the user's body. This includes scanning different parts of the body such as chest, waist, hips, etc. After creating a 3D body model, the system automatically measures various parameters such as chest, waist, hip, arm and leg length, etc. Some body scanners can also analyze the shape of the user's body, taking into account the proportions and characteristics of the figure, which allows it to recommend certain styles of clothing that are best suited for a particular figure. Based on the obtained measurements and figure analysis, the system can offer recommendations on the size and style of clothing that best suits the user. This can be useful for both online shopping and physical stores. Body scanners create a personalized experience for customers, helping them find the perfect clothes to suit their figure and style.

There are several programs and platforms that use body scanner technology for clothing selection. Fit3D is a platform that provides body scanning and shape analysis services for individual and business customers. It is widely used in the fitness industry, but can also be applied to clothing selection. ZozoSuit is a mobile application that works with a set of sensors and cameras on a smartphone to create a 3D model of the user's body. Based on this model, ZozoSuit offers personalized clothing size and style recommendations. BodyBlock AI - the platform uses artificial intelligence technologies to analyze the shape of the body and make recommendations for choosing clothes. It can integrate with online stores or brick-and-mortar stores to provide customers with a personalized clothing selection experience. MySizeID : uses machine learning algorithms to generate a 3D model of the user's body and clothing size recommendations. It can be used both for online shopping and for physical stores.

Virtual Dressing Room - the concept of a virtual fitting room, which can be implemented through various platforms and technologies, including body scanners. It allows customers to see how the clothes will look on their 3D body models before

buying.

These apps and platforms allow customers to conveniently select clothing based on their individual body and style preferences

Thus, body scanners are a powerful tool for obtaining objective information about objects in the real world. However, their use requires attention to accessibility and cost to make them accessible to a wide range of users.