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3-DIMENSIONAL SCANNER USING ARDUINO

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Abstract: This project outlines a cost-effective 3D scanning solution utilizing Arduino Nano technology. It utilizes structured light to capture the geometry of objects. The hardware setup comprises an Arduino Nano microcontroller, a camera module, and a laser module for structured light projection. Software-wise, it employs an open-source computer vision library for image processing and depth map generation. The workflow involves system calibration to ensure optimal performance and accuracy. Once calibrated, the structured light pattern is projected onto the object, and images are captured by the camera. These images are then processed to extract depth information, enabling the reconstruction of the object's 3D model. The resulting point cloud data can be refined further for improved accuracy. To evaluate the scanner's performance, experiments are conducted with objects of various shapes and sizes. Metrics such as accuracy, resolution, and scanning speed are analysed to gauge its practical usability. Overall, the developed 3D scanner demonstrates its ability to generate detailed and accurate 3D models, making it suitable for applications like rapid prototyping, reverse engineering, and educational purposes.

Keywords: Low-cost 3D scanner, Arduino Nano microcontroller, Rapid prototyping, Calibration for optimal performance.

I. INTRODUCTION

Echolocation, the use of sound to locate objects, is in theory a simple concept that animals, like the bat, use in order to navigate and hunt for food. Despite being the basis for old, yet advanced technologies like radar and sonar, it is not that widely available for the average consumer. Although, this is beginning to change as the 2020 iPhone 12 Pro series was launched with a LiDAR sensor, making the technology more accessible to the masses. The story is similar for 3D printing, a technology that can trace its roots far back in time when humans manually “3D printed” clay pots layer by layer. Today the processis automated and at the forefront of modern technology. However, 3D printing is often a complicated story thatrequires expensive equipment which makes it rare for ordinary people to be exposed to the technology outside of big industries.3D printing has many applications today including medical, aerospace and automotive.

The purpose of this project is to design and construct a device that, with the help of a distance sensor, can scan smaller objects and recreate them visually on a screen. That visual recreation will then be used to 3D print a copy of the object in an attempt atreverse engineering. The 3D scanner created in this project will be a cheaper and simpler model than what is currently availableon the market. It will contain resources including a microcontroller, cables and other components as well as access to tools, anda budget of 8000INR for additional purchases.

The first step is to gather relevant information regarding sensors and other potential components for the project in order to understand the limitations and potential obstacles that might be encountered. The construction and coding of the scanner will bea process of trial and error apart from what can be planned in theory. To design the prototype, the 3D CAD program Solid Edgewill be used, with some parts being 3D printed from there directly. Once the construction is completed, the code will be tested and altered based upon experiments in order to find the optimal solution or solutions for capturing the scanned object in detail.

The system's affordability, coupled with its ease of use, positions it as a valuable tool for hobbyists, educators, and small-scale industries seeking an entry-level 3D scanning solution. The purpose of this project was to construct a 3D scanner capable of scanning smaller objects and visualize them in a computer with satisfying accuracy. The goal was then to generate an STL file able to be 3D printed in an attempt at reverse engineering.

II. LITERATURE REVIEW:

Musa Alyaman , Alaa Abd-Raheem , and Farah AlDeiri has published in 2018. Dental anatomy is a field of anatomy dedicated to the study of tooth structure, it uses 3D physical model for teeth and jaw. Creating a computer aided design model from an existing teeth or jaw is called 3D scanning. This can be achieved using a variety of methods, including modern optical techniques, cameras, and lasers. Photogrammetry, a method based on camera scanning, will be employed in this work. A 3D model of a real set of teeth or jaw is produced using setoff photos that were captured by a camera at predetermined angles and points of view. The Structure from Motion technique generates a point cloud and, in the end, a fully textured mesh during the 3D reconstruction process from 2D photos. Our closed system regulates the scanning environment, including illumination levels and picture angles. 3D scanners are machines that map an object's surface digitally and gather information about its three-dimensional geometry. .. The fundamental ideas underpinning 3D scanning are dimension measurements, quality control,and reverse engineering. In industrial applications, 3D scanning is used to verify the finished product's quality [20]. In additionto intelligent robot control and vehicle obstacle detection, there are numerous more uses. The technique of creating a computer-aided design model from an existing physical part is known as 3D scanning. A reliable and more cost-effective option to laser scanning for 3D scanning is photogrammetry, or imagery-based 3D scanning. Unlike other approaches, camera scanning does not require additional editing with regard to flaws in the scanned model, which is what makes it unique. Therefore, cameras andimage processing techniques can be utilized to accurately capture objects with spaces.

Suchada Rianmora, Kittiphan Nuamchit, Natthakarn Vanasrivilai, Pornpim Tantipiched, Apisit Rammbuth has published in 2022. The primary goals of the suggested study are to identify and analyze certain characteristics needed for scanning procedures (such as ASAS and 3D laser scanners). To save time and money, the scanning tests will be planned and raised in a sequential manner to determine the ideal circumstances. The intended outcome will serve as the design's guiding principle. engineer to decide on the best techniques and programs to improve the quality of the 3D CAD model that will be supplied to the subsequence procedure. The preparation procedure, the cost of the data analysis for scanning, and the outcomes (a 3D model) from the two scanning approaches are the four primary problems that will be presented and discussed. The reverse engineering (RE) process begins with data collection. The technique known as RE enables the direct construction of 3D CAD models from their physical counterparts. Two forms of data acquisition can be distinguished: This study compares and contrasts the application of scanning and non-scanning acquisition techniques in order to achieve a good surface finish while reducing the time and expense associated with these procedures. It also addresses some important parameters. There are two types of data gathering methods in practice: contact and noncontact. Higher precision is presented in the contact techniquedata, even though certain surface sounds remain. It takes a lot of time to complete, though. The scanning concept has been employed for noncontact 3D laser scanning. Applying this technique can help designer to reduce the acquisition time for scanning object that contains many features which need to be merged from different side views.

Johan Moberg has published in 2017.3D scanning of objects and the surroundings have many practical uses. During the last decade reduced cost and increased performance has made them more accessible to larger consumer groups. The price point is still however high, where popular scanners are in the price range 30,000 USD-50,000 USD. The objective of this thesis is to investigate the accuracy and limitations of time-of-flight laser scanners and compare them to the results acquired with a low-cost platform constructed with consumer grade parts. For validation purposes the constructed 3d scanner will be put through several tests to measure its accuracy and ability to create realistic representations of its environment. The constructed demonstrator produced significantly less accurate results and scanning time was much longer compared to a popular competitor. This was mainly due tothe cheaper laser sensor and not the mechanical construction itself. There are however many applications where higher accuracyis not essential and with some modifications, a low-cost solution could have many potential use cases, especially since it only costs 1% of the compared product. The purpose of 3d scanning is to collect data of a real-world object or environment and recreate it in the form a digital 3d model. This 3d model has many applications, ranging from movie productions to industrial design andproduction quality control. To create a 3d model, the first step is the 3d scan. This results in a point cloud, often millions of points shaped like the scanned object and placed in a Cartesian coordinate system. These points are often so densely packed that they might appear as solid 3d model. To capture the color of each sample, point a camera can be used. This results in a “RGB point cloud”, a point cloud where each point has a color in the RGB (red, green blue) color scale.

III. METHODOLOGY:

The proposed methodology for the 3D scanner utilizing Arduino and stepper motors, integrated with an IR sensor, comprises several sequential steps. First, the hardware setup involves assembling the IR sensor, stepper motors, and Arduino microcontroller into a cohesive system. The IR sensor is positioned on a controllable platform driven by the stepper motors, all interconnected to the Arduino. Subsequently, software development ensues, crafted in Arduino's language. This software orchestrates the stepper motors' movement, orchestrates data collection and processing from the IR sensor, and orchestrates thecreation of a 3D point cloud representing the scanned object. Emphasis is placed on user-friendly and customizable software design. The scanning process commences by placing the object in front of the IR sensor and activating the system. The programmed stepper motors systematically manipulate the IR sensor to capture data from various angles. Laser emissions from the IR sensor bounce off the object's surface and are registered by the sensor. Collected data is relayed to the Arduino for processing. Following data acquisition, the software undertakes data processing tasks, employing algorithms to analyse the collected data and generate a 3D point cloud delineating the object's surface. The resultant point cloud constitutes a dataset representing the object's three-dimensional geometry. Finally, the system delivers an output in the form of a 3D point cloud, which can be saved in diverse file formats such as STL, OBJ, or PLY. This output can be seamlessly imported into 3D modellingsoftware for further refinement, including mesh generation, surface smoothing, or preparation for 3D printing.

SHARP IR SENSOR

PUSH BUTTON

SD CARDMODULE

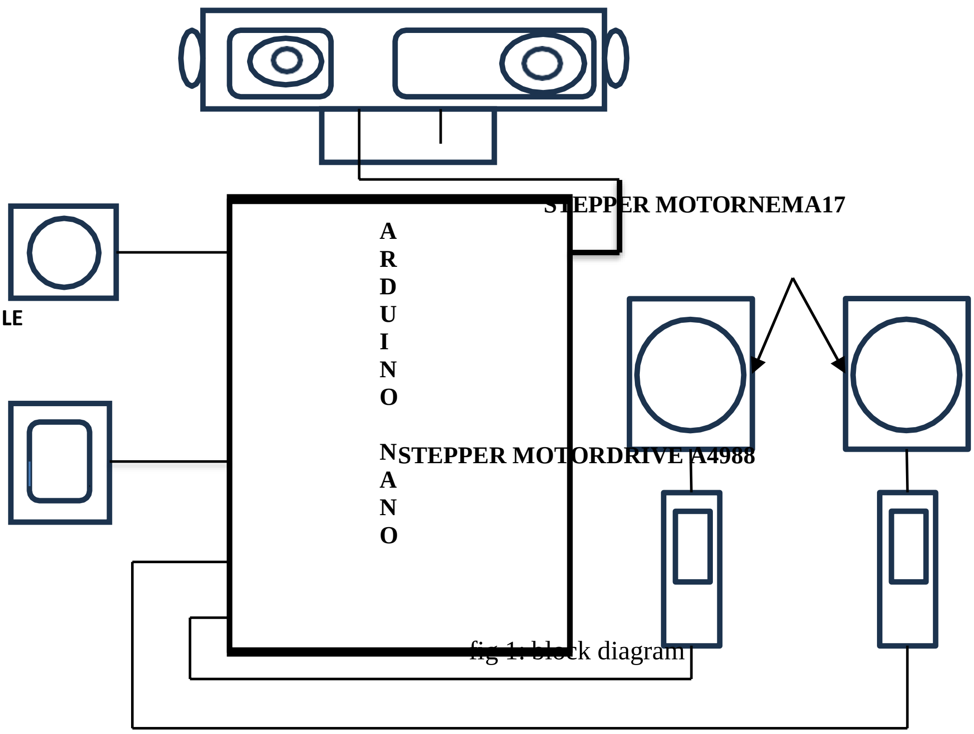

fig 1: block diagram

Components:

Arduino Nano: The Arduino Nano is a compact and versatile microcontroller board based on the ATmega328P chip. It featuresdigital and analog input/output pins that can be programmed to interact with various components. The Nano is ideal for projectswhere space is limited or where a smaller form factor is preferred. It can be powered via USB or an external power source, typically ranging from 7-12V. The Nano is programmable using the Arduino IDE, making it easy to develop custom software for controlling the entire system**.**

Stepper Motor: A stepper motor is a type of motor that moves in discrete steps, providing precise control over its position. It consists of multiple coils that are energized in a specific sequence to generate rotational movement. Stepper motors are commonly used in applications requiring accurate positioning, such as 3D printers, CNC machines, and robotics. The stepper motor used in this project is controlled by the Arduino and drives the platform holding the IR sensor. It typically requires a separate DC power supply, with voltage requirements ranging from 5-12V, depending on the specific motor.

Sharp IR Sensor: The Sharp IR sensor utilizes infrared light to measure distance accurately. It emits infrared light pulses and measures the time it takes for the pulses to bounce back after hitting an object. This time delay is used to calculate the distanceto the object. The sensor typically operates at 5V and can interface directly with the Arduino's digital pins for data transmission.It provides reliable distance sensing capabilities, making it suitable for applications such as proximity detection, object avoidance, and 3D scanning.

SD Card Module: The SD card module provides a means to read and write data to an SD card, enabling storage capability forsaving scanned data or other information generated by the system. It interfaces with the Arduino via SPI (Serial Peripheral Interface) communication protocol and typically operates at 5V. The module simplifies the process of storing and accessing data, making it convenient for applications where data logging or storage is required, such as 3D scanning or data acquisition systems.

Push Button: The push button is a simple switch used to initiate actions when pressed. It provides a tactile interface for user interaction, allowing users to trigger specific functions or commands within the system. The push button typically operates at 5V and can be connected to one of the Arduino's digital input pins. It serves as a user-friendly input mechanism for initiating the scanning process or triggering other actions as needed.

Power Supply:

Arduino Nano: The Arduino Nano can be powered through two main methods: via USB or an external power source. When connected to a computer or a USB power adapter, the Nano draws power from the USB port, typically providing 5V. Alternatively, it can be powered by an external power source connected to the VIN pin or the barrel jack. The recommended voltage for the external power source is between 7-12V. The Nano features a built-in voltage regulator that regulates the incoming voltage to provide a stable 5V supply to the board's components.

Stepper Motor: The stepper motor requires a separate DC power supply for operation. The voltage requirement for the powersupply depends on the specific stepper motor used in the project, typically ranging from 5-12V. It's essential to choose a powersupply that matches the motor's voltage requirement to ensure optimal performance and prevent damage. Additionally, the power supply should be capable of delivering sufficient current to meet the motor's current requirements under load conditions.

Sharp IR Sensor: The Sharp IR sensor operates at 5V and can be powered directly from the Arduino's 5V output pin. When connected to the Arduino, the sensor draws power from the microcontroller's onboard voltage regulator, ensuring a stable supplyvoltage. It's essential to provide a reliable power source to the Arduino to ensure consistent operation of the IR sensor. Additionally, proper decoupling capacitors should be used to filter out any noise or voltage fluctuations in the power supply line.

SD Card Module: The SD card module typically operates at 5V and can be powered directly from the Arduino's 5V output pin.When connected to the Arduino, the module draws power from the microcontroller's onboard voltage regulator, ensuring a stablesupply voltage. However, if the SD card module requires additional current beyond what the Arduino can provide, an external power supply may be necessary. It's essential to provide a stable power supply to the SD card module to ensure reliable data storage and retrieval operations.

Push Button: The push button operates at 5V and can be powered directly from the Arduino's 5V output pin. When connectedto the Arduino, the button draws power from the microcontroller's onboard voltage regulator, ensuring a stable supply voltage. It's essential to provide a reliable power source to the Arduino to ensure consistent operation of the push button. Additionally, proper debouncing techniques should be implemented in software to eliminate any noise or bouncing in the button signal.

IV. RESULTS AND DISCUSSION

The results of this research indicate that combining wireless dynamic auto charging with a subscription-based business model presents a strong argument for addressing the issues with the infrastructure supporting electric vehicle charging. The WDCC with subscription has the potential to accelerate the adoption of electric mobility and open the door for a more equitable and sustainable transportation future due to its combination of technical feasibility, operational efficiency, cost-effectiveness, accessibility, and environmental sustainability.

Functional 3D Scanning:

a. **Data Capture**: The IR sensor should effectively gather distance measurements from various points on the object'ssurface as the stepper motors rotate the sensor around the object.

b. **Complete Coverage**: The scanning process should capture data from a sufficient number of angles to create a comprehensive representation of the object's 3D geometry.

c. **Minimal Blind Spots**: The design and scanning strategy should minimize areas where the IR sensor might be occluded,leading to missing data points in the final point cloud.

Accurate Point Cloud Generation:

a. **Distance Accuracy**: The IR sensor measurements should correspond to the actual distances between the sensor andthe object's surface. Calibration of the sensor is crucial for achieving this.

b. **3D Point Representation**: The software algorithms must accurately translate the collected distance data into a 3D point cloud. Each point in the cloud should represent a specific location on the object's surface based on the distance measurement and its corresponding position during the scan.

c. **Minimal Noise**: The point cloud should be free of excessive noise or outliers caused by erroneous sensor readings or software processing issues.

Usable Output:

a. **Compatible File Format**: The generated 3D point cloud should be saved in a standard file format like STL, OBJ, orPLY. These formats are widely recognized by 3D modelling software, allowing users to import the scanned data for further manipulation.

b. **Usable for 3D Printing**: Ideally, the point cloud should be of sufficient quality and resolution to enable the creation of a watertight mesh suitable for 3D printing the scanned object.

c. **Potential for Refinement**: The 3D modelling software should allow users to refine the point cloud data, such as by smoothing the surface or filling in any minor gaps, before generating the final mesh for 3D printing.

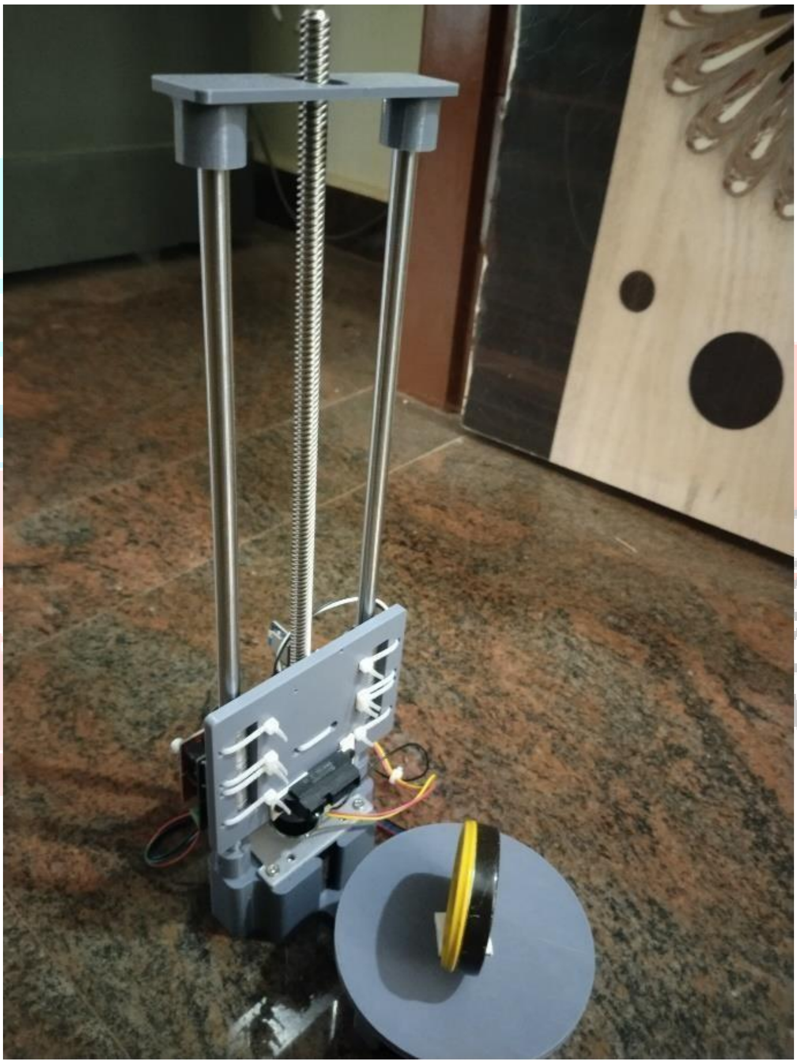

fig 2: 3D Scanning module

V. CONCLUSION AND FUTURE SCOPE

The development of a cost-effective 3D scanning solution utilizing Arduino Nano technology and structured light projection represents a significant advancement in the field of accessible digital fabrication. Through a systematic approach to design, calibration, and optimization, the project has successfully delivered a versatile and user-friendly system capable of generating detailed and accurate 3D models of objects. By leveraging the capabilities of Arduino Nano microcontrollers, along with off- the-shelf components and open-source software libraries, the system achieves remarkable affordability without compromising on performance. This affordability, coupled with its ease of use and versatility, positions the system as a valuable tool for a widerange of users, including hobbyists, educators, and small-scale industries. The system's ability to capture intricate details with high accuracy and resolution makes it suitable for various applications, including rapid prototyping, reverse engineering, and educational projects. Its competitive scanning speed and streamlined workflow further enhance its practical usability, enabling quick and efficient data acquisition.

Looking ahead, the project lays a solid foundation for future advancements in the field of low-cost 3D scanning technology. Further refinements and enhancements could be explored to expand the system's capabilities and address specific user needs. Additionally, efforts to promote accessibility and usability, such as the development of intuitive software interfaces and comprehensive documentation, will contribute to the system's widespread adoption and impact. Overall, the developed 3D scanning system represents a compelling solution that democratizes access to digital fabrication tools, empowering individualsand organizations to explore creativity, innovation, and problem-solving in new and exciting ways. As technology continues toevolve, projects like this serve as catalysts for positive change, driving progress and democratization in the digital manufacturing landscape.

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