# 3D Scanning Device
# Using Computer Vision

**Project Proposal**

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# 1. Introduction

A 3D scanner is a device that analyzes a real-world object to collect data on its shape and appearance. Then the collected data can be used to reconstruct digital three dimensional models. The collected 3D data is very useful for a wide variety of applications, especially for the entertainment industry in the production of movies and video games. There are plenty of technologies for digitally acquiring the shape of a 3D object. Most of the well-known 3D scanners are active scanners, which emit some kind of radiation and detect its reflection in order to probe an object. The active scanners are precise but expensive, because most active scanners are laser-based. Our project aims to make a passive scanner without using any laser, which is affordable for home-use. Our passive 3D scanner is camera-based, and is thus much cheaper than the laser-based scanners.

Objective

Our camera-based 3D scanner is capable of reconstructing at most a 3D model of approximately a 3`×3`×3` object. Meanwhile, it maintains simple installation process and friendly user interface. The product will be designed to reconstruct a general shape of the object in 3D, along with some simple color on the reconstructed model.

Benefits

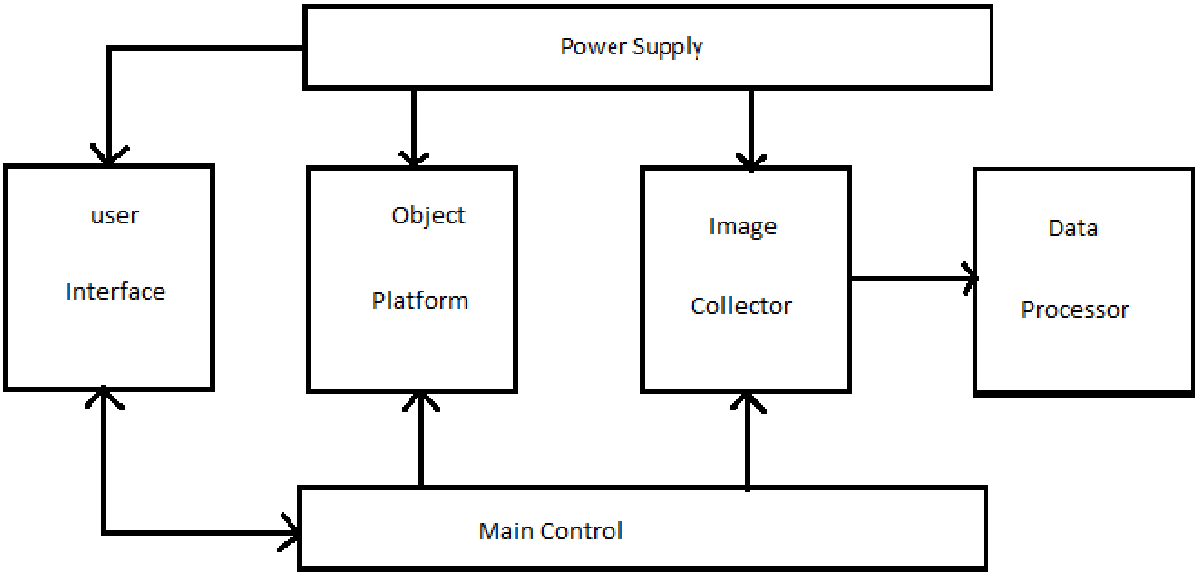
- Accessible 3D scanner for computer users
- Affordable 3D scanner for home-use
- Easy installation and user-friendly
- Environment for further algorithm development

Features

- High resolution Web camera
- A DC Motor with speed control
- Image segmentation algorithm
- 3D model reconstruction algorithm

# 2. Design

## 2.1 Design Block Diagram




## 2.2 Block Descriptions

***Object Platform***: The object platform unit is a basic mechanical structure that designed to hold the scanning object and the rotating arm for a camera and LED lights.

***Main Control***: The main control unit controls three parts in our system. Firstly, it interacts with the user interface which allows the user to start/end the scanning process. Secondly, it controls the motor in the object platform to obtain the desired angular velocity for the camera. Thirdly, it controls the LED lighting and camera to collect images of the object.

***Power Supply***: The power supply unit is a DC power supply that provides power to the object platform, control unit and data collector. This unit consists of two different DC voltage supplies. First, a 5V USB DC power supply from a PC USB port is used to provide power to the control unit and data collector. Second, a higher voltage from DC battery is needed to provide power to the motor in the object platform unit.

***User interface***: The user interface unit contains a start up button and other control buttons.

***Image collector***: The data collector unit consists of a web camera and several LED light sources. LED light sources are used to create an ideal artificial lighting condition. Meanwhile, the web camera captures frame data for 3D model reconstruction.

***Data processor***: The duty of the data processor unit is to manipulate the collected frame data and output a 3D model file that can be read by other common software. This unit can be further separated into two parts: image segmentation and 3d model reconstruction. Based on computer vision techniques, the algorithm creates object image segmentations and removes the background. Then these image segmentations are used to reconstruct a 3D model.

### 2.3 Performance Specification

- Camera rotating Speed: 2 rpm
- Scanning time: 1 minutes
- Display resolution: 640x480

## 3. Verification

### 3.1 Testing Procedures

This is the process utilized to ensure that all portions of the 3D scanner are implemented correctly.

- Power Supply
    - Camera Power Supply
      Our Web Camera is driven by USB. In order to keep the Web Camera functioning correctly, a voltage measurement will be performed before the camera is installed.
    - Motor Power Supply
      Our Motor is driven by DC battery. In order to keep the motor working well, a voltage measurement will be performed before the motor is installed.
- User Interface
    - The user interface will also be tested before setting up the whole system. The test will guarantee that the user interface has the correct input to output response.
- Main Control

- The main control will receive different combination of input signals, and then check the corresponding outputs.

- Image collector
  - The image collector receives the video from the camera first. Then, a sequence of frames will be obtained. Each frame according to a view from a specific angle. In order to check the correctness of each frame, a special sample object on which the surface is marked with values of angle will be used. Then the image of each frame has its own corresponding current angle.
    (Initial angle – current angle) ÷ angle speed = frame number.

- Data Processor
  - This is the most important component, and it will be explained in detail in the Tolerance analysis.

## 3.2 Tolerance Analysis

The most important component in this project is the data processor unit. The function of the data processor unit is to convert 2D image data into a 3D model. To achieve this transformation, a robust kernel algorithm is needed to be developed. The algorithm will process through all images, segment out object data and reconstruct the model from it. The failure of this kernel algorithm will immediately result in the failure of the project.

- Detail verification steps:
  1. The data collected is clear enough for the algorithm to process it. No corrupted data.
  2. Image segmentation part (i.e: background subtraction) is working correctly. The algorithm is able to perform a good enough segmentation on all image data. Furthermore, these segmentations must be continuous and physically correct.
  3. 3D reconstruction part is to reconstruct the 3D model of the object. Debug the algorithm to make sure matrix transformation and other related mathematical calculation function correctly.
  4. Make sure the output data is in right and readable formation.

- Corner cases:
  There will be a few unpredictable corner cases as well as predictable ones. Corner cases may be generated by weird colors and structures of the object. Our algorithm is not sensitive to concave surfaces. Applying different lighting conditions such as 30 or 15 degree strong light may help to detect concave surface according to the shadow. However, analyzing shadows will need higher level computer vision technique together with a more complex algorithm. Meanwhile, collecting data will take much more time. As one of the main objectives of this project is for family use, this project will tolerate some level of inaccuracy and focus more on fast algorithm and friendly user interface.

# 4. Cost and Schedule

## 4.1 Labor

| Name | Rate | Hours | *2.5 |
|---|---|---|---|
| Hansen Chen | $60/hour | 200 | $30000 |
| Xiaobo Dong | $60/hour | 200 | $30000 |
| Xingqian Xu | $60/hour | 200 | $30000 |
| | | Total Labor Cost | $90000 |

## 4.2 Parts

| **Parts** | **Price** | **Qty** | **Subtotals** |
|---|---|---|---|
| Metal Platform | $40 | 1 | $40 |
| DC motor | $20 | 1 | $20 |
| LED light | $1 | 4 | $4 |
| Camera | $40 | 1 | $40 |
| Micro-controller | $20 | 1 | $20 |
| USB Cable | $4 | 2 | $8 |
| Light cover | $5 | 1 | $5.00 |
| | | Parts Total: | $137 |
| | | Grand Total: | $90137 |

## 4.3 Schedule

| Week | Task | Leader |
|---|---|---|
| 02/06—Proposal due | Finish Proposal; | Xingqian |
| | Research on Algorithm about image segmentation; | Xiaobo |
| | Design Object platform; | Hansen |
| 02/13 | Finish Design Review; | Xingqian |
| | Design image collector; | Xiaobo |
| | Build Object Platform; | Hansen |
| | Research on 3D model representation; | Xingqian |
| 02/20—Design review | Design Review; | Hansen |
| | Design main controller; | Xinqian |
| | Build image collector; | Xiaobo |
| 02/27 | Finish Mechanical part of object platform and image collector; | Hansen |
| | Research on 3D model reconstruction; | Xingqian |
| | Design main controller; | Xiaobo |
| 03/05 | Build main controller; | Hansen |
| | Research on camera data collection; | Xingqian |
| | Coding on segmentation algorithm; | Xiaobo |
| 03/12—Individual Report | Finish individual report; | ALL |
| | Finish object platform, LED , main controller and Image collector; | Hansen |
| | Coding on 3D reconstruction; | Xingqian |
| 03/19—Spring Break | Testing on main controller; | Xiaobo |
| | Testing on object platform, LED, image collector; | Hansen |
| | Build user interface; | Xingqian |
| 03/26—Mock Demos | Mock Demos; | Xiaobo |
| | Build interface protocol for data processor; | Xingqian |
| | Coding on 3D model representation; | Hansen |
| 04/02 | Test on segmentation code; | Xiaobo |
| | Test on interface protocol; | Hansen |
| 04/09 | Test on 3D construction code; | Xingqian |
| | Test on 3D representation code; | Xiaobo |
| 04/16 | Prepare for final demo; | Hansen |
| | Overall testing on the whole system; | Xiaobo |
| 04/23—Final Demos | Start final paper; | Xingqian |
| | Final Demo; | Hansen |
| 04/30—Final Paper | Finish final paper and Check out; | Xiaobo |

Note: All group members will be responsible for the project.