THESIS

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VISUALIZING THE SUN'S BURNING EFFECT ON HUMAN SKIN

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Abstract

To further our knowledge of the physiological effects of solar radiation on the human epidermis, this thesis explores the complex link between skin thickness and Sunshine exposure. The study examines the complex relationship between Sunlight and skin, considering possible effects on disease, aging, and skin health.

A thorough examination is carried out using a combination of modern imaging techniques and clinical data to investigate this link. Variations in skin thickness are measured in various populations, considering age, skin type, and geographic location, to capture a wide range of influences on skin structure.

This research has practical implications for skincare education and public health. By determining which parts of the face are more vulnerable to the effects of the Sun, people may make educated judgments regarding the use of sunscreen, wearing protective gear, and general Sun safety procedures. With this knowledge, people can modify their Sun protection strategies to target the areas most susceptible to damage, perhaps reducing long-term effects on the health of their facial skin.

This thesis contributes to understanding the complex link between skin thickness and Sunlight. The results emphasize how crucial it is to consider Sunshine exposure as a significant determinant in skin health and lay the groundwork for further studies to improve skincare routines and enhance general well-being.

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1. Introduction

The construction of precise and eye-catching 3D models is essential in various industries, from simulations and architecture to entertainment and entertainment technology. The ability to faithfully simulate how Sunlight interacts with different surfaces, particularly the human body, is essential to attaining realism in these representations. For realistic 3D models to be created, knowledge of Sunlight direction and its effects on various body regions is crucial. This section explores the process used to compute angles between vectors (normal vector and Sunlight direction), a key for determining how Sunlight illuminates multiple human body areas.

Normal vectors are fundamental in computer and 3D graphics because they reveal essential details about how light interacts with surfaces. These vectors provide information on the orientation of a surface by existing among the plane of that surface at a particular location. Understanding the behavior of light and shadows on the surface requires knowledge of the object's orientation.

We have devised a particular approach for computing normal vectors adapted to skin surfaces to examine how Sunlight interacts with different human body regions. There are several steps in this process:

1. Surface Sampling: We start by carefully sampling points on the 3D model's skin surface. For authentically representing areas with varying skin thickness, this is essential.
2. Normal Calculation: We determine the surface normal vector, which is perpendicular to the skin surface, at each sampled face of the object (human body parts).
3. Normal Calculation: We calculate the normal vector simultaneously at each point in the skin surface. The accurate texture mapping is made possible by this exact normal vector alignment.
4. Sunlight Direction: The direction of the Sun's rays as they hit the skin can be determined using the normal vector. Understanding how light affects the skin, including the subtleties of shadows and highlights, depends on this information.
5. Skin thickness: Display the skin thickness of human body parts; the thickness level can visualize the effect of the Sun.
6. Combination of skin thickness and Sun: The mixed texture displays the level of the effect of the Sun on the skin by caring thickness at the same time.

The normal vector computation procedure dramatically improves the realism of 3D models for various body components. It makes it possible to accurately describe how Sunlight interacts with skin while considering changes in skin thickness and minor lighting effects. The lifelike images produced by this level of accuracy emphasize the interaction between light and shadow.

The correctness of normal vector calculations is essential for various applications, including character modeling, medical visualization, and architectural design. In these fields, it is crucial to accurately depict Sunlight's effects on multiple parts of the human body.

In conclusion, it is crucial to comprehend and use normal vector theory to develop 3D models that accurately represent how Sunlight interacts with different body parts. This method emphasizes accuracy and careful attention to detail in 3D modeling, ultimately assisting in creating visually appealing and convincing digital representations.

1.1 Statement of the Problem

Data visualization is one of the most powerful tools for explaining complicated ideas and insights to audience members with different educational backgrounds and degrees of competence. Because of how rapidly and accurately our brains are programmed to process visual information, visualizations are crucial for deciphering massive volumes of data. A human can recognize any picture for a brief period. The human brain can comprehend full images that the eye sees in as little as **13 milliseconds**, according to a team of neuroscientists at MIT. This is the first indication of such high processing speed [1].

Data visualization is fundamentally a storytelling technique. We can successfully convey challenging facts to our people and make our findings more approachable and exciting by turning unstructured information into a visual representation. Data visualization's ultimate purpose is to make it easier for people to comprehend complex information so they can act on that understanding.

It is an established and empirically supported fact that excessive exposure to solar radiation can result in detrimental damage to the skin, which manifests in various forms, such as the development of skin cancer and other adverse outcomes. Given this consideration, there has been a growing need to comprehend the influence of the Sun on human physiology, particularly regarding the solar angle and skin thickness as essential determinants of the extent and impact of solar exposure and associated harm.

To optimize the advantages of solar irradiance while mitigating the associated hazards, it is vital to appreciate the most favorable alignment of various anatomical regions to the Sun's angle. Moreover, the degree of solar exposure and resulting harm could be influenced by the dermal thickness divergences amongst distinct anatomical regions. A heat map-based solution can facilitate the visualization of information about the impact of various factors on different anatomical components, particularly in specific body postures or movements. This may enable a more comprehensive analysis of such information.

This thesis aims to thoroughly investigate information visualization to enhance our comprehension of the interplay between the angle of the Sun and skin thickness and their influence on the degree of exposure and harm caused to the human body. Blender will calculate vertex color values and show colors dynamically to achieve our goal. Python will be used to analyze the data precisely. To give consumers a thorough grasp of the influence of solar radiation, a visually compelling representation of the data will be provided by utilizing Unity's powerful animation capabilities. Furthermore, the robust heatmap generation features in ParaView will make it possible to create intricate visualizations that clearly and informatively illustrate solar radiation patterns.

1.2 Objectives

The main goal of this thesis is to present an advanced technique for tracking the angle value between each triangular face's normal vector and the Sunlight directing vector in a three-dimensional (3D) visualization of the effects of Sun exposure on the human body. Using this strategy, the thesis seeks to create a thorough heatmap-based system that precisely colors the human body model according to the differing levels of solar radiation exposure in various body parts.

The study also aims to create an interactive application that lets users evaluate the possible risks of Sun exposure depending on how they move and stand. By integrating advanced data visualization tools like Blender, ParaView, and Blender Python (BPy), the study aims to offer an in-depth analysis of how Sunlight direction and skin thickness affect the distribution of solar radiation on the human body.

Furthermore, taking age, gender, and skin type into account, the thesis attempts to investigate the possible differences in Sun exposure risks for various people. The research aims to provide individualized Sun protection guidelines and solutions by establishing a correlation between the physiological and anatomical features of the skin and UV absorption.

This extra dimension will allow the visualization to represent the different skin thicknesses more accurately and how Sun radiation affects the various parts of the human body. This thorough depiction will provide insights into the interactions among skin thickness, skin pigmentation, and solar radiation, resulting in a comprehensive understanding of the possible risks of extended Sun exposure.

This multi-dimensional study combines anatomy, physiology, and data visualization to advance our understanding of skin health and solar exposure to create more effective public health initiatives and better Sun protection techniques. To promote the adoption of efficient skin protection measures, the study seeks to raise public awareness and understanding of the risks associated with solar radiation by highlighting the importance of information visualization in communicating complex data about the dangers of Sun exposure.

1.3 Technology Fundamentals

The information visualization in this thesis was developed using various advanced tools and techniques. The addition of Blender, an adaptable open-source 3D graphics program, was vital for producing complex mesh structures that depict the human body. The obj file format was used to extract and analyze complex data to calculate vertex color values using Blender Python (BPy).

Renowned for its robust visualization features, ParaView played a crucial role in producing detailed heatmaps that showed the complex relationship between the position of the Sun and various skin thickness levels in different areas of the mesh canvas. This gave rise to a thorough knowledge of how solar radiation affects the human body.

The gradient color feature of Power BI, a potent corporate analytics tool, has improved the visualization capabilities. This function made it possible to create color codes based on the data, giving the information a visually appealing representation. By enabling a clearer and more intuitive comprehension of the complex nuances connected to solar radiation's impacts on the human body, Power BI integration greatly enhanced the analysis.

Moreover, realistic data representations were produced by utilizing Unity's dynamic animation features, which made it possible to explore the complex connection between solar radiation and human physiology excitingly and educationally. It was made possible by carefully selecting and combining these advanced technologies, which enabled the creation of a solid and trustworthy data visualization system and promoted an in-depth investigation of the subtleties of solar radiation's effects on the human body.

2. Background Theory

2.1 Importance of Visualizing Sun Exposure Data for Public Health

Excessive Sun exposure can lead to a variety of health issues, including skin cancer and eye impairment. Public health groups and medical professionals have stressed the need for Sun protection education to prevent these disorders. However, many still need to fully comprehend the risks of Sun exposure, so visualizing data on Sun exposure is vital. Individuals can better understand the potential dangers of Sun exposure and take proper precautions to protect themselves by presenting information such as UV radiation levels, skin cancer rates, and sunburn incidence. Data visualization can also assist politicians and public health experts in making informed judgments about Sun safety legislation and programs. Sun exposure carries both harms and benefits. Exposing the skin to the Sun is the leading modifiable cause of skin cancers, which exert a considerable health and economic burden in Australia. The most well-established benefit of exposure to ultraviolet (UV) radiation is vitamin D production. Australia has the highest incidence of skin cancer in the world. Still, despite the high ambient UV radiation, approximately one-quarter of the population is estimated to be vitamin D deficient. Balancing the risks and benefits is challenging and requires effective communication. In addition to examining the relationships between these variables and Sun protective actions, we aimed to present an overview of public attitudes and knowledge surrounding vitamin D and Sun exposure. They conducted an online survey in 2020, and the analysis included 4824 respondents who self-reported having fair or medium skin tone. Only 25% of participants were concerned that using sunscreen affects vitamin D synthesis, and 34% could not determine how much time is needed outdoors in the summer and winter to maintain optimal vitamin D status. Inadequate Sun protection methods were linked to this ignorance. It is necessary to promote natural vitamin D production while preventing overexposure through public education [2] [3].

It is tough to weigh the benefits and risks of Sun exposure. Despite significant levels of ambient UV exposure in Australia, the 2011 National Health Survey reported that over 25% of the population was vitamin D deficient, with a blood 25-hydroxyvitamin D concentration of less than 50 nmol/L. It is commonly accepted that repeated sub-erythemal doses of UV light with plenty of skin exposure are the best way to keep vitamin D levels stable. Current studies also suggest that using sunscreen regularly does not result in vitamin D insufficiency. However, guidelines differ on balancing the dangers and benefits of Sun exposure, and there is evidence that both primary care practitioners and the general population may need clarification about this topic [3].

2.1.1 Overview of Information Visualization Techniques for Sun Exposure Data

In today's technology world, effectively visualizing data has become essential to explain the data to people who are not technology-related, as data is one of the most critical parts of each technology. This section of the thesis explores the significance of information visualization techniques, mainly in the context of Sun exposure data analysis. Effective visualization methods not only aid in comprehending data but also facilitate the exploration and interpretation of critical factors related to Sun exposure, such as solar elevation angle and skin thickness. This context will introduce an overview of information visualization techniques for Sun exposure data, discuss the suitability of various visualization methods for studying solar elevation angle and skin thickness, and evaluate the benefits and drawbacks of these techniques to provide a thorough understanding.

Various methods and technologies for visually expressing data are included in the multidisciplinary topic of information visualization. Its main objective is to convert complicated datasets into understandable and valuable visual representations. Information visualization techniques are essential for getting insights into patterns, trends, and correlations in the context of solar exposure data, which frequently involves a wide range of variables and enormous datasets. It is impossible to stress the importance of information visualization in the context of solar exposure statistics. Data on Sun exposure is essential for many disciplines, including dermatology, environmental science, and public health, since it aids in understanding how Sunshine affects the skin and general health. Researchers and experts can get essential insights from data on Sun exposure by using information visualization techniques [5].

A few well-liked information visualization approaches are particularly relevant for data on Sun exposure, where the most common data visualization techniques are:

1. Heatmaps: Heatmaps help display sizable datasets with numerous factors, such as UV radiation levels, skin type, and location. Heatmaps offer a quick visual summary of how different components interact, indicating potential correlations and patterns using color gradients to represent data values.

2. Geographic Information Systems (GIS) Maps: GIS maps are essential when examining the geographical components of Sun exposure data. They can illustrate the differences in UV radiation levels between geographical areas, assisting researchers in locating riskier Sun exposure zones. Additionally, GIS maps can be combined with demographic information to analyze the effects of Sun exposure on various populations.

3. 3D Visualization: 3D visualizations can be helpful in investigations considering the interplay between solar elevation angles and skin thickness. They give academics a better understanding of how these elements interact by enabling them to perceive intricate interactions in three dimensions.

When the viewer's objective necessitates comprehending the three-dimensional geometric structure of objects or sceneries, 3D is most advantageous. Users will be able to create a usable mental model of dataset structure more rapidly utilizing a 3D view with interactive navigation controls to select the 3D viewpoint in virtually all of these situations than they will by simply using many 2D axis-aligned views. All of the drawbacks of using 3D for these tasks mentioned above are overcome by the advantage of assisting the observer in creating a mental picture of the 3D geometry [4].

4. Interactive Dashboards: Users can dynamically analyze solar exposure data using interactive dashboards, which integrate multiple display techniques. They enable data exploration, filtering, and customization based on user preferences or particular research questions. Professionals and decision-makers requiring immediate access to Sun exposure data can benefit most from interactive dashboards.

5. D3 and Interactive Web Visualizations: D3 is a potent JavaScript package that excels at producing dynamic and interactive web data visualizations. Researchers can utilize D3 to create interactive web-based visualizations that make it simple for consumers to investigate data on solar exposure. With D3, one may create unique interactive maps, charts, and graphs showing real-time correlations between skin damage and solar elevation angles. These visualizations can be integrated into websites or dashboards to improve user engagement and accessibility.

In conclusion, various visualization methods can be used to examine solar elevation angle and skin thickness in Sun exposure data analysis, including line charts, heatmaps, GIS maps, Blender for 3D visualizations, D3 for web-based interactive visualizations, and interactive dashboards. By integrating these methods, researchers can develop a thorough understanding of how skin thickness and solar elevation angle interact and affect outcomes related to Sun exposure, ultimately assisting in the development of better public health policies and skin cancer prevention initiatives or teaching people to be educated about the Sun effect to the skin in an effective way. The eyes are crucial for memory and comprehension. They record outside inputs like text, images, and videos as the principal sensory organs for visual information. A key component of general memory is visual memory, which enables us to recall the shapes, colors, and spatial relationships related to our memories. Visual tools like charts and diagrams help to clarify complicated ideas and improve understanding. The eyes are excellent at seeing patterns, which enables us to spot trends and connections in data. They connect, give context to information, and arouse our emotions in response to the material. Navigation is aided by spatial memory, and pertinent information is provided priority via selective attention. Metaphors and visualization approaches take advantage of the eyes' capacity for symbol recognition to aid comprehension and memory retrieval.

2.2 Advantages of Information Visualization Techniques for Sun Exposure

The importance of information visualization approaches in the context of Sun exposure data analysis, a topic of utmost significance in disciplines like dermatology, public health, and environmental science, was covered in the previous sections. As we explore this area, it is crucial to critically evaluate the benefits and restrictions connected with different information visualization techniques specifically designed for solar exposure data. For academics, practitioners, and policymakers, having a solid understanding of these issues is essential because it helps them choose the best visualization techniques and successfully evaluate data on solar exposure.

Benefits of Sun Exposure Data Information Visualization Techniques:

Enhanced Comprehension: Information visualization techniques turn unstructured data into understandable visual representations that are easier to access. The understanding of complex patterns and correlations is made simpler by visualization when dealing with solar exposure data, which frequently consists of complex datasets. Users may quickly identify trends, peaks, and anomalies using charts, graphs, and maps.

Pattern Recognition: Visualization assists in identifying patterns and trends in data on Sun exposure. Researchers can find geographic areas with high UV radiation levels, changes in solar elevation angles over time, and associations between skin disorders and Sun exposure. The creation of hypotheses and data-driven decision-making both benefit from this pattern recognition.

Interactive Exploration: Interactive exploration is a feature of several visualization techniques that allow users to study solar exposure data in real-time. Users can filter data, zoom in on particular timeframes, or choose specific geographic locations of interest using interactive dashboards. This interactivity encourages a deeper understanding by considering different research topics and attractions.

Geospatial Insight: Geographic Information Systems (GIS) maps offer geospatial insights into data on solar exposure. Researchers can examine regional variations in Sunray angles and UV radiation levels. For public health professionals, this information is crucial because it makes it easier to identify regions with a higher risk of Sun exposure and adapt actions to those areas.

Effective Communication: Most visualization techniques are powerful tools for presenting data about Sun exposure. Visual representations are more exciting and efficient in communicating information than raw statistics or prose explanations, whether used to communicate with legislators, healthcare professionals, or the general public. Visuals that are easy to understand can help spread knowledge and raise awareness of Sun safety.

Time-Series Analysis: Time series visualizations, such as line charts, facilitate examining solar exposure data over time. They make it possible to recognize trends, patterns, and fluctuations in solar elevation angles throughout time. To help with Sun protection advice, researchers can identify peak Sun exposure hours and evaluate how these fluctuate with the seasons.

Multi-Dimensional Data Representation: Information about Sun exposure frequently consists of several factors, including UV radiation levels, skin types, and geographic locations. Multi-dimensional data is particularly well-represented by methods like heatmaps and 3D. They demonstrate the correlations between different variables, assisting researchers in analyzing the complex relationships found in the dataset.

Support for Risk Assessment: Visualization can be helpful when evaluating the risks of Sun exposure. Stakeholders can decide on Sun protection measures, including sunscreen, protective gear, and shade, by being educated with data on UV radiation levels and solar angles in particular places.

When used to analyze data on Sun exposure, information visualization approaches have numerous significant advantages. These benefits include improved comprehension, pattern identification, interactive exploration, geospatial insight, effective communication, time-series analysis, multi-dimensional data representation, and help with risk assessment. Researchers, medical professionals, policymakers, and the general public can better understand solar patterns, UV radiation levels, and their implications for skin health and public safety thanks to visualization methods that convert complex data on Sun exposure into visually appealing forms [6].

2.3 Limitations of Information Visualization Techniques for Sun Exposure Data

Although information visualization approaches offer valuable resources for comprehending data on Sun exposure, it is crucial to recognize their limitations. In this section, we explore the difficulties and limitations of using these tools to analyze data on Sun exposure. These restrictions cover difficulties with data quality, information overload, subjective interpretation, accessibility, and the possibility of deceptive graphics. They also cover concerns with oversimplification and technical knowledge. These constraints must be acknowledged and addressed for visualization techniques to be used in Sun exposure research responsibly and effectively.

- **Oversimplification of Complex Data:** The risk of oversimplification is one of the main issues with information visualization. Visualizations try to simplify complex data into understandable forms; however, this might result in the loss of information. For instance, complex correlations between many variables (such as UV radiation levels, skin types, and geographic locations) in Sun exposure data may be represented through visualizations that hide crucial information and interactions.
- **Subjective Interpretation:** Determining the meaning of visuals can be a personal endeavor. People could come to different conclusions from the exact representation, especially when presented with cloudy or complex patterns. Subjectivity in interpretation can increase uncertainty and make it more difficult for stakeholders and researchers to agree.
- **Issues with Data Quality:** The quality of the underlying data significantly impacts the effectiveness of information visualization. Sun exposure data that is inaccurate, lacking,

or biased can produce deceptive visuals and incorrect conclusions. It is crucial to ensure data quality through data gathering and validation procedures.

- **Information Overload:** Visualizations can overload viewers with abundant information when dealing with enormous datasets. While rich data representation is necessary for some research goals, balancing clarity and detail to stop consumers from feeling overloaded with data is essential.
- **Technical Expertise Requirements**: Technical skill is needed to produce and interpret advanced visualization approaches, such as 3D modeling, complex data processing, and interactive dashboards. Researchers and users may need training to apply these methodologies completely and effectively. This technical barrier can limit the accessibility of visualization tools to an audience that needs to be explained.
- **Accessibility Issues**: Not everyone has access to or is skilled at interpreting visualizations. Insufficient visual literacy and limited access to technology may bring accessibility issues. These issues must be resolved to guarantee that information on Sun exposure reaches various demographic groups.
- **Risk of Misleading Visuals:** Care must be taken while designing and presenting visuals to prevent unintentionally delivering false or misleading information. The interpretation of data about Sun exposure might be distorted by poorly designed or biased visualizations, potentially leading to poor decisions.

In conclusion, information visualization techniques are effective for studying and conveying data on Sun exposure, but they have substantial drawbacks. When using visualization techniques in Sun exposure research, several factors need to be carefully considered and managed, including the oversimplification of complex data, subjective interpretation, data quality problems, information overload, the need for technical expertise, accessibility issues, and the possibility of misleading visuals. Providing users with the proper training and support, building representations with clarity and accessibility in mind, and maintaining transparency in interpreting visualized data are all necessary to address these limitations [6].

3. Research Methodology

3.1 Definition and Explanation of Solar Elevation Angle

Determining how the Sun affects intensity requires knowledge of the solar elevation angle. It is the angle between the horizontal plane and the Sun's center. Solar radiation is more intense when the Sun appears higher in the sky because the solar angle of incidence is greater. On the other hand, the Sun's elevation angle is less when the Sun lowers in the sky, which results in less intense solar radiation. For various purposes, including the production of solar energy, agriculture, and human health, it is crucial to comprehend the effect of the Sun's elevation angle on solar radiation intensity.

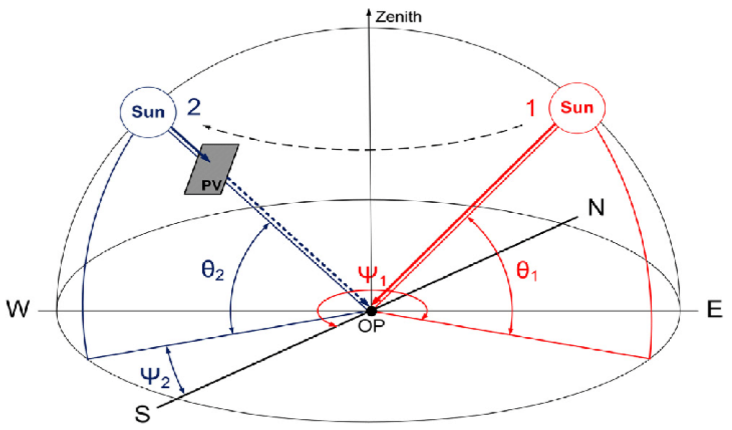


Figure 1. Sun Position around PV Panel and Observation Point (OP) [21]

Solar elevation angle and azimuth angle of the Sun, about the position of the PV panel and the observation point OP. Case 1 (Sun 1) depicts a part of the Sun where the OP is under direct Sunlight. In case 2 (Sun 2), the OP is under the shading of the PV panel, θ and ψ are the solar elevations and azimuth angles.

The angle between the horizon and the Sun's center, as seen from a specific spot on the globe's surface, is known as the solar elevation angle. The solar altitude angle, solar height angle, or solar zenith angle are other names for it. Due to the inclination of the Earth and its orbital motion around the Sun, the solar elevation angle fluctuates throughout the day and with the seasons.

The solar elevation angle is at its greatest, or 90 degrees when the Sun is directly overhead. The solar elevation angle is 0 degrees during dawn and dusk (Dawn is the time of morning when the Sun is 6° below the horizon. Respectively, Sunset occurs when the Sun is 6° below the horizon in the evening). The quantity of the Sun's rays that reach a specific spot on the Earth's surface depends on the solar elevation angle. The straight the solar radiation is, the higher the amount of solar radiation because of the higher solar elevation angle.

3.2 The Effect of Solar Elevation Angle on Solar Radiation Intensity

The time of day, season, latitude, altitude, cloud cover, and atmospheric conditions are some variables that influence the intensity of solar radiation. These variables may alter the quantity and quality of solar radiation that reaches the Earth's surface and, as a result, the amount of solar radiation exposed to the skin. For instance, solar energy must pass through the Earth's atmosphere at higher latitudes and altitudes to reach the surface. This can cause more scattering and absorption, reducing the intensity of solar radiation. When evaluating the hazards of solar radiation exposure, it is crucial to understand these elements. Doing so can assist patients and healthcare providers in making educated choices on Sun protection and skin cancer prevention.

Several factors affect solar radiation intensity, including:

1. **Latitude:** The amount of solar radiation received at a specific location depends on its latitude. Areas closer to the equator receive more intense solar radiation than those farther away.

2. **Time of day:** The Sun's angle changes throughout the day, affecting the intensity of solar radiation. The highest solar radiation intensity is usually between 10 am and 4 pm.

3. **Season:** The Sun's angle changes throughout the year, affecting the intensity of solar radiation. Summer months typically have higher solar radiation intensity than winter months.

4. **Altitude:** Higher altitudes receive more intense solar radiation due to thinner atmosphere.

5**. Cloud cover:** Clouds can block or scatter solar radiation, reducing its intensity.

6. **Air pollution:** Air pollution can absorb or scatter solar radiation, reducing its intensity.

7**. Ozone depletion:** Depleting the ozone layer can result in higher ultraviolet (UV) radiation levels reaching the Earth's surface.

These factors produce observable variations in solar radiation intensity across various locations, seasons, and weather conditions. Understanding the factors that affect solar radiation intensity is crucial for several businesses, including agriculture, climate modeling, and renewable energy.

3.3 Damage of Solar Angle on Skin Exposure Based on Skin Thickness

Human skin and eyes are harmed by UV light exposure. The hazards, particularly for the skin, change depending on the color of the skin. Due to the type of melanin present and the level of pigmentation, those with intensely pigmented skin have a shallow risk of developing UV-induced skin cancer. In contrast, those with light pigmentation have a significantly higher chance of developing skin cancer, especially if they live in a region with a lot of ambient UV exposure. Habituation is the idea that low-dose repeated exposures to UV radiation can develop skin thickness and pigmentation, providing some protection against skin damage during subsequent exposures. Though photoprotection factors, which are comparable to the Sun protection factor (SPF) found in sunscreens, are only 2-3 for darker skin types at high northern latitudes and 10-12 for lighter skin types at lower European latitudes (e.g., 35°North) for darker skin types, the level of security is still only moderate [8] [9].

When it comes to skin exposure to ultraviolet (UV) radiation and the potential for skin damage, the angle of the Sun, at times referred to as the solar angle or solar elevation angle, can be a significant factor. Several variables, including the part of the day, the season, and the geographic location of the place, affect how the Sun appears to us during the day. Several variables, including skin thickness, can influence skin exposure and potential harm by interacting with the solar angle. Here is how it works:

UV Radiation and Solar Angle: The solar angle is the angle at which the Sun's rays impinge on the surface of the Earth. The solar angle is more direct when the Sun is higher in the sky, such as during midday, and less of the Earth's atmosphere must be penetrated by UV radiation from the Sun. This indicates that UV radiation is stronger and can easily enter the skin.

UV Penetration and Skin Thickness: Genetics, age, and prior Sun exposure are among the variables that affect skin thickness, which varies from person to person. Because there are more layers of tissue for the UV rays to pass through, thicker skin offers better natural protection against UV radiation. Before UV radiation reaches deeper skin layers, including the delicate cells in the epidermis and dermis, thicker skin can absorb and scatter it.

Skin protection: It is essential to shield the skin from too much UV radiation, regardless of the solar angle or the thickness of the skin. This entails using high-SPF sunscreen and protective gear, putting on sunglasses, and looking for cover during the hottest parts of the day. Thinnerskinned people may be more vulnerable to UV damage; thus, they should be extra careful to use Sun protection.

Seasonal Variations: The Sun angle changes throughout the year, rising higher in the summer and falling lower in the winter. This implies that UV exposure levels will vary throughout the year depending on where a person lives. It is critical to adapt to Sun's safety precautions appropriately.

The Sun’s angle generally impacts how much UV radiation reaches the Earth's surface, affecting skin exposure and potential harm. While skin thickness is one of many characteristics that affect a person's vulnerability to UV radiation, appropriate Sun protection is necessary to avoid skin damage and lower the risk of skin cancer regardless of skin thickness.

3.3.1 Analysis of Topographic Thickness of Face Skin

The complex layers and architecture of face skin have long captivated dermatology, cosmetic surgery, and facial aesthetics. The study carried out by Karan Chopra and colleagues explores the topographic thickness of human facial skin in detail. The work is crucial to plastic surgery because it guides resection and restoration procedures in oncologic, cosmetic, and reconstructive settings. The authors focused on 39 different facial subunits during their extensive investigation, which they carried out on ten human cadaveric heads. The tissue samples underwent computerized measurements and a careful embedding of paraffin procedure for analysis. Following analysis, the data were presented as relative thickness (also known as values and mean thickness values. The study aimed to map the thickness of the human face in detail, enabling researchers to gain essential insights into relative thickness index (RTI) values and provide a thorough grasp of the skin's topography across various facial subunits [10].

Plastic surgeons must thoroughly understand the various facial subunits' precise dimensions and relative thicknesses. This information is essential for directing many surgical procedures, including reconstructive surgeries, aesthetic procedures, and oncologic interventions. This study has significantly contributed to developing a standard for evaluating and comparing skin thickness in various facial regions by thoroughly examining skin thickness in each region.

The geographical variations in facial skin thickness are one of the study's most important findings. The results show that the thickness of facial skin varies significantly across different parts of the face rather than being distributed equally. The information obtained through the 3D scanning procedure provides priceless insights into these local variations.

The protective outermost layer of the face is thinnest at the radix and dorsum, where it measures an average of roughly 1.51 mm. These sections, frequently connected to the bridge and upper portion of the nose, best represent how delicate the skin is in these locations.

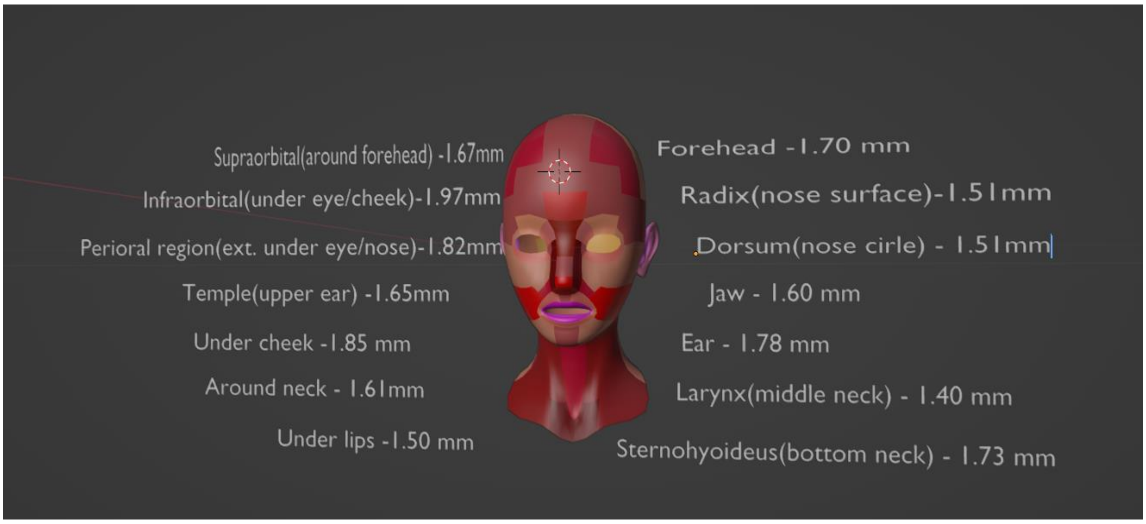


Figure 2. Blender Analysis - Skin Thickness

"The facial skin tended to become thicker in the order of the radix and dorsum, and the temple, supraorbital, forehead, perioral, cheek, and infraorbital areas," they wrote. The supraorbital, forehead, temple, cheek, infraorbital, and perioral regions tended to have the thickest facial superficial fat [10].

The study's authors noticed a regular pattern in the thickness of facial skin, noting that it usually thickens in a particular order. In their statement, they state that "the facial skin tended to become thicker in the order of the radix and dorsum, and the temple, supraorbital, forehead, perioral, cheek, and infraorbital areas." This regional variation in face skin thickness has essential consequences for various medical and cosmetic operations, enabling professionals to customize their strategies to the distinct anatomical features of each location.

The detailed information from the study revealed precise measurements for the thickness of the skin on the face and the distribution of superficial fat in various facial regions:

- **Forehead:** The skin of the forehead is typically 1.70 mm thick, whereas the superficial fat layer is generally 1.99 mm thick.

- **Radix and Dorsum:** The average thickness of the skin in the radix and dorsum regions is 1.51 mm. Averaging 1.61 mm, the superficial fat layer in these areas is also negligibly thin.
- **Supraorbital Region:** The surface fat layer has an average thickness of 1.82 mm, whereas the supraorbital region's skin has an average thickness of 1.67 mm.
- **Infraorbital Area:** The skin thickens significantly beneath the eyes, with an average thickness of 1.97 mm. The equivalent superficial fat layer is considerably thicker, with an average thickness of 4.93 mm.
- **The superficial fat layer** is significantly thicker, with an average thickness of 5.14 mm, than the skin, which has an average thickness of 1.82 mm in the area around the mouth.
- **Temple:** The temple has an average skin thickness of 1.65 mm and is located on the side of the face. The average thickness of the surface fat in this area is 2.58 mm.
- **Cheek:** The average skin thickness of the cheek, recognized for its function in defining facial contours, is 1.85 mm. Surprisingly, the thickness of the superficial fat layer in the cheek region is an average of 4.54 mm.

The ramifications of these discoveries for aesthetic and medical procedures are significant. For instance, it is helpful to know that facial skin thickens as one moves toward the lower part of the face. It helps doctors choose the best cannula entry points for injecting fillers, improving precision and producing better results. This research can change medical and cosmetic operations by revealing the regional variations in skin thickness and superficial fat distribution and providing customized techniques that prioritize patient safety and attractive outcomes. Our knowledge of the intricate details of facial structure is poised to grow as technology develops, opening up new opportunities for improving patient care and the artistry of facial aesthetics.

3.3.2 Understanding UV Radiation and its Effects

One of the many types of radiation that the Sun, a potent celestial body, emits is UV radiation, which significantly impacts the skin. Most people will eventually be exposed to Sun radiation, and while this exposure has many health advantages, excessive or unprotected exposure can result in various skin-related problems. This thesis investigates how the Sun affects the skin, concentrating on the processes of UV radiation-induced deterioration, the effects of continuous Sun exposure, and the current preventative methods and treatments to lessen its harmful effects.

Let us look at the mechanisms of Skin Damage Caused by UV Radiation:

The Sun emits three different wavelengths of ultraviolet radiation: UVA (320–400 nm), UVB (280–320 nm), and UVC (100–280 nm). However, UVC radiation rarely reaches the skin's surface because the Earth’s ozone layer successfully absorbs it. As a result, UVA and UVB are the leading solar radiation rays affecting the skin.

Most UV radiation that reaches the Earth's surface is UVA radiation, currently referred to as "aging rays" due to its role in accelerating the skin’s aging process. Reactive oxygen species (ROS) are produced by UVA radiation, which has been shown in scientific research to reach the skin's deeper layers (the dermis). ROS are very reactive chemicals that can harm lipids, proteins, and DNA, among other biological constituents [12].

Oxidative stress is one of the main mechanisms of UVA-induced skin damage. This oxidative stress destroys collagen and elastin fibers, essential for preserving the skin's suppleness and firmness. As a result, prolonged UVA radiation can cause the skin to sag and develop wrinkles and fine lines. Additionally, matrix metalloproteinases (MMPs), the enzymes that degrade collagen and other extracellular matrix components, can be stimulated by UVA radiation. “photoaging” refers to premature aging brought on by UV exposure, highlighting how the dysregulation of MMP activity might accelerate skin aging.

In contrast to UVA radiation, UVB radiation predominantly affects the epidermis, the top layer of skin. Because UVB radiation can result in Sunburn, it is frequently called “burning rays.” This form of radiation can directly harm the DNA in skin cells and is more energetic than UVA radiation. DNA alterations brought on by UVB-induced DNA damage can result in skin malignancies such as basal cell carcinoma, squamous cell carcinoma, and melanoma.

Additionally, UVB radiation has a strong inflammatory effect on the skin. It causes erythema (redness of the skin) and the attraction of immune cells to the afflicted area by causing the release of pro-inflammatory cytokines and chemokines.

As mentioned, prolonged exposure to UVA and UVB radiation hastens skin aging. Fine lines, wrinkles, uneven pigmentation, and decreased skin suppleness are all signs of photoaging. These outward indicators of aging can severely impact an individual's self-esteem and quality of life. According to scientific research, the degree of photoaging is directly correlated with the total lifetime exposure to UV radiation.

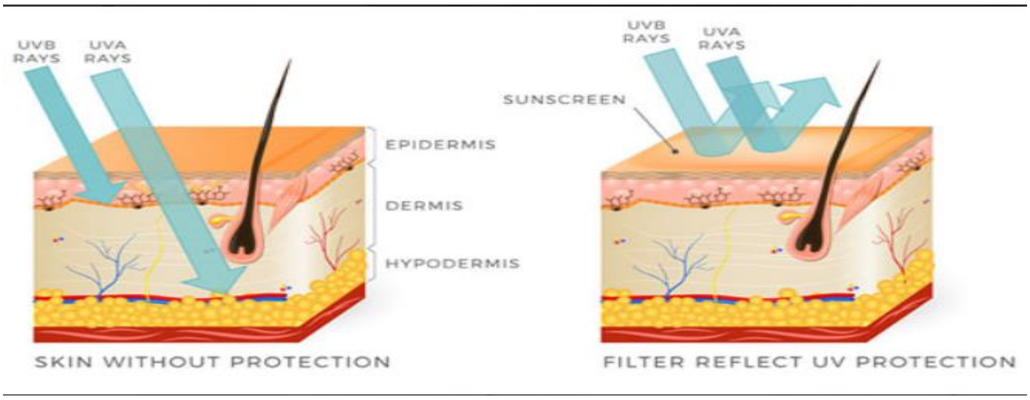
The increased risk of skin cancer may be the effect of excessive Sun exposure that concerns people the most. UV radiation is a proven carcinogen.

- Basal Cell Carcinoma (BCC): The most prevalent type of skin cancer, BCC directly correlates with UVB radiation exposure. When untreated, it often presents as a raised, pearly bump on the skin, seldom metastasizes, and can potentially be locally invasive.
- Squamous Cell Carcinoma (SCC): SCC is also linked to UVB exposure and frequently manifests as a raised nodule or a scaly, red patch. SCC has a more significant propensity for metastasis and can be more aggressive than BCC.
- Melanoma: UVA and UVB radiation have an impact on melanoma, the most lethal type of skin cancer. Melanocytes, the skin pigment-producing cells, are the source of melanoma. Melanoma can arise because of genetic alterations caused by UV exposure in melanocytes. Early detection and treatment are essential for improving melanoma patient outcomes.

Prolonged Sun exposure can exacerbate pre-existing skin disorders and lead to new ones, in addition to photoaging and skin cancer. For instance:

- Psoriasis: Due to UVB radiation's capacity to reduce the excessive proliferation of skin cells, it is occasionally used as a treatment for psoriasis. However, in people with a genetic predisposition, excessive or uncontrolled UVB radiation can exacerbate psoriasis symptoms or potentially cause psoriasis [13].
- Atopic Dermatitis: People with atopic dermatitis (eczema) frequently have flare-ups of their condition when exposed to UV rays. The research shows that it may cause eczematous lesions to become more itchy, red, and irritated [11].
- A pre-cancerous skin condition: It is called actinic keratosis characterized by rough, scaly spots on the skin's surface. It frequently results from prolonged exposure to the Sun and serves as a precursor to the development of skin cancer [13].

Preventive measures and efficient treatments are crucial for preserving skin health and lowering the risk of UV radiation-induced damage, given the Sun's significant influence on the skin.



(a) (b)

Figure 3. Skin Layers – The three layers are the epidermis, dermis, and hypodermis. Shows the effect of UVA/UVB Rays on skin with suncream protection in (a) and (b) the same skin without protection [20]

4. Development Techniques

4.1 Tools and Methods for Information Visualization on Solar Angle Calculator among 3D Mesh

The development process for a solar angle calculator with a 3D mesh visualization component is the main topic of this thesis portion. The objective is to create and deploy a platform that enables users to see Sun angles and how they affect 3D objects like solar panels, buildings, and landscapes. In this project, computer graphics, information visualization, and solar geometry are all combined. Here are specific directions for carrying out this project:

Objects of the Project:

- **Create a solar angle calculator:** Create an algorithm for calculating the solar angle that accepts location, time, and date as inputs and outputs the solar elevation and azimuth angles.
- **Create a 3D model of the environment or the desired objects:** We can also import the selected model. This might apply to structures, positions, or the texture of the imported object.
- **Integrate Solar Angle Data:** To see how Sunlight affects the environment's items, overlay the estimated solar angles onto the 3D model. This can entail rendering the angles on the 3D object as lines, vectors, or color gradients.
- **Develop an Interactive Interface:** Design a user-friendly interface that lets users choose location, date, and time while dynamically seeing the solar angles. Users should be able to adjust the 3D view to investigate the effects of solar angles from various angles.
- **Implement Real-time Updates:** The Sun angle calculations and 3D visualization update instantly as users alter the input settings. This functionality is essential to get accurate and dynamic visualization.

Project Components and Steps:

Solar Angle Calculation:

- Research and select an appropriate algorithm for solar angle calculations.
- Implement the algorithm in a programming language (We used BPython).

- Test the accuracy of the solar angle calculations against established solar models or data.

3D Mesh Generation or Import:

- Regarding the scope of our project, we created a 3D mesh using the modeling software Blender or importing existing 3D models, ParaView for the Heatmap, and Unity for the animation part.
- The Mesh accurately represents the objects or environment we want to visualize.

Integration of Solar Angle Data:

- Develop a method to map solar angle data (elevation and azimuth) onto the 3D.
- Implement visualization techniques that effectively convey solar angles, such as line segments indicating Sun direction or color-coding.

User Interface Development:

- Create a graphical user interface (GUI) that allows users to choose location, date, and time parameters.
- Design interactive controls for manipulating the 3D visualization, such as camera angles and time of day adjustments.

Real-time Updates:

- Changes in input parameters trigger real-time solar angle calculations and 3D visualization updates.
- Implement efficient algorithms to handle real-time updates without significant performance degradation.

User Testing and Feedback:

- Conduct user testing to gather feedback on the usability and functionality of the Solar Angle Calculator.
- Use feedback to make improvements and refinements to the tool.

Tools and Technologies Used:

- HTML, JavaScript (with libraries), CSS, and Bootstrap were employed to create the user interface and web-based components of the Solar Angle Calculator.

- Python, specifically PyCharm, was used to implement the solar angle calculation algorithm, handle linear algebra calculations, and other backend functionalities.
- Blender and the bpy (Blender Python) API were utilized to create and manipulate 3D models and meshes.
- Unity enhanced graphical rendering, user interaction among the 3D visualization, and position animation.

Using these tools and technologies, we created a thorough Solar Angle Calculator with interactive 3D visualization. It covers various topics, including web-based user interfaces, intricate calculations, 3D modeling, and graphics rendering. This varied technology stack allowed the project to be completed successfully and gave us a flexible tool for visualizing solar angles and their environmental effects.

4.2 Tracking Sunlight on the Human Body

In this section, we explore the nuances of monitoring Sunlight on the human body, which is essential to maximizing Sun exposure for health and well-being. The demand for advanced tools and procedures to determine the ideal angles for solar exposure grows as urban areas become denser and the health benefits of Sunlight exposure become more apparent.

Natural Sunlight is the primary source of vitamin D, which is necessary for many physiological processes. However, striking the right balance between Sun exposure and possible damage from too much UV radiation calls for a careful strategy. This section focuses on using Blender Python to create a computational model that computes the angles between normal vectors that represent the surface of the human body and vectors that direct the Sunlight.

We use BPython, a powerful Python package for numerical computations, to implement a robust technique for tracking Sunlight angles. Geometric data describing the surface of the human body is extracted and combined with the approach using real-time solar position data. This data fusion allows for precise calculation of the angles between vectors pointing to the Sunlight direction and normal vectors, allowing for a thorough examination of solar exposure.

We can use trigonometry and the dot product to find the angle between each triangle face's normal vector and the Sunlight direction vector. Let us write N for the triangle face's normal vector and S for the Sunlight direction vector. The arccosine function and the dot product can be used to find the angle between these vectors.

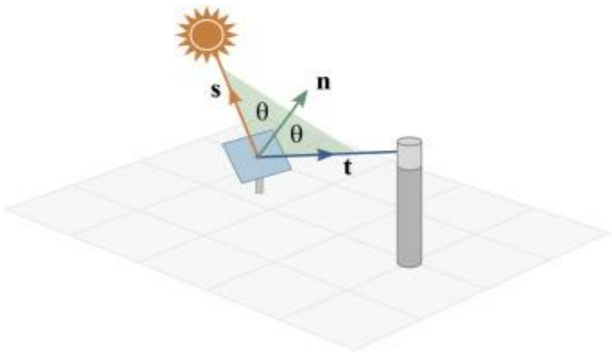


Figure 4. The angle between the Normal Vector and Sun direction Vector [22]

The formula for calculating the angle θ is given by:

$$\cos(\theta) = \frac{\mathbf{N} \cdot \mathbf{S}}{\|\mathbf{N}\| \cdot \|\mathbf{S}\|}$$

Where:

- denotes the dot product.
- ‖N‖ and ‖S‖ represent the magnitudes of vectors N and S, respectively, which signifies the dot product.

Next, find the angle by taking the arccosine of the outcome:

$$\theta = \arccos\left(\frac{\mathbf{N} \cdot \mathbf{S}}{\|\mathbf{N}\| \cdot \|\mathbf{S}\|}\right)$$

Explanation:

Dot Product: The similarity between two vectors is calculated using the dot product. Finding the angle at which the triangle face's normal vector aligns with the Sunlight direction vector is helpful.

Normalization: The vectors are normalized by dividing by their magnitudes, guaranteeing that the outcome is a cosine value between -1 and 1.

Arccosine: The actual angle can be obtained from the cosine value by taking the arccosine. In a right-angled triangle, the cosine of an angle is equal to the adjacent side divided by the hypotenuse.

5. Result

5.1 Mesh Generation Techniques

Software tools such as Blender (for sculpting and detailing), ParaView (using the Heatmap method for data-driven insights), and Unity (with its Animation features for dynamic and interactive elements) are used to facilitate the mesh generation process. Examining the synergy that results from combining these tools, a comprehensive method of mesh generation that addresses functional interactivity and visual detailing is presented.

Discussions of real-world visualization and analysis applications highlight how adaptable the selected methods are for expressing intricate spatial data and phenomena. The ensuing sections illustrate the mesh generation techniques' efficacy by delving into examples, visual outputs, and critical analyses.

The mesh generation is based on Blender, an open-source 3D creation suite with much power. To create complex and lifelike 3D models, we explore Blender's sculpting and detailing features. Blender's user-friendly interface facilitates accurate control over vertex placement, producing intricate and aesthetically pleasing meshes.

A flexible visualization tool called ParaView is used, with a special emphasis on the Heatmap technique, to improve the mesh generation. We produce visuals that depict underlying patterns and variances in the data by integrating data-driven insights into the mesh construction process. This technique helps identify essential features and enriches the Mesh with an extra layer of information.

Integrating Unity, a well-known game development engine, elevates our mesh generation to a new level by incorporating dynamic and interactive elements. Our 3D models are given life through the Animation features in Unity. Mesh animations make it possible to simulate dynamic processes and explore complex structures more interestingly.

This section examines the results of using Blender, ParaView, and Unity's strengths. A comprehensive approach to mesh generation is made possible by the smooth integration of these tools, which combine their strengths to produce detailed and aesthetically pleasing 3D representations.

5.1.1 Computational Analysis with Blender and BPython

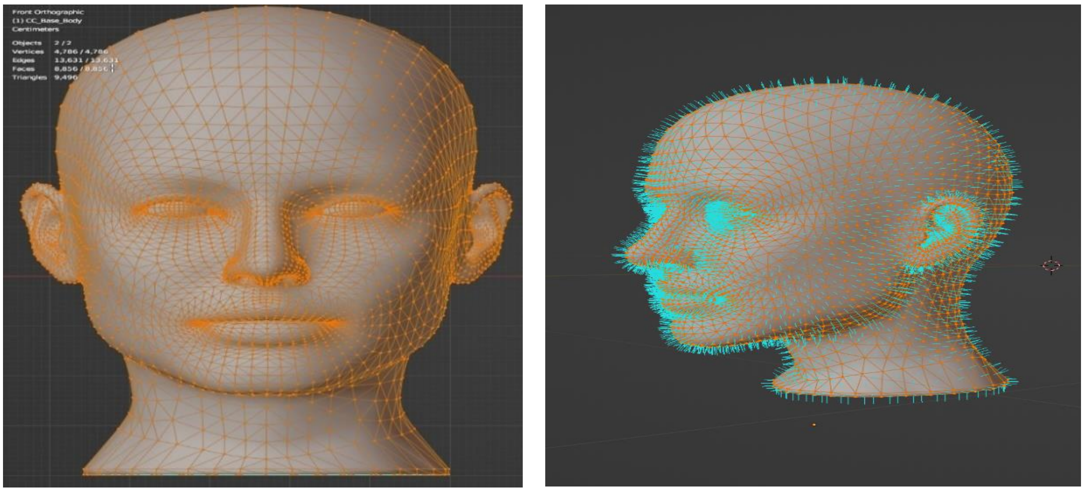
This section describes using Blender to create a realistic human body and face and import the results object file into our BPython-built computational analysis framework. Faces, edges, vertices, and normal vectors are all included in the generated object, which gives a complete picture of the mesh geometry.

Utilizing the robust features of Blender, we embarked on the intricate task of modeling a human body and face. The detailed creation involved sculpting and detailing to capture the complexity and nuances of the human form. The result was exported in object file format, encapsulating the rich geometry comprising faces, edges, vertices, and essential normal vectors for each triangular face. Below is the example format of the object file for a look.

```
v 0.000028 0.843992 0.268705
v 0.000566 0.422772 -0.301391
v 0.000394 0.612222 0.300310

vn -0.7272 0.6813 -0.0834
vn -0.8457 0.5274 -0.0810
vn -0.9315 0.3552 -0.0779

vt 0.447800 0.492100
vt 0.452300 0.490600
vt 0.454600 0.489400

f 509/515/515 581/602/602 546/561/561 462/464/464
f 585/605/605 584/606/606 553/568/568 586/607/607
f 589/608/608 588/609/609 587/610/610 590/611/611
```

Code 1. Parsing OBJ Files for Vertex, Normals, Texture Coordinates, and Faces

Because of the sheer mesh data, we encountered a significant computational load when we imported the object file into our BPython-based computational analysis environment. Optimization was essential because there were more than 16,000 faces in the original mesh.



(a) (b)

Figures 5. Illustration of 3D Head Representation with Triangular Faces and Smoothed Object (a), and Visualization of Face Normals in Blue (b)

In Figure 5, the human head model is dissolved into triangular faces from rectangular after being imported as an object file, and the dissolving approach aids in smoothing the object to display the coloring result better. In our method, we use the normal vector of the face. This concept helps us in selecting the suitable normal vector for each face to use or scripting the color to fill each face in BPy (Blender Python).

Calculating the angle between each triangular face's normal vector and the Sunlight direction vector formed the basis of our analysis. A critical point was reached when the initial mesh size presented computational difficulties in the loop portion of our Python code. In response, we streamlined the procedure by implementing strategic optimizations, which made it possible to calculate angles on the reduced set of 9,496 faces efficiently.

The provided Python script uses Blender's scripting features to import wavefront object file, access mesh data, and apply a shading effect based on a specified Sun position. After importing the object, the script configures smoothing for the Mesh and calculates colors for each face. It loops through the polygons, computes the Sun position's dot product and the face's normal, and converts the result to a color value. This color information is then assigned to the Mesh's vertices, resulting in a shading effect.

```
# Import the object file
bpy.ops.import_sceneobject file (filepath=obj_file_path)
# Access the mesh data
obj = bpy.context.selected_objects[0]
mesh = obj.data
# Set up smoothing
Mesh.use_auto_smooth = True
Mesh.auto_smooth_angle = 3.14159
# Calculate the color for each face
color_layer = mesh.vertex_colors.new()
for polygon in Mesh.polygons:
    for loop_index in polygon.loop_indices:
        loop_vert_index =mesh.loops[loop_index].vertex_index
        vertex = mesh.vertices[loop_vert_index]
        normal = vertex.normal
        sun_dot_normal = sun_position.dot(normal)
        color_value = (sun_dot_normal + 1) / 2
        color_layer.data[loop_index].color =
(color_value, color_value, color_value, 1)
# Update mesh
mesh.update()
```

Code 2. Computing Average Vertex Normals for Each Face in a 3D Mesh.

The computed angles between the Sunlight direction vector and the normal vectors of the chosen triangular faces are displayed in the output figures of our computational analysis. The graphical depictions offer valuable information for applications in architecture, urban planning, and health by illuminating the ideal amounts of Sunlight exposure for various parts of the human body.

A reassessment of the methodology was necessitated by differences in the results when the. The Obj file was imported into Blender for Sunlight analysis. To obtain a more thorough and accurate evaluation of the effects of Sunlight on the human body, it was decided to switch the study to ParaView while acknowledging the limitations encountered.

5.1.2 Coloring in Vertex paint mode in Blender and Power BI gradient tool

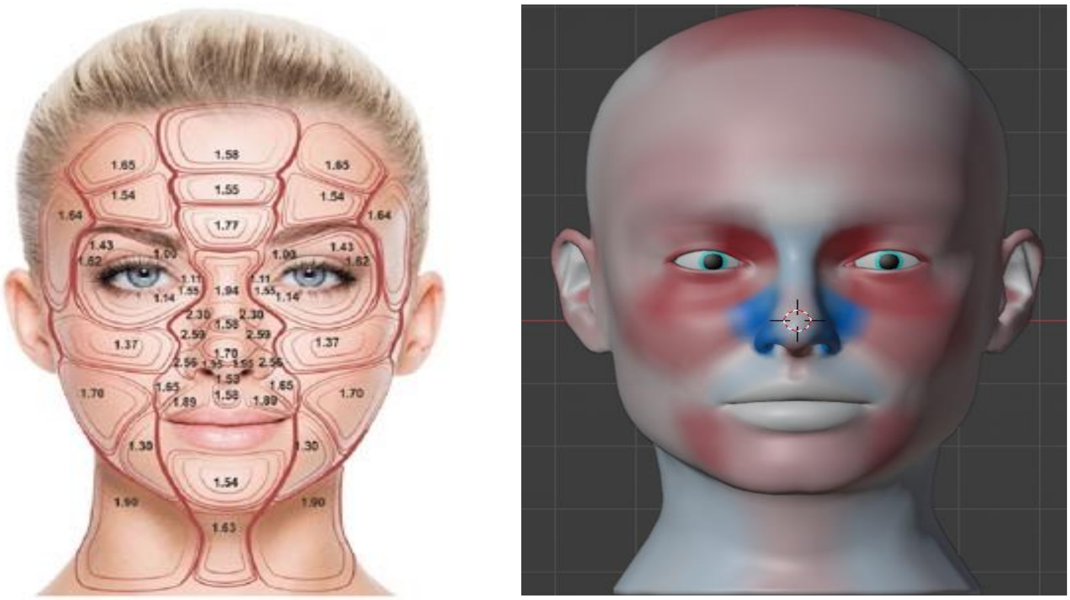
We describe the process of visualizing skin thickness on the human face using Blender's vertex coloring and Power BI to determine the color gradient. This novel method improves the accuracy of skin thickness representation while presenting a visual gradient that allows for a thorough comprehension of facial features.

Blender's vertex coloring feature proved to be an effective tool for visualizing the skin thickness on the face. A detailed representation was made possible using vertex coloring, which allowed each vertex to be given a color corresponding to the skin thickness value associated with [18].

Figure 6. Power BI Gradient Coloring Method Result.

Power BI was used to introduce a visually appealing and meaningful color gradient. A file with thickness values for every facial region was uploaded to Power BI to extract color values for the gradient mapping process. The selected color gradient was derived from Power BI's visualization tools. It goes from blue for maximum thickness to red for minimum thickness, with white representing intermediary values.

Next, Blender's Vertex Paint mode implemented the color codes extracted from Power BI. Every facial area was given a color corresponding to its skin thickness value, creating a complex and aesthetically pleasing representation. Using a gradient color scheme, blue was used to indicate thicker areas, red to indicate thinner areas, and white to ensure a smooth transition between values, effectively communicating variations in skin thickness.



(a) (b)

Figure 7. The image used for reference in (a) with values of the thickness and in (b) the result of the colored object in Vertex Mode in Blender with the color code from Figure 6

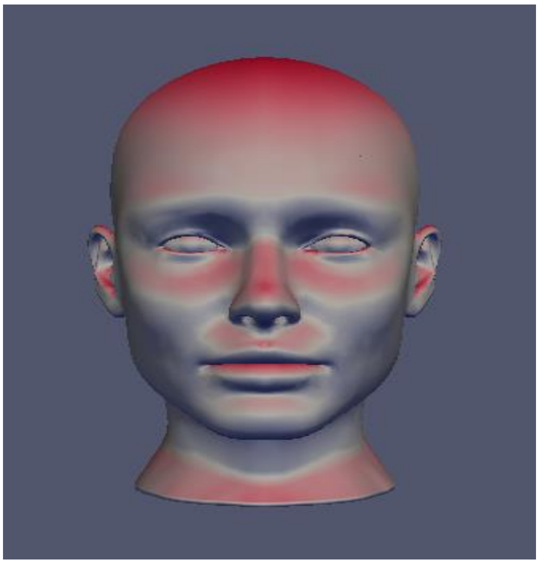
The output obtained from this vertex coloring technique provides a detailed and realistic representation of skin thickness variations across the human face. The gradation of colors offers insights into facial features, with the blue-to-red gradient allowing for an intuitive interpretation of thickness disparities.

5.1.3 ParaView with Heatmap Method

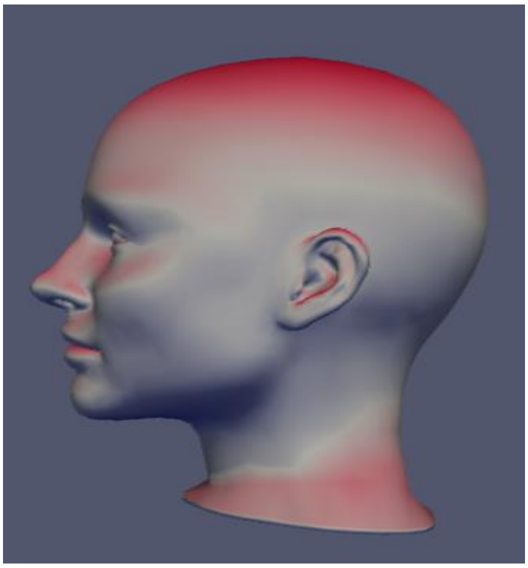
In this part of the project, we explored using the Heatmap function in ParaView to show how Sunlight affects the skin’s surface. Using this technique, we investigate how well the color depiction conveys the different levels of Sun exposure on the selected surface.

Understanding the impact along the normal vectors is emphasized in the model below. A more nuanced representation of the effects is possible thanks to the heatmap's configuration, which highlights variations in Sunlight exposure along the Y-axis.

With a color spectrum ranging from dark red, which indicates the most affected areas, to dark blue, which means less affected regions, the resulting heatmap vividly illustrates the impact of Sunlight. The color gradient offers a visually appealing and educational depiction of Sunlight effects by smoothly grading between these extremes.



(a)



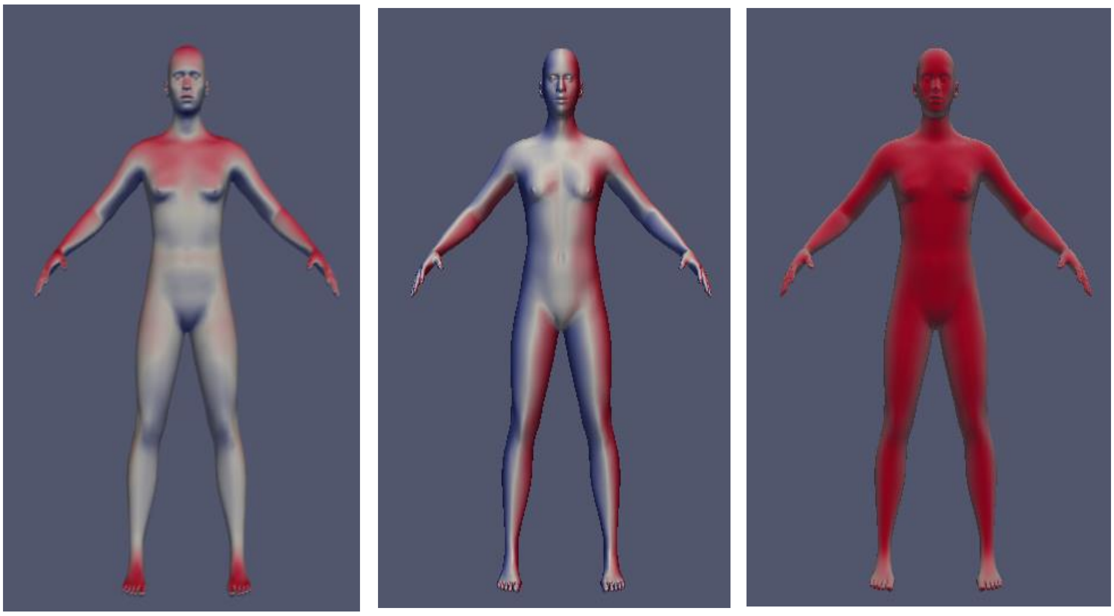
(b)

Figure 8. ParaView Visualization of Human Head with Sunlight Impact

The Heatmap method in ParaView is shown to be effective by the visualization output. One helpful tool for comprehending the distribution and intensity of solar exposure in the three-dimensional space is the color representation on the selected surface [16].

After the human face experiment, we continued testing the Sun effect on the entire body. First, we imported a ready human body male average-aged model that was downloaded. The object file was uploaded to ParaView. We used the same configuration and method of color toward the body and decided to visualize it from different Sun positions.

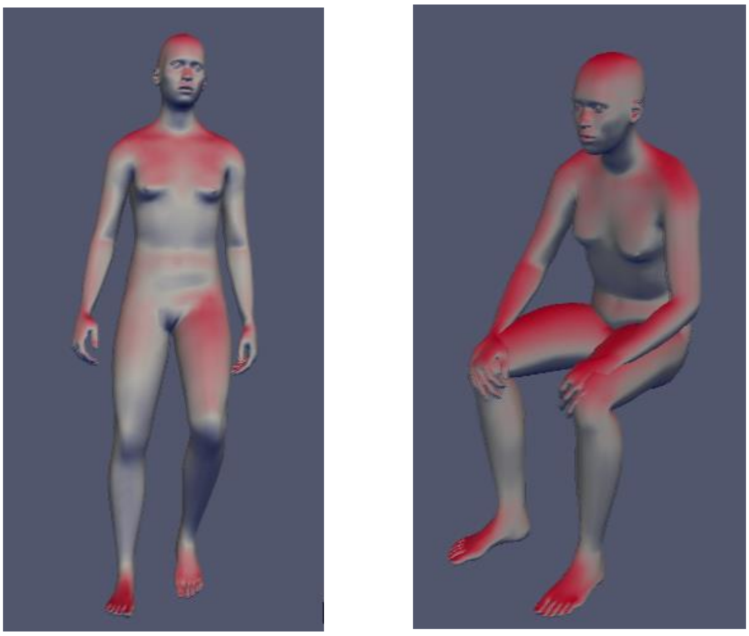
Below is a human body model with the Sun effect in the red part, which is the most affected, and the blue region, which is less affected, and the color is smoothing between blue and red.



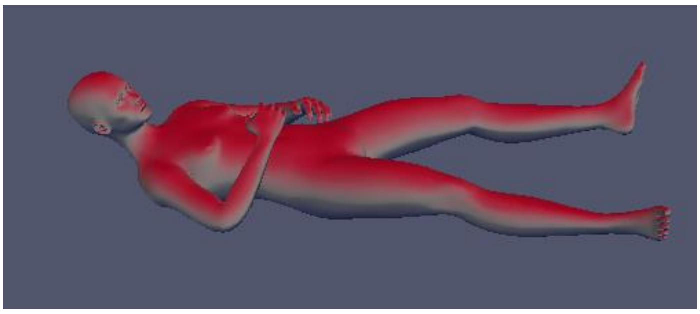
Y – axis X – axis Z – axis

Figure 9. ParaView Visualization of Human Body Model with Sunlight Effects

The Color Map Editor in ParaView customizes the color and opacity transfer functions. The View > Color Map Editor menu option allows us to toggle the Color Map Editor visibility.



Walking Sitting



Lying down

Figure 10. Sunlight Effects in Various Poses Using Heatmap Method in ParaView

Figure 10 depicts human faces and bodies in various situations, such as walking, sitting, and lying down. The depiction emphasizes areas influenced by sunlight, which are displayed in red. The goal is to understand how sunshine affects people in various stances, providing knowledge that can be applied in situations such as outdoor activities. This visualization acts as an instructional tool, offering information on Sun exposure for health and safety, and it has the potential to contribute to customized sun safety recommendations as well as broader public health programs.

5.1.4 Unity with Animation Features

The use of Unity's Animation features to produce a dynamic and interactive depiction of the human body's interaction with Sunlight is covered in detail in this section. By utilizing animations, real-time Sun position adjustments, and environmental elements, our goal is to create a variety of scenarios that demonstrate how Sunlight changes the human form.

Four essential postures are covered in the animation sequence: sitting, lying, sitting to lying transition, and standing from lying. Every animation scenario is designed to imitate authentic movements, offering a dynamic depiction of the interactions between Sunlight and the human body at various times.

The Sun's position is dynamically adjusted over 24 hours using Unity's Animation features to improve realism. Through interactive time manipulation, users can see how the angle and intensity of Sunlight change according to the selected hour. Visiting the source and direction of Sunlight is more accessible when the compass is included in the scene.

Body movement is incorporated to explore the dynamic nature of Sunlight interaction further. Because the human body is designed to move in four different directions, users can see how adjustments to the body's position alter the body's exposure to Sunlight. As the body moves around the scene, the time interval changes in real-time to reflect the new perspective.

Realistic Sun effects on human skin are simulated using Unity's rendering capabilities. The dynamic reddening of regions reflects the areas where solar radiation has the most significant effect, depicting the different impacts of solar radiation exposure.

Shading effects are introduced to depict the human body's shadow on the underlying surface. This improvement allows users to see how the body's position affects shadowing and shading, adding depth and realism.

Essential libraries like Unity's Standard Shader, Post-Processing Stack, and Animation Rigging Package are used to maximize functionality. These libraries guarantee a smooth and visually appealing animation by improving efficiency and realism.

With ready compositing, exact timing intervals, dynamic diffuse color changes, shading effects, facial modeling, and realistic rig movements, the resulting visualization output offers unprecedented detail. Now, users can interact with a lifelike simulation that faithfully depicts the complex interaction between Sunlight and the human form.

This section's conclusion highlights the importance of these cutting-edge Unity features, libraries, and animations, which set new benchmarks for the level of realism and depth that can be achieved when simulating how Sunlight interacts with the human body [19].

Figure 11. Human Body Animation - Surface Details (Effect of the Sunlight, Timing, Position, Sunlight Direction, Location)

6. Conclusion and Future Work

6.1 Summary

This study's investigation and examination of how Sunlight interacts with the human body offers a comprehensive grasp of the intricate dynamics at play. Every step of the process, from the detailed mesh creation in Blender to the sophisticated simulations and visualizations in ParaView and Unity, has added to a thorough depiction of how Sunlight affects the human form.

Detailed models of the human face and body created in Blender served as the basis for further analysis. Nonetheless, pursuing more precise techniques for skin thickness coloring and recognizing computational difficulties highlights the necessity of continuous Blender optimization or investigation of substitute software options.

The Heatmap technique from ParaView demonstrated how well it could depict the effects of Sunlight in three dimensions while providing insightful information about exposure intensity. The discovery of shading impacts as a possible improvement emphasizes how research is iterative, with new opportunities for improvement being found at every stage.

The animation features in Unity allowed for dynamic interactions with Sunlight in addition to bringing the human body to life. Advanced visual enhancements such as facial modeling, rig movements, diffuse color changes, ready compositing, timing intervals, and shading effects enhanced the simulation's realism. Future research is necessary to address the impact of clothing on Sun exposure, investigate demographic differences, and implement protective measures.

To sum up, this research offers a comprehensive framework for examining how Sunlight interacts with the human body, setting the stage for in-depth studies into how Sunlight affects various demographic groups and environmental factors. To promote health, well-being, and informed decision-making, this research is a stepping-stone towards a more nuanced and customized understanding of Sunlight effects as technology and methodology advance.

6.2 Future Work

In this final section, we suggest directions for future research that will focus on improving and extending the existing framework for Sunlight analysis on the human body.

Enhancing Blender Skin Thickness Visualization: One of the main ongoing projects will be investigating more precise ways to color skin thickness in Blender. This entails searching for alternate software programs or creating improved Blender techniques to produce a more accurate and thorough representation of variations in skin thickness.

Putting Shading Effects into Practice in ParaView: Using ParaView made us aware of the lack of implemented shading effects. Future work will incorporate shading effects to see the human body's shaded areas. With this improvement, we hope to offer a more thorough knowledge of the interactions between Sunlight and various surfaces.

Customizing Approaches for Various Populations: In the future, work on customizing the analysis for various demographic factors will be conducted to expand the methodology's reach and practicality. This considers changes in skin thickness with age, accommodating a range of age groups, including young children, adults, seniors, and infants. A more comprehensive analysis will also benefit from investigating the influence of race on skin protection from Sunlight, emphasizing people of different racial backgrounds.

Clothing and Protective Measures in Unity Animation: Future work will extend the Unity animation by adding clothing and protective measures and demonstrating how well they shield the skin from the Sun. This also involves including extras like hats and umbrellas to show how they reduce Sun exposure visually.

Comprehensive Protection Strategies: Subsequent versions of the methodology will investigate all-encompassing approaches to safeguard against solar radiation. This entails determining which protective measures are most effective, comprehending how clothing and accessories can act as barriers, and offering visual aids that illustrate how well these tactics protect the skin.

Enhanced Visualization for Specific Conditions: Future iterations of the methodology will consider visualizations customized for conditions like skin diseases or illnesses that may impact skin thickness. This personalization will help make the analysis of Sunlight's effects on people with health concerns more focused and insightful.

To sum up, future research will concentrate on improving skin thickness visualization techniques, adding shading effects, customizing the analysis for various demographics, investigating considerations specific to gender and race, and improving the Unity animation to incorporate safety precautions. These developments aim to increase our comprehension of how Sunlight affects the human body in various settings and circumstances.

Key Acronyms

Abbreviation	Meaning
IV	Information Visualization
IVD	Information Visualization Discipline
CDC	Centers for Disease Control and Prevention
GIS	Geographic Information Systems
D3	Data-Driven Documents
HTML	Hypertext Markup Language
UV	Ultraviolet
Solar Elevation Angle	The angle formed between the horizontal plane and the Sun's center affects the intensity of solar radiation.
Latitude	The location’s distance from the equator influences the amount of solar radiation received.
Altitude	The height above sea level influences solar radiation intensity due to the thinner atmosphere.
Cloud Cover	The presence of clouds in the sky can block or scatter solar radiation.
Ozone Depletion	The reduction of the ozone layer leads to higher levels of ultraviolet (UV) radiation reaching the Earth's surface.
UV Radiation	Ultraviolet radiation from the Sun
GUI	Graphical User Interface
CSS	Cascading Style Sheets
API	Application Programming Interface
3D	Three-Dimensional
GPS	Global Positioning System

DST	Daylight Saving Time
WCAG	Web Content Accessibility Guidelines
BPY	Blender Python
SPI	Solar Position and Intensity
NOAA	National Oceanic and Atmospheric Administration
UI	User Interface
SPI	Solar Position and Intensity
OBJ	Object (file format)
DOT	Dot Product
BM	BMesh
ParaView	An open-source, multi-platform data analysis and visualization application.
Blender	A powerful and open-source 3D creation suite that encompasses modeling, sculpting, animation, rendering, compositing, motion tracking, and game creation.
Unity	A popular game development engine that allows developers to create 2D, 3D, augmented reality (AR), and virtual reality (VR) applications.
Power BI	A business analytics service by Microsoft that provides interactive visualizations and business intelligence capabilities.
Vertex Positions (v)	The lines starting with 'v' represent vertex positions in 3D space.
Vertex Normal (vn)	The lines starting with 'vn' represent vertex normal.
Texture Coordinates (vt)	The lines starting with 'vt' represent texture coordinates.
Faces (f)	The lines starting with 'f' represent faces, where vertices are connected to create a polygon.

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