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Improving Area Determination of Leather Arches using Image Processing Techniques

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***Abstract-* One of the key issues in image processing is calculating the area of surfaces from their images. In this article, we attempt to estimate the surface area of a piece of leather. First, the algorithm for this process will be explained, and then the results will be validated by presenting some examples and models. These images were recorded without editing and in real conditions. Using Python and the OpenCV library, pre-processing is applied to the images, and through algebraic calculations, the output of the algorithm is obtained as the surface area of the desired object. In this process, lighting and the selection of algorithms are very important. By creating favorable conditions, a result with an error margin of 1% to 3% can be achieved in the shortest possible time compared to the results of the mechanical measuring devices.**

***Index Term*: Image Processing, Python, Leather area, Area estimation, Reference surface.**

I. INTRODUCTION

Artificial Intelligence (AI) has increasingly become an integral part of our daily lives, driving innovation and efficiency across various sectors. Image processing has emerged as one of AI's most compelling and transformative branches. Image processing involves analyzing and manipulating visual data to extract meaningful information and enhance visuals. This technology powers a wide range of applications, from face recognition systems to medical imaging, self-driving cars, and even artistic endeavors such as style transfer and image generation.

One particularly challenging aspect of image processing is the calculation of areas for surfaces with uneven or irregular margins. Unlike traditional shapes such as rectangles or circles, these surfaces demand advanced algorithms that can accurately measure their dimensions while accounting for their complexity.

The main applications of surface area calculation can be summarized as follows:

❖ **Geographical Mapping**

- Image processing is crucial in remote sensing and geographical information systems (GIS), where satellite imagery is analyzed to estimate the size of landmasses, vegetation covers, or water bodies with irregular boundaries.

❖ **Healthcare and Medical Imaging**

- In medical fields, measuring the area of tumors, wounds, or organs using imaging technologies such as MRIs or CT scans plays a critical role in diagnostics and treatment planning. These surface areas are rarely uniform, posing additional challenges that AI-powered image processing can address.

❖ **Industrial Manufacturing**

- Factories use image processing to ensure the quality control of products with unique shapes, ensuring their dimensions fall within specific thresholds. The ability to calculate the surface area of uneven materials contributes to precision engineering.

❖ **Environmental Monitoring**

- Monitoring glaciers, deforestation, or even oil spill areas benefits from accurately calculating surface areas of regions with irregular edges, facilitating better environmental action plans.

Calculating the area of different surfaces with uneven margins adds to the importance of this topic [1]. Leather, as the primary raw material for leather product factories, plays a crucial role in the economic cycle. Measuring the area of leather using mechanized devices, such as the footing machine [2], has increased both time and cost. The maintenance, space occupancy, noise, and the need for a large workforce associated with these devices pose challenges for industrial units [3]. The footing machine is one of the oldest machines and serves as a model for developing other leather measuring machines.

With the increasing advancement of new technologies,

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mechanical tools have been replaced by smart machines, and challenges have taken on a new dimension that requires sophisticated processing capabilities. One significant area where this transformation is evident is in image processing. Artificial Intelligence (AI) has revolutionized how images are analyzed, manipulated, and improved, allowing for applications such as facial recognition, medical imaging analysis, and enhanced photo editing techniques.

(a)

(b)

Fig. 1- (a) A natural Leather Sample, (b) A Footing machine used for leather area measurement

Now, using image processing and optimal algorithms [4], calculations can be performed with much greater accuracy and speed. Saving energy and reducing maintenance costs are additional advantages of this method. This approach can be optimized under various lighting and environmental conditions to provide optimal performance [5]. Despite the ability to update algorithms and software, image processing can yield highly beneficial results for companies and users by enhancing efficiency, accuracy, and speed. Artificial intelligence algorithms can analyze vast amounts of visual data, identifying patterns and features that may be invisible to the human eye, thereby improving tasks such as image recognition, classification, and even automated editing techniques [6].

II.RESEARCH METHOD

This process is generally divided into six parts (Fig. 2). It begins by preparing images from a known surface. By applying edge detection algorithms to determine the boundaries of objects in the photo, the images are converted to absolute black and white, and then the number of surface pixels is extracted [7]. The greater the difference in brightness between the pixels of the leather surface and the background in the image, the more accurate the detection of the leather surface will be [8]. In fact, the Canny algorithm, which determines the edges of objects based on the rate of brightness changes [9] between adjacent pixels, is utilized. Displaying this image allows the user to monitor the correct detection of the leather surface. In this situation, if there are miscellaneous and extraneous objects in the image [10], they can be easily recognized and removed. Throughout the process, the distance from the camera to the center of the surface should remain constant [11] [12], and there should be no change in the location of the image or the object. As a result of unwanted changes in ambient light or the proximity of brightness between the leather and the background, the brightness of the pixels can be improved by calibrating the threshold limit [13] in the coding commands. In the calculation section, the ratio of the number of pixels of the reference surface (Pref) to its area (Aref) becomes the PPM coefficient. Finally, the desired surface area can be obtained by finding the number of pixels of the desired surface and dividing it by the PPM coefficient. PPM is a coefficient used to determine the level of detail in the potential image that the camera provides at a certain distance. Digital images are divided into grids of pixels or blocks, each containing the color of that particular point in the image. [14]

In the first step, having the area of the reference surface A_{ref} and the number of pixels of the reference surface P_{ref}, using Python and the white-black image, the size of the PPM coefficient will be calculated in pixels per square centimeter:

$$PPM = P_{ref} / A_{ref} \quad (1)$$

Then, using the same coding instructions as before, the number of pixels of each desired surface (P_{obj}) will be calculated. Finally, using (2), the size of the desired surface area is obtained in square centimeters.

$$A_{obj} = P_{obj} / PPM \quad (2)$$

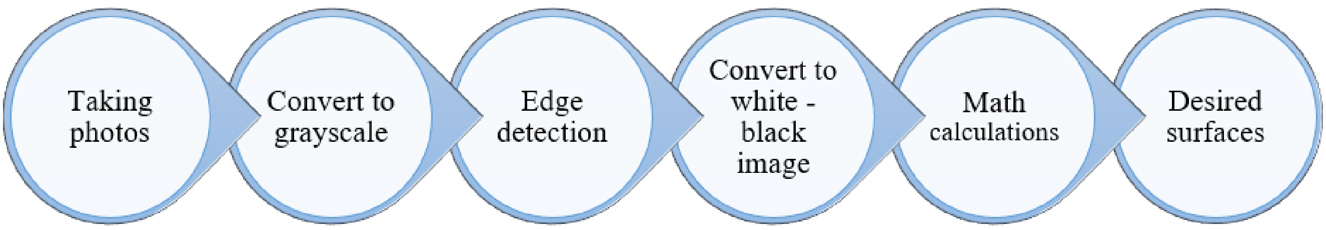

Fig. 2. Area measurement process by image processing

III. PROGRAMMING AND IMPLEMENTATION

At this stage, the programming and implementation will be examined. The entire processes of imaging, processing, and computation will be executed within a Python program named main.py, accompanied by several files that contain distinct functions and responsibilities. A portion of the leather surface detection process is illustrated in Fig. 3. The main.py program will integrate several libraries, such as OpenCV for image processing, NumPy for numerical computations, and TensorFlow for machine learning tasks. These tools will facilitate the training of models that recognize leather textures effectively, enhancing the overall accuracy of the detection process.

In Fig. 3, the image is processed as a matrix. At this stage, for detecting leather and other objects, attention is paid to the color changes of the image pixels. As long as the difference between the pixels remains within a specified range, a new object will not be identified. This range is adjustable and can be utilized as a rate of color change in the pixels, allowing for the earlier and more sensitive detection of new surfaces. Fig. 4 also presents another segment of the image processing. Applying machine learning algorithms further enhances this process, enabling the system to learn from previous images and improve its accuracy in recognizing leather and similar materials. This adaptability is crucial for effective object detection in diverse lighting and environmental conditions.

Now, in Fig. 4, the counting and determination of the pixel values for the background and leather surface are performed. These values are accessible after applying filters and preprocessing steps, which are coded in separate files. Ultimately, a value is generated as ppm, which describes the behavior of the leather surface in the image relative to reality.

As indicated in Fig. 5, the camera used in the research and experiments is the OV2640 model, equipped with the ESP32 Wi-Fi module. The OV2640 is a compact camera module that integrates a 2-megapixel image sensor. It is widely used in various applications, including robotics, drones, and smart home devices. Its small size and versatility make it a popular choice for developers and hobbyists. Given that this module is mounted on an Arduino board, programming languages such as C and C++, as well as MATLAB software, can be utilized to establish communication between the system and the camera.

```
for i in range(startY, stopY, step):
    for j in range(startX, stopX, step):

        loop += 1

        b, g, r = cpy[startY,startX]
        sub = max(b,g,r) - min(b,g,r)

        if( sub < 20 ):
            okeys += 1
        else:
            nots += 1
```

Fig,3. Preprocessing on pictures

```
# Make ref_thresh binary image a row vector:
ref_threshRow  = ref_thresh.ravel()
# on: object (white)/  off: background (black)
ref_numOnPxls  = np.count_nonzero(ref_threshRow == 255)
ref_numOffPxls = np.count_nonzero(ref_threshRow == 0  )
print("REF: OnPixels={}, OffPixels={}".format(ref_numOnPxls, ref_numOffPxls))
ppm = ref_numOnPxls / ref_Area #pixel/cm^2
print("ppm: {} / {} ({:.2f})\n".format(ref_numOnPxls, ref_Area, ppm))
```

Fig.4. Computing ppm

Fig. 5. OV2640 module with ESP32 WiFi

IV. RESULTS

As mentioned, this method requires a reference surface to obtain the area of other surfaces. Before starting the process, converting color images to grayscale, as well as to absolute black and white, allows for a more accurate statistical collection of the number of pixels in question, thereby increasing the measurement accuracy. This conversion makes the leather and background pixels more distinct, maximizing the differentiation between these two categories. Then, using edge detection algorithms and converting the images to absolute black and white, the pixel processing and related mathematical calculations begin.

The area of the desired surface can be estimated by obtaining the PPM value from the image of the reference surface. The values of the mentioned samples will be calculated along with the percentage of errors created (Table I).

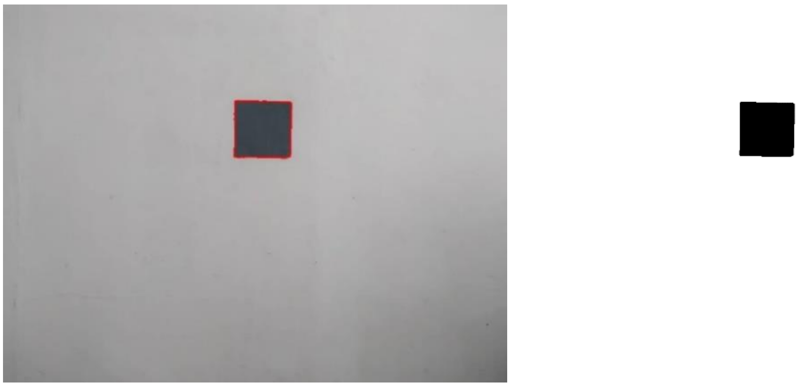

Fig. 6. White-black image (right) and edge detection (left) from the reference surface

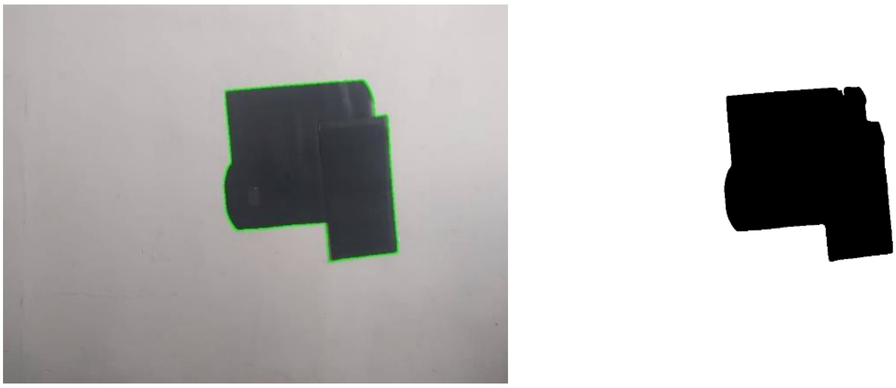

Fig. 7. White-black image (right) and edge detection (left) of the desired surface (first sample)

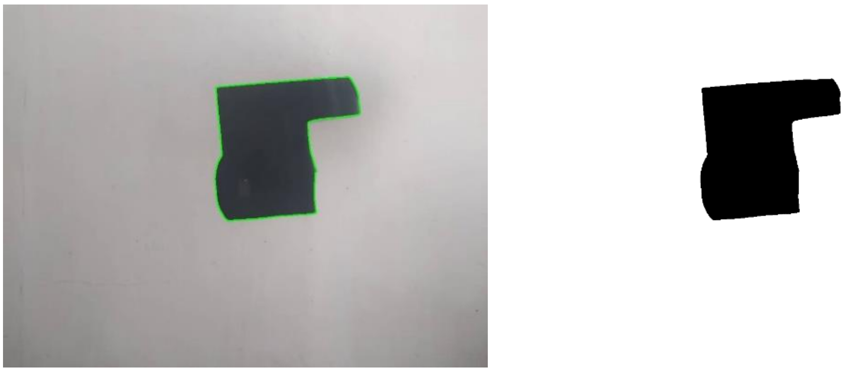

Fig. 8. White-black image (right) and edge detection (left) of the desired surface (second sample)

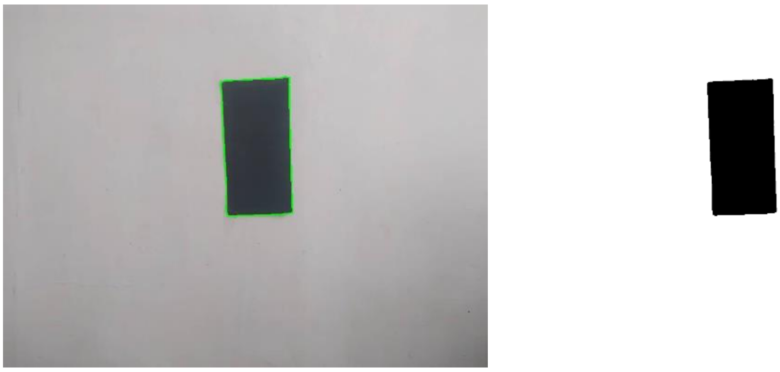

Fig. 9. White-black image (right) and edge detection (left) of the desired surface (third sample)

TABLE I
Measurement of the Samples

	Actual area (calculated by software) (cm2)	Leather measuring (cm2) machine	Calculated by AI (cm2)	Machine error	AI error	PPM
Reference surface	56.25	56.25	56.25	0%	0%	222.6
First sample	462.50	441.50	456.96	4.54%	1.19%	222.6
Second sample	282.70	298.25	289.37	5.52%	2.51%	222.6
Third sample	177.45	189.75	180.19	6.93%	1.40%	222.6

The size of the reference area is provided as input to the algorithm. The samples were designed using AutoCAD software, and then their areas were extracted. This area is considered the actual surface area. The PPM size will be obtained by processing the image's pixels. Given that the camera and object positions are fixed, the PPM number remains constant, using the initial value extracted from the reference surface for other surfaces. Changes in the distance between the camera and the object will alter the number of pixels representing the object in the image. As a result, the algorithm's output will yield an incorrect area for the desired surface. For larger pieces of leather, it is possible to first record and process one half, followed by the other half. The sum of the pixels obtained from the two images will represent the total size of the leather pixels in the image.

The advancements in image processing can be applied under various conditions and challenges effectively [15]. However, the heavy weight of the footing machine limits its mobility and placement in different locations. In contrast, the portability and lightweight nature of the camera setup is a significant advantage [16], allowing for easy installation and quick operation in diverse settings.

V. DISCUSSION

The unique applications of artificial intelligence and image processing have been proven. What is important now is to create new and strategic ways to meet basic human needs. This includes enhancing accessibility for those with visual impairments, improving healthcare diagnostics through advanced imaging techniques, and automating quality control in manufacturing processes. By harnessing AI, we can transform traditional image analysis into powerful tools that elevate human potential.

For example, the situation is completely different when working with cameras with a wide lens. These cameras can be an optimal choice for limited space conditions during the photography process. These lenses provide a wider viewing angle. In fact, the focal length of these lenses is shorter than that of standard lenses. A shorter focal length makes the horizontal range of the image wider. In this way, subjects close to the camera are recorded larger than distant subjects. In fact, one should expect a slight change in the shapes, as a result of which the density of leather pixels will be different in different parts of the image.

In this case, a complementary process is needed to improve this imbalance and make the leather size as close to the real value as possible. It is possible to identify the amount of stretching of the image at different points by designing a weight function and monitoring the behavior of these changes by creating suitable intervals or mathematical calculations.

Calculating surface area through image processing and machine learning [17] represents one of the most significant advancements in various industries. This application is both diverse and essential. Such a product can be designed not only to measure area but also to identify elements within the image and execute specific commands based on the collected data. For instance, it can detect weeds and pests or analyze soil erosion and the growth of salt marshes in desert and mountainous regions. To date, substantial progress has been made in industrial applications, with numerous experimental products being developed for various purposes, including measuring leather area. It is hoped that dedicated and innovative professionals will drive the prosperity and growth of new industries worldwide by creating practical and cutting-edge technologies.

VI. CONCLUSION

In this paper, the idea of using image processing tools to estimate the area of a surface has been investigated. Due to its popularity and open-source libraries, the Python programming language has been used. The main application proposed in this research is to apply this method to evaluate the area of natural leather sheets used in the leather products industry.

Since implementing such a process in a real situation requires some professional equipment, the first step was chosen to be conducted on small-scale samples in a more controlled environment. The results show that the precision of the estimated area is acceptable compared to the real values of test samples, and the proposed method can be used further in the next steps toward the industrial application, but subsequently, some challenges and practical considerations should be discussed:

a) The most significant challenge of this research is the adjustment of ambient light and the consistency of illumination during imaging. In the event of darkness in the image, this range will be considered as the subject area. Using specific detection methods, a model can be trained for leather detection in the image, allowing for the elimination of other factors that cause disturbances.

b) Another existing challenge is maintaining a fixed distance between the camera and the surface of the table (leather surface). An adjustable system can be developed by binding the camera base to the table and implementing several simple mechanical mechanisms. This way, with the movement of the table, a constant distance between the table and the camera will be ensured.

c) Another existing challenge is the distance from the camera to the table. When large rolls of leather are positioned, it is necessary to install the camera at a greater distance from the table. In this scenario, not only does access to the camera system become problematic, but the imaging quality will also decrease. To address this issue, a wide lens can be employed, which can fully cover the subject at a shorter distance. However, due to the curvature introduced in the image after using the wide lens, it is essential to develop a function to detect the subject's behavior in the images, as the leather surface image will no longer change linearly with distance from the camera.

Future steps of this research can involve refining image processing algorithms using artificial intelligence. We can improve image recognition and analysis efficiency by training models on various leather textures and conditions. This would enhance quality control processes, enabling precise detection of defects and inconsistencies in the leather surface.

Next, the industrial implementation of these advanced algorithms can lead to real-time monitoring solutions in manufacturing environments. By integrating AI-powered image processing systems into production lines, companies can ensure consistent quality and reduce waste through early defect detection, ultimately improving efficiency and productivity across their operations. Furthermore, incorporating deep learning techniques can further advance the precision of defect detection. We can extract intricate features from leather images by utilizing convolutional neural networks (CNNs), leading to a deeper understanding of quality indicators and potential anomalies. This synergy of AI and image processing presents vast opportunities for innovation in the leather industry.

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