AUTOMATIC COLOR SEGMENTATION FOR HYBRID SUNFLOWER RAY FLORETS

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Abstract: *As an aesthetic trait, ray floret color has high importance in the development of new sunflower genotypes and their market value. The standard methodology for the evaluation of sunflower ray florets is based on the International Union for the Protection of New Varieties of Plants (UPOV) guidelines for sunflowers. Applying it, however, requires expert evaluators and results in evaluations that are still highly subjective. In this study, we focus on hybrid sunflower ray florets which are bi-colored, for which we propose a new methodology for automatic segmentation of the regions inheriting the dominant color of each of the parents in digital images, which can objectively quantify the contribution of each parent color to the offspring. To achieve this, we use a deep-learning model to extract the ray floret (the Segment Anything model), followed by a traditional automatic thresholding approach. We test our approach on a dataset comprised of 53 digital images, including parent variety images of "Pacino gold" and "Neoplanta", as well as images of hybrid offspring resulting from the crossing of these varieties. Our results show that the proposed approach can objectively quantify the contribution of each parent.*

Key words: *sunflower, ray floret, Segment Anything model, segmentation, Otsu thresholding, deep learning, computer vision*

1. INTRODUCTION

Commonly cultivated as an oil crop, sunflower (Helianthus annuus L.) also encompasses several varieties that are classified as ornamental (Mladenović et al. 2020). Ornamental sunflowers could be grown as cut flowers, in gardens, and as potted plants (Kaya et al. 2012). Their primary appeal lies in the beauty of their flowers, therefore flower traits, such as the color, size, and shape of florets, are primary targets in breeding programs. The sunflower inflorescence, referred to as a flower, is composed of ray and disc florets. The sterile ray florets are located on the outer part of the sunflower flower. Ray florets are usually yellow but may appear in different shades of red, orange, lemon-yellow, white, or a combination of these colors, thus making sunflowers desirable as an ornamental crop (Cvejić et al. 2016).

A comprehensive understanding of the hereditary factors influencing flower color inheritance and the generation of new color combinations is essential for enhancing genetic diversity and achieving success in the breeding of ornamental sunflowers (Kaya et al. 2012). This knowledge is also crucial for improving pollination success and yield in modern elite sunflower hybrids (Dowell et al. 2019). When two parent plants with different colors of ray flowers are crossed, the red color of ray florets in the F1 generation is partially dominant over yellow colors, resulting in a "gaillardia" pattern, meaning two colored ray florets. This trait is typically governed by one or two dominant genes in subsequent generations, as confirmed by various studies on sunflower germplasm. These studies indicate that floral pigmentation traits are controlled by a few loci with significant effects (Fick 1976, Yue et al. 2008, Cvejić et al. 2016). The expression of red color in ray florets requires the presence of two dominant genes, while the most common coloration, yellow, is controlled by the complementary interaction of dominant alleles from different genes (Fick 1976).

Researchers are now exploring more objective methods, such as image analysis, to replace the subjective and laborious manual methods in agricultural applications (Sunoj et al. 2018). In that sense, ornamental sunflower breeding requires a detailed description of phenotype to avoid inconsistencies between variety descriptions and actual plants in the field. In order to reduce costs, prevent product damage, and improve

the efficiency and quality of products offered to consumers, the ornamental sunflower market is expected to adopt automatic classification methods (Lino et al. 2011), (Dawod et al. 2022).
To address this issue, Zorić et al. (2020) developed a new, objective methodology for sunflower ray floret color evaluation based on digital image classification into the UPOV color groups. The Flower Color Image Analysis (FloCIA) software enables visualizations of segmentation of the sunflower images, the percentages of pixels belonging to each UPOV color category with graphical representation, and the position of the examined sunflower mean vector in Lab color space in relation to the mean vectors of the UPOV category. The precision of FloCIA was greater between UPOV-based expert color evaluation and software evaluation than between two UPOV-based evaluations performed by the same expert. With an accuracy of 91.50% in color category matching, the FloCIA software can serve as a guideline for evaluators to determine the dominant color and to identify multiple significant colors in the examined genotype. The current breeding, production, and sales of ornamental sunflowers face challenges under current guidelines and methodologies, particularly in defining new genotype colors, especially if they are multi-colored.
Color does have a strong influence on human perception and is commonly used to convey aesthetic information. It can affect people on an emotional level and determine the preferences, interpretation, memorization, and reactions of people to visual stimuli (Sartori et al 2015). However, mapping regions in digital images to what humans perceive as a single color is not a trivial task (Van de Weijer 2009).
In this paper, we propose a new methodology for ornamental sunflower ray floret color quantification that focuses on sunflowers with the "gaillardia" pattern but makes no assumption as to what the two colors exhibited by these flowers are. The approach uses a state-of-the-art image segmentation model (Segment Anything model proposed by Kirillov et al. 2023), to determine the area of the image corresponding to the ray floret of a sunflower. Once this is done, we employ automatic thresholding (Otsu 1979), (model to determine the relative ratio of each of the two colors. Such a descriptor is invariant to the colors themselves and the variance in the pixel values stemming from different illumination and image acquisition conditions and is applicable whenever the ray floret is bicolored.

2. PROPOSED APPROACH

Our approach is a two-step procedure. We first need to determine the pixels within an image that correspond to the ray floret. Then we need to find an adaptive way of quantifying the distribution of the two colors in this area. The whole process is illustrated in Figure 1.

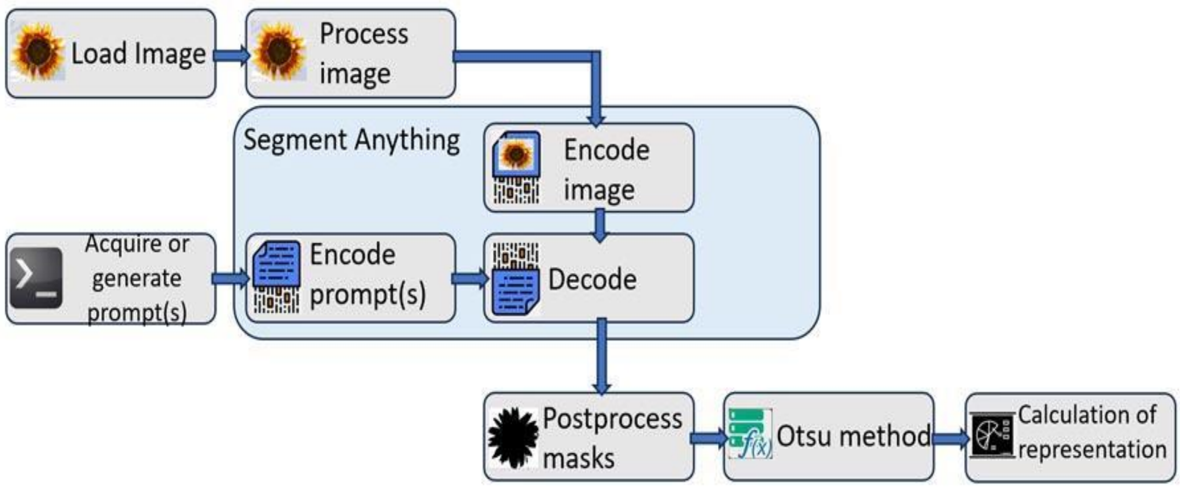


Figure 1: Data flow chart of sunflower image processing based on SAM

For the first step, we opted to employ the recently proposed Segment Anything model (SAM), which is a foundational model trained on the largest image segmentation dataset proposed this far. The model can often generalize to classes previously not seen without any training (so-called zero-shot performance), better than models designed for specific purposes.
The SAM builds on the success of large language models and can be prompted in different ways, including prompting it with a bounding box and the coordinates of a specific point located on the object we want

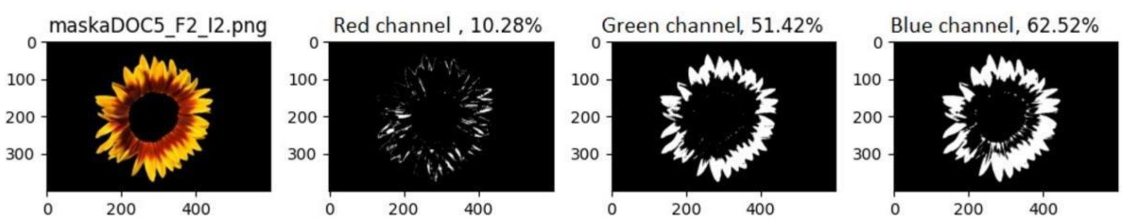
to extract. In the work presented here, two prompts were used: the first is a bounding box that encompasses the entire sunflower, and the second is a point located in the central part of the sunflower that we want to remove, leaving only the petals. Prompted in this way, we were able to correctly identify the region of the input images corresponding to the ray floret. Sample results are shown in Figure 2. The results are obtained in the "native' R, G, B color space. We opted not to employ the LAB color space used in Zorić et al. 2020.

Figure 2 shows the application of the "Segment anything" model on three different sunflower images. The model is prompted with a bounding box encompassing the entire sunflower and the coordinates of a point indicating the location of the seeds. This point marks the area within the bounding box that we want to remove.

Original image | *Image processed with SAM model*

Figure 2: Original images of sunflowers, and images processed with SAM model.

While SAM can correctly identify the region of interest to us, the pixel values within it vary significantly, as shown in Figure 3.



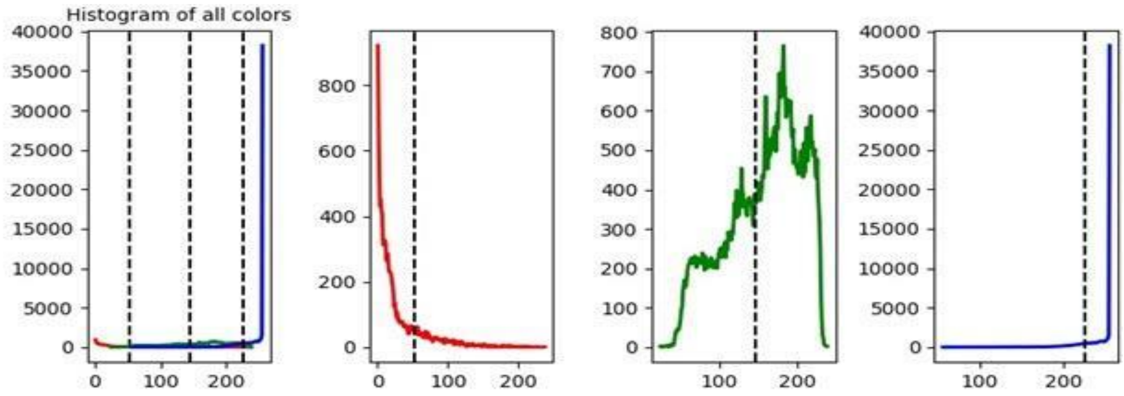


Figure 3: The application of the Otsu algorithm.

As Figure 3 illustrates, the red and blue channels seem to contribute little information when it comes to the distribution of the colors of interest to this study, so we opted to carry out subsequent analysis using the green channel. To separate the pixels corresponding to the two colors we used the classical method for determining the threshold separating them automatically proposed by Otsu (Otsu 1979). The dashed vertical lines in Figure 3 show the location of the threshold thus determined for each of the channels of the image. In the masks shown above the pixel-value distributions for each channel indicate in white pixels with values above the threshold.

3. EXPERIMENTS AND RESULTS

To evaluate the proposed approach, we used a data set collected by the researchers of the Institute of Field and Vegetable Crops of Serbia. The dataset consists of 51 images of the hybrid offspring of two varieties, called “Pacino gold” and “Neoplanta”, shown in Figure 4.

Figure 4: The parent varieties “Neoplanta” (left) and “Pacino gold” (right)

When run on an image of a bicolored offspring, our method can automatically determine the percent of each of the colors in the ray floret, providing a descriptor that would be too labor-intensive to calculate manually. Figure 5 shows the distribution of this descriptor when evaluated for all images in our dataset, showing that the majority of the offspring flowers inherit more color from the darker parent.

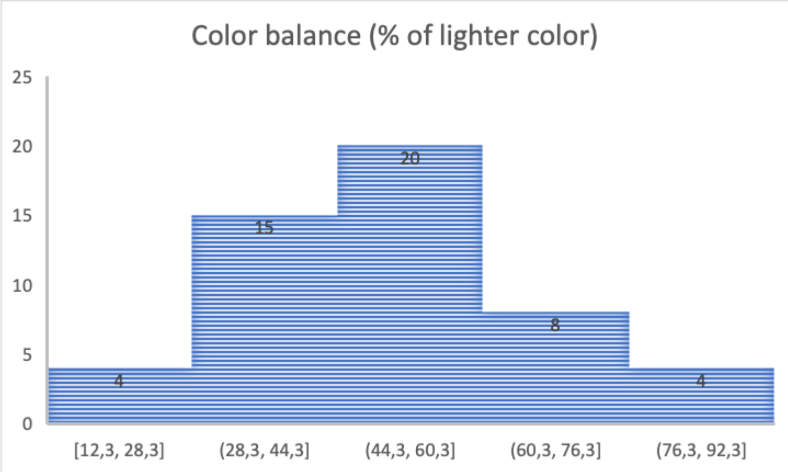


Figure 5: Portion of the color inherited from "Pacino gold" for hybrids in our data set.

4. CONCLUSIONS

We proposed a new methodology for quantifying the appearance of "gaillardia"-patterned sunflower hybrids. The proposed approach can be applied to other flower varieties as we have based it on a zero-shot method for segmenting the region of interest and an adaptive thresholding method to extract our descriptor. Further study is needed to evaluate if the descriptor can be effectively used to help enhance genetic diversity and achieve success in the breeding of ornamental sunflowers. In the near future, we will extend the method to enable the automatic detection of flowers that are bicolored and for which we can reliably apply the methodology.

5. REFERENCES

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