III. METHOD

The proposed structure for solar panel image segmentation, as shown in Fig. 1, is proposed along with region-based image enhancement approach to satisfy the regions of interest described in Sec. A. The concept of a background removal algorithm for masking a solar panel is presented in Sec. B. The details of a region-based segmentation are described in Sec. C.



**Fig. 1** Illustration of the proposed algorithm for solar panel image segmentation

*A. Region-Based Image Enhancement*

In this sub-section, our gold is to improve a local contrast based on the quadtree decomposition proposed in [III-1]. The fundamental concept is to repeatedly divide the entire image into block-based sub regions until the local mean of each sub-region is less than a certain threshold. As an overview, the region-based image enhancement based on quadtree decomposition is summarized as follows:

| **Algorithm 1:** Local Contrast Enhancement Based on Quadtree Decomposition |
| --- |
| **Input:** Luminance image component, % a monochrome image  **Output:** Enhanced image component, % an enhanced image  Initialize where and denote the size of , and represent a constant.  **while** % Define a new width      **end**  **while** % Define a new height      **end**  % Resize to [2,4,...,2k]  where denotes an image resize operator.  **for** **to** **do** where denotes a threshold of a quadtree decomposition.  where denotes a quadtree operator, and denotes a local region.  where denotes an image enhancement operator.  **for** **to** size of **do**  % Arrange a local region to an enhanced image  **end**  % Resize to the original size  **end**  % Resize to a monochrome domain by minimizing pixels |

*B. Background Removal*

Based on the solar panel dataset [III-5], Maximally Stable External Regions (MSER) algorithm [III-6-III-10] is used as a method to detect objects in an image. In this sub-section, MSER is adapted for removing background objects. The background removal image is produced by the *detectMSERFeatures* function in MATLAB.

*C. Local-Region Enhancement*

Let denote an intensity of a local region consisted of discrete monochrome intensity level as . For a local region, the transformation function is defined as:

where denotes a constant, refers to a discrete intensity level, and represents a cumulative density function.

*D. -Trim* *Tangent Logarithmic Square (TL2) Entropy-Based Threshold for Segmentation*

Image segmentation techniques with a scalable threshold have been researched extensively [III-11-III-13]. In the proposed approach, -trim as a threshold is introduced as follows:

and

where and refer to a constant, is an offset value, and represents a cumulative density function. To identify the region of interest, the masking image can be defined as:

where refers to -trim *TL2* entropy-based threshold.

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