



THE EFFECTS OF NOISE FILTERS ON SEGMENTATION BASED SEEDED REGION GROWING

Mürsel Ozan İNCETAŞ^{1*}, Ufuk TANYERİ²

¹Alanya Alaaddin Keykubat Üniversitesi, ALTSO Meslek Yüksekokulu, Elektrik ve Enerji Bölümü, Antalya, Türkiye

²Ankara Üniversitesi, Nallıhan Meslek Yüksekokulu, Bilgisayar Teknolojileri Bölümü, Ankara, Türkiye

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Abstract

Image segmentation is a process of grouping pixels to make parts of objects into distinct image areas using their texture, edge, color properties. The segmentation process plays an important role in the analysis of images and in image processing. One of the techniques developed for segmentation is SRG (Seeded Region Growing). The noise generated during the acquisition of images affects the segmentation success negatively. Filters used to eliminate noise reduce it, but the effect of filtering on the segmentation success is not fully known. In this study, the effects of noise and filters on the SRG algorithm are investigated. For this purpose, various noises were added to Weizmann database images at different levels. Later, filters were applied to noisy images. Finally, F-Score values were obtained from the images segmented by the SRG algorithm and compared with the values of the original images.

GÜRÜLTÜ FİLTRELERİNİN TOHURLU ALAN GENİŞLETME TABANLI BÖLÜTLEMeye ETKİLERİ

Anahtar Kelimeler

Gürültü Filtreleri,
Bölütleme,
Tohumlu Alan Genişletme.

Öz

Görüntü bölütleme, doku, kenar ve renk özelliklerini kullanarak nesnelerin parçalarını farklı görüntü alanlarına dönüştürmek için pikselleri gruplama işlemidir. Bölütleme süreci, görüntülerin analizinde ve görüntü işlemede önemli bir rol oynar. Bölütleme için geliştirilen tekniklerden biri de SRG'dir (Tohumlu Alan Genişletme). Görüntülerin elde edilmesi sırasında oluşan gürültü, bölütleme başarısını olumsuz yönde etkiler. Gürültüyü ortadan kaldırmak için kullanılan filtreler gürültüyü azaltmaktadır, ancak filtreleme işleminin bölütleme başarısı üzerindeki etkisi tam olarak bilinmemektedir. Bu çalışmada, gürültü ve filtrelerin SRG algoritması üzerindeki etkileri araştırılmıştır. Bu amaçla Weizmann veri tabanına farklı seviyelerde çeşitli gürültüler eklenmiştir. Daha sonra gürültülü görüntülere filtreler uygulanmıştır. Son olarak, SRG algoritması tarafından segmentlere ayrılmış görüntülerden F-Skor değerleri elde edilmiş ve orijinal görüntülerin değerleri ile karşılaştırılmıştır.

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Yazar Kimliği / Author ID (ORCID Number)

M. O. İncetas, 0000-0002-1016-1655
U. Tanyeri, 0000-0002-7039-9577

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1. Introduction

Image segmentation is one of the most important and challenging aspects of image analysis and processing. In general, segmentation, which is the process of

composing multiple meaningful fields by splitting a visual, is applied in many areas. Image segmentation is frequently used in areas such as medical images, satellite images, face recognition systems, fingerprint recognition, and Seeded Region Growing (SRG)

* İlgili yazar / Corresponding author: ozan.incetas@alanya.edu.tr, +90- 242-510-6180

algorithm is one of the most well-known region based image segmentation techniques (Adams & Bischof, 1994). In this algorithm, after the selection of seeds, they are grown by including the adjacent pixels which are close to the average gray level value of the neighboring seeds. The growing process continues until all the pixels are included in a region. Seed selection can be done with the help of the user, as well as methods for automatic seed selection (Gómez et al., 2007; Fan et al., 2001). It has been observed that the use of SRG has been successful in solving many problems (Pohle & Toennies, 2001; Dreizin et al., 2016; Yeom et al., 2017; Pan & Wang, 2016; Wu et al., 2008; Al-Faris et al., 2014).

Noise is an undesirable result in the acquisition of images. Different noises can be seen in the images obtained with various methods and tools. For example, the sensor and the circuit of a digital camera can cause noise. When it occurs, there is random brightness or color change in the images. The most known types of noise in the literature are gauss, salt-pepper and speckle noise (Gonzalez et al., 2009). Gaussian noise is caused by poor lighting, high heat, or the transfer of data to the electronic circuit. Salt-pepper noise is seen during data transfer due to bit errors or conversion from analog to digital. Salt-pepper is also common in satellite images. Speckle noise is naturally present in active radar, synthetic aperture radar (SAR), medical ultrasound, and optical coherence tomography, and is a granular noise.

Filters are used to eliminate the noise problem and are defined as devices or processes that remove some unwanted components or features. It is known that certain filters have a high success against various noises. The most commonly used filters in the literature are mean, median and Gaussian filters.

Noise negatively affects the result of image segmentation process. In addition, it has been observed that the effect of different noise types and intensities on the success of SRG is also different (İncetaş et al., 2017). Especially, it was determined that the performance of SRG against noises in Salt-Pepper type was higher. It is also seen that image filtering is applied before segmentation in noisy images (Savkare et al., 2016; Kostopoulos et al., 2017; Samantaray et al., 2016). However, the effect of the filters on the SRG technique has not been measured quantitatively. For this reason, it is important to determine which filter is more effective against different noise types to increase the success of the SRG method.

In this paper, the effect of seed selection, noises and noise filters on the success of the SRG algorithm was investigated and tried to be determined quantitatively. This investigation is a continuation of the study (İncetaş et al., 2017) presented in 2017 and the first parts of the results were taken from the

previous study. Weizmann's one-object image segmentation database (Alpert et al., 2012), consisting of 100 images, was used throughout the study. First, noisy images were obtained by adding salt-pepper, speckle, and Gaussian noises to the images at different levels. Then, these noisy images were filtered through average, median and Gaussian filters. Finally, the original, noisy and filtered images were segmented by SRG according to the manual seed selections and the F-Score results were calculated with the Weizmann evaluation tool. By comparing the results obtained, the effect of filtering techniques on SRG success was evaluated.

2. Seeded Region Growing (SRG)

The SRG algorithm, first developed by Adam and Bischof in 1994, performs the decomposition of an image according to a set of points known as the kernel (Adams & Bischof, 1994). The algorithm starts with seed points grouped in n sets (A_1, A_2, \dots, A_n). Some seed sets may consist of a single pixel. Each step of the algorithm involves adding a pixel to one of these seed sets. After step m , the states of the A_i sets can be shown as follows. Let T be a set of pixels that are bound to at least one set and have not yet been assigned to a set.

$$T = \{x \notin \bigcup_{i=1}^n A_i \mid N(x) \cap \bigcup_{i=1}^n A_i \neq \emptyset\} \quad (1)$$

where $N(x)$ is the set of neighbors of the x pixel. These neighbors refer to 8 adjacent pixels in the original study. For $x \in T$, if there is an $N(x)$ that corresponds to one of the A_i sets, that is, if some of the neighbors of the x pixel are included in one of the sets A_1, A_2, \dots, A_n $i(x) \in \{1, 2, \dots, n\}$ index is defined, which is $N(x) \cap A_i(x) \neq \emptyset$.

$$\delta(x) = \left| g(x) - \text{mean}_{y \in A_{i(x)}} [g(y)] \right| \quad (2)$$

$g(x)$ represents the gray level of the x pixel, and $\delta(x)$ indicates the difference of x pixels to the neighboring seed pixel. If $N(x)$ meets two or more of A_i sets, i.e. the neighbor pixels of the x pixel assigned to different seed sets, the i value of index $i(x)$ with the smallest $\delta(x)$ is selected. That is, i is the index of the set $A_i (A_1, A_2, \dots, A_n)$ includes the neighbor pixel which is the closest x pixel as the gray level value. Then a $z \in T$ is taken, such that

$$\delta(z) = \min_{x \in T} \{\delta(x)\} \quad (3)$$

This selected z value is added to $A_i(z)$. Thus step $m+1$ is completed. This process continues until all pixels are added to one of seed sets. Equation (2) and (3) ensure that the segmentation is as homogenous as possible.

2. Material and Method

In the study, 100 images were used in the single object Weizmann segmentation evaluation database. In this database, there are segmentation results for which

each image is divided into two parts manually by 3 different users as object and background. These manual segmentation results were used as a reference to measure the success of the SRG algorithm for the noisy and filtered images. The F-Score values calculated for determining the performance were also made with the evaluation functions provided by the Weizmann database.

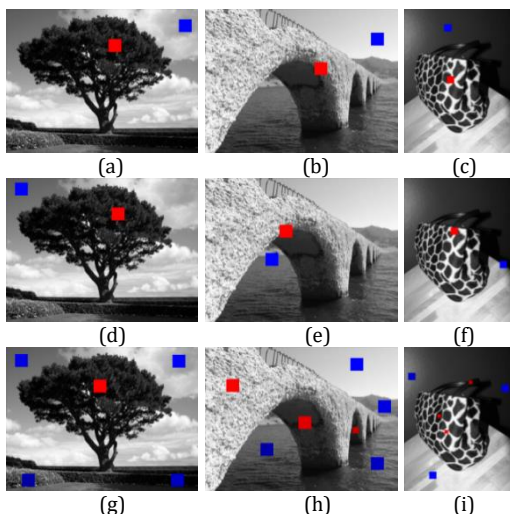


Figure 1. Seed selection examples for three groups (a) (b) (c) First group, (d) (e) (f) Second group, (g) (h) (i) Third group

Seed selections were made with the help of the user and marking an area of up to 20x20 pixels which would be in different numbers for the object and the background on the image. Selected seeds for each image were recorded in a file so that it could be reused in the SRG algorithm. In addition, three different groups of seeds were selected for each images to determine the spreading effect of SRG. In the first two selection groups, one seed field was marked for the object and the background, and the selections were made randomly. There are seed marking examples of the first selection group in Figure 1 (a) (b) (c) and examples of the second selection group in Figure 1 (d) (e) (f). In the third seed selection group, more than one seed fields were selected for the object or the background. By examining the SRG results of the first and second seed selection groups, we marked the third group seeds that cover all the gray levels of the pixels in each object and the background areas. In this way, the transition between pixels in same area was facilitated. In Figure 1 (g) (h) (i), there are examples of seeds from the third selection group. In the images shown in Figure 1, the seed areas of the object are shown in red, and the seed areas in the background are shown in blue.

In the second phase of the study, noise was added to all images in 10 different levels (0.01, 0.02, 0.03, 0.04, 0.05, 0.10, 0.20, 0.25, 0.30, and 0.40) for each of the salt-pepper, speckle and Gaussian noises respectively. In Figure 2 (a), there are examples of salt-pepper noise added images from top to bottom at a level of 0.04,

0.10 and 0.20. Similarly, in Figure 2 (b) there are speckle noise samples in the level range from 0.04, 0.10 and 0.20 from top to bottom. In Figure 2 (c), there are examples of Gaussian noisy images with the same order.

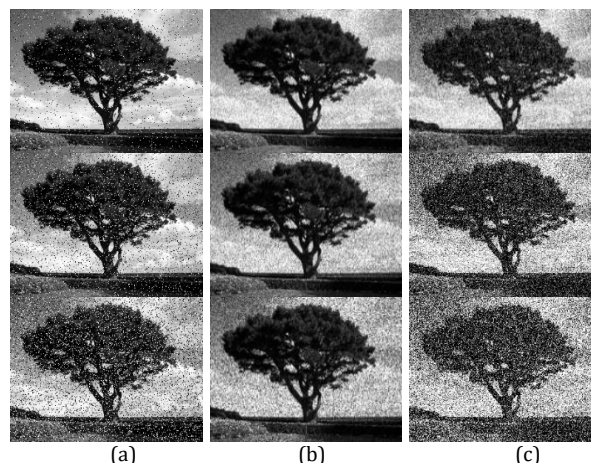


Figure 2. Noisy image examples (a) Salt-pepper noise, (b) Speckle noise, (c) Gaussian noise

In the third stage of the study, mean, median and $\sigma = 0.5$, $\sigma = 1.0$ and $\sigma = 1.5$ Gaussian filters were applied to noisy images. Figure 3 shows filtered images that are ordered from top to bottom in mean, median, and Gaussian ($\sigma = 1.0$) filters. There are filter results for salt-pepper noise in Figure 3 (a), speckle noise in Figure 3 (b), and Gaussian noise in Figure 3 (c). All images shown in Figure 3 have 0.04 noise level.

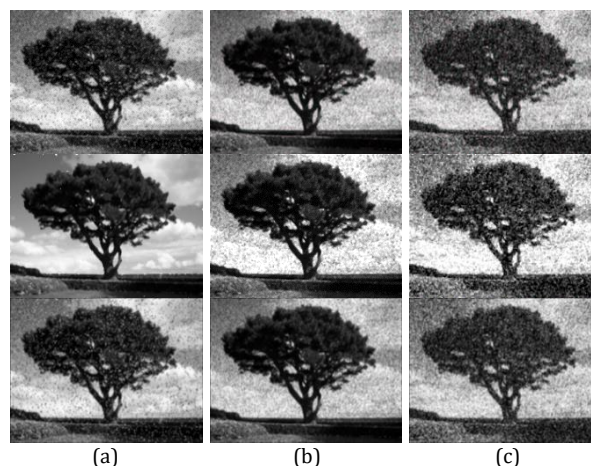


Figure 3. Filtering results for noisy images (a) Salt-pepper noise, (b) Speckle noise, (c) Gaussian noise

Finally, the SRG segmentation technique was applied to all the original, noisy and filtered images, using the three different seed selection groups mentioned earlier. F-score values of the SRG results were obtained using the evaluation tool of the Weizmann segmentation database.

The F-score value is used to measure the success of segmentation algorithm on images in Weizmann dataset. The evaluation tool provided by the database finds F-score values based on reference pictures. The intersection of the segmentation results determined

manually by three different users is taken and the final reference result of the object is obtained. Figure 4 shows the segmentations made by the users. The red marked areas in the images in Figure 4 (a, b and c) show the object, while the other pixels which have original gray level values are the background.



Figure 4. Reference images in the Weizmann segmentation database

The F-score calculation in Equation (6) is based on the harmonic mean of the precision in Equation (4) and recall in Equation (5) values. The precision value gives the ratio of the true object pixels in all selected object pixels by algorithm and recall gives the ratio of the pixels selected by algorithm in reference object. The terms used for F-score calculation are shown in Table 1.

Table 1. Evaluation of segmentation results

Calculation		Algorithm Results	
		Object	Background
Definite Reference	Object	A	B
	Background	C	D

A: True Positive, B: False Negative, C: False Positive, D: True Negative

$$Precision = \frac{A}{A+C} \tag{4}$$

$$Recall = \frac{A}{A+B} \tag{5}$$

$$FScore = 2 \times \frac{Precision \times Recall}{Precision + Recall} \tag{6}$$

3. Experimental Results and Discussion

The experiments were completed in three steps. In the first step, seed areas were selected manually and these selections were applied to the original images using SRG. Noisy images were segmented by SRG technique by selecting seed areas in the second step. Finally, SRG results were obtained for filtered noisy images. F-Score values for all these segmentation results were also calculated using Weizmann evaluation tool.

At the first stage of the experiments, the seed area selection was made manually as three different groups for each image as mentioned before. Thus, with the help of selected seed groups for 100 images in the database, 300 segmentation results were obtained for original images and one of them is shown in Figure 5. Figure 5 (a) shows the original image and Figure 5 (b) shows the first seed selection for this image. The seed selected for the object is shown in red color, and the seed selected for background is shown in blue color. SRG result of these seeds are shown in Figure 5 (c) and

the object pixels is seen as black while the background pixels is seen as white.

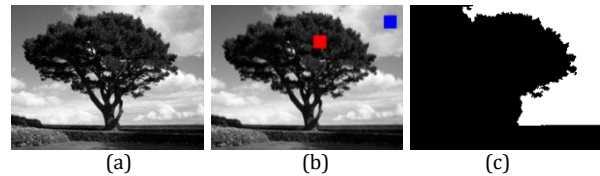


Figure 5. (a) An image in the Weizmann database, (b) First group seed sample, (c) SRG segmentation result of the first group seed sample

When the first and second groups of seed selection results were examined, the second group gave better results on some images, but generally the F-score average values were close to each other. The second group seed selection example and segmentation result with a better F-Score than the first one are shown in Figure 6. The reason for such improvements is the selection of a background seed that is close to the gray level intensity of the object in the second example. With this way, background pixels that have gray level value that close to the object seed intensity are added background seed.



Figure 6. (a) Second group seed sample (b) SRG segmentation result of the second group seed sample

During the growing of the background seed (blue color) in Figure 5 (b), the clouds are added to background due to the density of the white color. Non-cloud background pixels are included in the object since the gray level values of them are low. In Figure 6 (a), the background seed was selected from the pixels of non-cloud background area, which is closer to the object as the gray level. Thus, the background first grew to the cloudless background, and then clouds that were far away from the object in terms of gray level intensity were added to this seed.

In the third group seed selection, unlike the first two groups, more seeds were selected for background and object. In addition, effects and results of the first two selections were taken into consideration when seed selection was made. Thus, seeds were selected to increase the segmentation success.

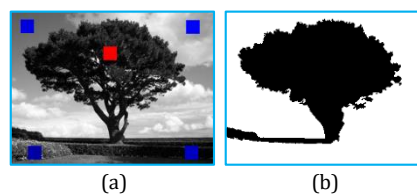


Figure 7. (a) Third group seed sample (b) SRG segmentation result of the third group seed sample

As shown in Figure 7, the use of more than one background seed produces a more successful segmentation result than the other two seed selections. The average F-score results obtained from the seed selection groups are shown in Table 2. As can be seen in Table 2, the third group seed selection produces the higher F-score values than other two. Therefore, it is considered that the results to be investigated should be interpreted through the third group seed selections.

Table 2. Comparison of SRG seed selection results

Seed Selection Group	Segmentation Results (Average)		
	F-Score	Precision	Recall
1st Selection	0.6663	0.8066	0.6848
2nd Selection	0.6738	0.7944	0.7034
3rd Selection	0.7910	0.7717	0.8758

In the second stage of the experiments, different levels of salt-pepper, speckle and Gaussian noises were added separately to 100 images in the database. Each image with noise added with 10 different levels (0.01, 0.02, 0.03, 0.04, 0.05, 0.10, 0.20, 0.25, 0.30 and 0.40) was recorded in different folders. With this process, 3000 noisy images were generated for 100 images in Weizmann dataset. Segmentation results obtained for the noisy images by applying SRG for each seed group selected in the first stage were recorded in different folders. Due to 3 different seed selection group, a total of 9000 noisy image segmentation results were obtained for all noisy images. The F-Score values were calculated for the segmentation results using the evaluation tool provided by the Weizmann database. F-Score results of noisy images are presented in Table 3.

Table 3. Noisy image F-Score values

Noise Level	Salt & Pepper			Gaussian			Speckle		
	Seed Group			Seed Group			Seed Group		
	1	2	3	1	2	3	1	2	3
0.01	0.668	0.677	0.791	0.672	0.671	0.784	0.678	0.669	0.783
0.02	0.667	0.674	0.787	0.665	0.644	0.747	0.671	0.669	0.771
0.03	0.664	0.681	0.79	0.654	0.654	0.747	0.666	0.669	0.762
0.04	0.667	0.69	0.791	0.655	0.636	0.748	0.668	0.674	0.772
0.05	0.662	0.677	0.792	0.643	0.64	0.743	0.671	0.654	0.738
0.10	0.669	0.69	0.796	0.617	0.619	0.701	0.646	0.631	0.715
0.20	0.669	0.697	0.789	0.588	0.584	0.624	0.605	0.603	0.668
0.25	0.665	0.686	0.787	0.575	0.562	0.603	0.575	0.595	0.661
0.30	0.664	0.687	0.753	0.551	0.55	0.59	0.568	0.573	0.638
0.40	0.65	0.684	0.752	0.532	0.533	0.541	0.551	0.533	0.623

According to the F-Score results in Table 3, the segmentation success is seriously decreased at high level of noise. On the other hand, at low level of noise, the F-Score values are similar to that of the original

images. Also it is observed that segmentation success and F-score values are increased for some images where salt-pepper and Gaussian noises are low-level. This is because some pixels that have not been included in homogenous areas previously are added to their region due to the salt-pepper noise. Another reason is that the average gray level values of similar areas become closer to each other when the Gaussian noise is added. Thus, it makes easier to add similar pixels to the same region. Figure 8 shows the corresponding situation.

The SRG algorithm produces successful results even at the 0.40 level of the salt-pepper noise. The reason is that the regions are grown according to gray level average of their own pixels. Therefore, salt-pepper noisy pixels are included in the growing process lastly, because they are far from the average values of regions.

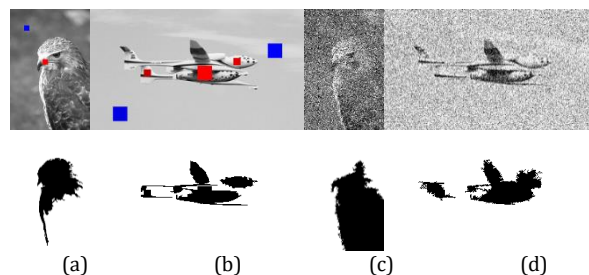


Figure 8. (a) Example of second seed selection group and SRG result, F-score: 0.52 (b) Third seed selection group example and SRG result, F-score: 0.38 (c) Salt pepper image at 0.40 level and SRG result, F-score: 0.88 (d) Gaussian image at 0.40 level and SRG result, F-score: 0.60

The results of SRG segmentation at different noise types and levels are shown in Figure 9 for three seed selection groups separately. Decreasing of the segmentation results for all noise types appears to have similar characteristics in all seed selection groups. The success rate appears to start to decrease after the 0.04 and 0.05 levels for the speckle and Gaussian noises, while the segmentation success continues even at 0.40 for the salt pepper noise. The reason why the salt-pepper noise is more successful than other noises is that black-and-white noise pixels are included the growing process lastly.

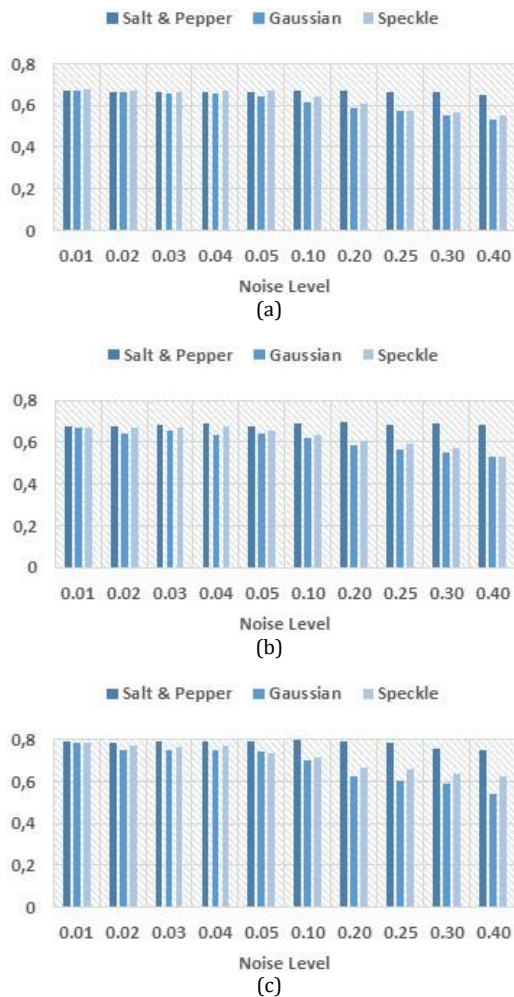


Figure 9. SRG segmentation F-score values of images with different noise levels for three seed selection groups a) First group, b) Second group, c) Third group

Table 4. SRG algorithm F-score results of filtered noisy images according to first seed selection group

Filter	Noise Level									
	0.01	0.02	0.03	0.04	0.05	0.10	0.20	0.25	0.30	0.40
Gaussian ($\sigma=0.5$)	0.659	0.661	0.657	0.653	0.654	0.641	0.619	0.615	0.604	0.576
Gaussian ($\sigma=1$)	0.657	0.660	0.671	0.657	0.663	0.664	0.655	0.630	0.650	0.632
Gaussian ($\sigma=1.5$)	0.660	0.657	0.662	0.663	0.660	0.669	0.649	0.652	0.644	0.641
Mean	0.665	0.657	0.660	0.660	0.663	0.666	0.649	0.643	0.645	0.633
Median	0.668	0.662	0.662	0.658	0.667	0.649	0.647	0.629	0.627	0.629
Gaussian ($\sigma=0.5$)	0.662	0.661	0.671	0.668	0.664	0.653	0.677	0.669	0.653	0.650
Gaussian ($\sigma=1$)	0.662	0.673	0.666	0.669	0.669	0.661	0.656	0.652	0.625	0.640
Gaussian ($\sigma=1.5$)	0.659	0.654	0.663	0.666	0.664	0.664	0.657	0.651	0.649	0.650
Mean	0.664	0.659	0.663	0.661	0.659	0.659	0.663	0.660	0.651	0.645
Median	0.673	0.671	0.671	0.673	0.673	0.673	0.675	0.666	0.668	0.672
Gaussian ($\sigma=0.5$)	0.676	0.662	0.665	0.663	0.673	0.671	0.648	0.642	0.640	0.638
Gaussian ($\sigma=1$)	0.659	0.661	0.675	0.664	0.654	0.661	0.660	0.659	0.663	0.648
Gaussian ($\sigma=1.5$)	0.659	0.661	0.666	0.667	0.657	0.661	0.671	0.658	0.665	0.652
Mean	0.668	0.664	0.662	0.667	0.665	0.662	0.670	0.661	0.661	0.652
Median	0.678	0.672	0.669	0.672	0.676	0.673	0.644	0.654	0.649	0.652

In the last stage of the experiments, Gaussian ($\sigma = 0.5$), Gaussian ($\sigma = 1.0$), Gaussian ($\sigma = 1.5$), mean, and median filters were applied to each of 3000 noisy images, respectively and 15000 filtered images were obtained. SRG was applied to all filtered images using three different seed selection groups, and the segmentation results of 45,000 filtered images in total were obtained as F-score. As a result, 72100 image segmentation results were generated from 100 images in the database. Each of the five lines of Tables 4, 5 and 6 shows the F-score results for the "Gaussian", "Salt & Pepper", and "Speckle" noise, respectively.

Table 5. SRG algorithm F-score results of filtered noisy images according to second seed selection group

Filter	Noise Level									
	0.01	0.02	0.03	0.04	0.05	0.10	0.20	0.25	0.30	0.40
Gaussian ($\sigma=0.5$)	0.664	0.678	0.653	0.668	0.664	0.656	0.629	0.632	0.615	0.623
Gaussian ($\sigma=1$)	0.663	0.667	0.659	0.664	0.661	0.655	0.632	0.633	0.620	0.620
Gaussian ($\sigma=1.5$)	0.663	0.677	0.656	0.659	0.663	0.653	0.640	0.636	0.628	0.618
Mean	0.660	0.673	0.659	0.667	0.667	0.653	0.641	0.618	0.623	0.607
Median	0.671	0.644	0.654	0.636	0.640	0.619	0.584	0.562	0.550	0.533
Gaussian ($\sigma=0.5$)	0.664	0.655	0.664	0.663	0.666	0.665	0.667	0.654	0.645	0.645
Gaussian ($\sigma=1$)	0.664	0.671	0.669	0.672	0.659	0.652	0.652	0.659	0.642	0.642
Gaussian ($\sigma=1.5$)	0.664	0.665	0.670	0.671	0.666	0.665	0.645	0.650	0.641	0.643
Mean	0.669	0.671	0.669	0.669	0.669	0.672	0.673	0.663	0.672	0.672
Median	0.677	0.674	0.681	0.690	0.677	0.690	0.697	0.686	0.687	0.684
Gaussian ($\sigma=0.5$)	0.672	0.672	0.674	0.669	0.662	0.682	0.664	0.663	0.645	0.657
Gaussian ($\sigma=1$)	0.667	0.672	0.665	0.659	0.659	0.674	0.655	0.670	0.655	0.647
Gaussian ($\sigma=1.5$)	0.658	0.666	0.664	0.662	0.654	0.665	0.661	0.664	0.662	0.655
Mean	0.678	0.667	0.666	0.671	0.652	0.655	0.652	0.661	0.659	0.664
Median	0.700	0.703	0.685	0.694	0.670	0.632	0.599	0.580	0.534	0.499

The graphs of the F-Score results obtained from filtered salt-pepper noisy images are shown in Figure 10. As can be seen in the figures, there is no significant difference between the filtered and unfiltered results. The reason why the SRG algorithm is less affected by the salt-pepper noise is that the added noisy pixels have the extreme gray level values like black or white and they are included in the growing process lastly, as mentioned earlier. The median filter produced the most successful results for the first seed selection group in Figure 10 (a). For the second and third seed selection group in Figure 10 (b) and (c), it is seen that the results of the unfiltered image have the highest values. For the third seed selection group with higher F-score, the success of the median filter appears to exceed the success of the unfiltered images in images with a noise level higher than 0.25.

In Figure 11, segmentation results of an image added salt & pepper noise with 0.10 level and applied filters are shown for all seed selection groups. On the sample image, it is seen that the mean and Gaussian ($\sigma = 1$) filters increase success in first group seed selection

and decrease in second and third group seed selections. It is also clear that the median filter increases success in the first group seed selection and does not change the result in the second and third group seed selections.

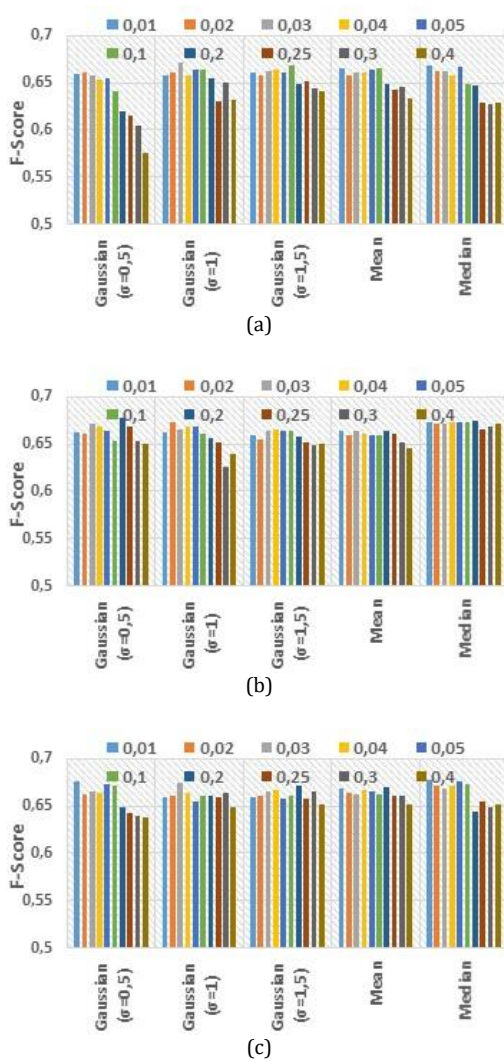


Figure 10. SRG segmentation F-Score results of filtered images added salt-pepper noise for three seed selection group (a) First group, (b) Second group, (c) Third group

The graphs of the F-Score results obtained from filtered Gaussian noisy images are shown in Figure 12. The results of the unfiltered images appear to have the lowest F-score value in each seed selection group. It is evident that the all filters used trough the experiments improve SRG performance against Gaussian noise. For all seed selection groups, the SRG results of unfiltered images produce lower results from the noise level 0.05.

For the first seed selection group in Figure 12 (a), values are similar up to 0.05 noise level. F-score value for unfiltered images at 0.10 level decreases from 0.66 to 0.61. The median, Gaussian ($\sigma = 1$) and Gaussian ($\sigma = 1,5$) filters improve the F-score to initial value of 0.66, while the median and Gaussian ($\sigma = 0.5$) filters

improve to 0.64. The same situation is repeated as the noise levels increase. In addition, mean, Gaussian ($\sigma = 1$) and Gaussian ($\sigma = 1,5$) filters produced results close to their initial value, while median and Gaussian ($\sigma = 0.5$) filters could not make an effective improvement.

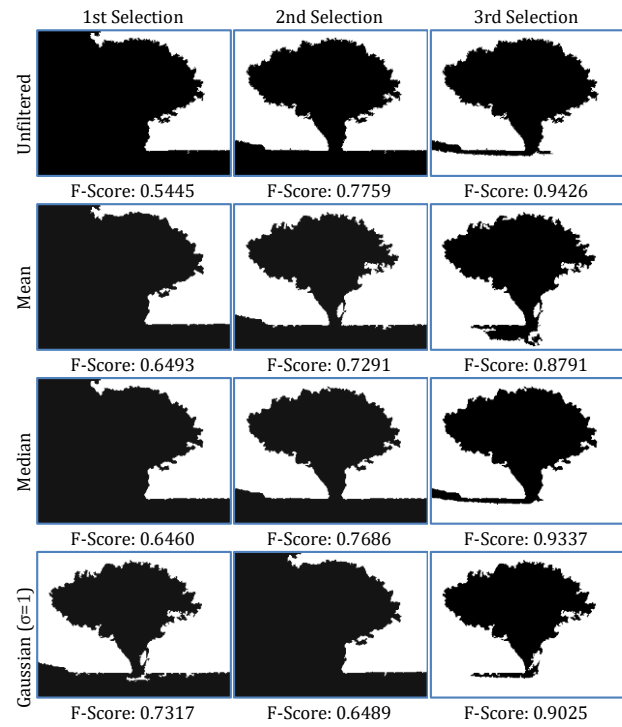


Figure 11. Examples of SRG results for salt-pepper noise with 0.10 level

Table 6. SRG algorithm F-score results of filtered noisy images according to the results of the third seed selection

Filter	Noise Level									
	0.01	0.02	0.03	0.04	0.05	0.10	0.20	0.25	0.30	0.40
Gaussian ($\sigma=0.5$)	0.781	0.778	0.774	0.751	0.762	0.747	0.734	0.732	0.727	0.710
Gaussian ($\sigma=1$)	0.779	0.762	0.761	0.755	0.759	0.749	0.734	0.741	0.717	0.721
Gaussian ($\sigma=1.5$)	0.779	0.774	0.760	0.752	0.760	0.748	0.745	0.732	0.723	0.715
Mean	0.788	0.768	0.767	0.750	0.771	0.738	0.710	0.703	0.697	0.672
Median	0.784	0.747	0.747	0.748	0.743	0.701	0.624	0.603	0.590	0.541
Gaussian ($\sigma=0.5$)	0.780	0.781	0.786	0.775	0.775	0.771	0.780	0.757	0.723	0.724
Gaussian ($\sigma=1$)	0.782	0.774	0.779	0.769	0.776	0.764	0.758	0.757	0.729	0.726
Gaussian ($\sigma=1.5$)	0.781	0.778	0.784	0.774	0.779	0.758	0.757	0.754	0.733	0.715
Mean	0.786	0.785	0.781	0.784	0.785	0.786	0.779	0.784	0.777	0.764
Median	0.791	0.787	0.790	0.791	0.792	0.796	0.789	0.787	0.753	0.752
Gaussian ($\sigma=0.5$)	0.784	0.777	0.777	0.776	0.776	0.772	0.772	0.749	0.759	0.758
Gaussian ($\sigma=1$)	0.785	0.776	0.772	0.772	0.773	0.769	0.781	0.754	0.759	0.744
Gaussian ($\sigma=1.5$)	0.787	0.782	0.776	0.778	0.774	0.776	0.784	0.760	0.749	0.743
Mean	0.791	0.774	0.785	0.765	0.775	0.758	0.753	0.766	0.733	0.759
Median	0.783	0.771	0.762	0.772	0.738	0.715	0.668	0.661	0.638	0.623

F-score values shows very little ups and downs in the unfiltered results up to 0.05 noise level for the second group of seed selections in Figure 12 (b). However,

this is not seen in F-score values of filtered images. F-score results for unfiltered images at 0.10 noise level decrease from an initial value of 0.67 to 0.62. All of the filters applied increase the F-score value from 0.62 to 0.65. The F-score values of the filters are separated from each other at noise level of 0.20. The lowest improvement at 0.40 noise level is achieved by Gaussian ($\sigma = 0.5$) filter with 0.57 F-score value and this is done by median filter with 0.61 F-score and mean, Gaussian ($\sigma = 1$) and Gaussian ($\sigma = 1.5$) filters with 0.62 F-score value.

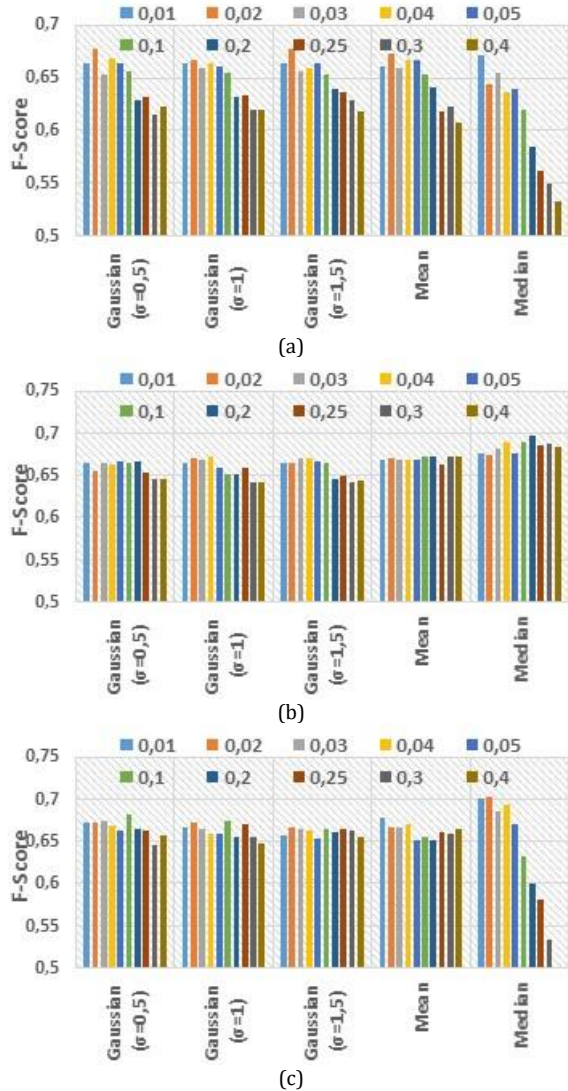


Figure 12. SRG segmentation F-Score results of filtered images added Gaussian noise for three seed selection group (a) First group, (b) Second group, (c) Third group

As can be seen in Figure 12 (c), the results of the third seed selection group which generally produces better results show the difference between the filters more clearly. The noise effect starts from the noise level 0.02. All filters produce results close to the initial value at low noise levels. The difference of the filters is clearly seen after the noise level 0.20. The F-Score value of SRG results for unfiltered images decreased from 0.78 to 0.54 at 0.40 noise level. The Gaussian (σ

= 0.5) filter with 0.54 F-score and the median filter with 0.67 F-score are less effective than others. The average and Gaussian ($\sigma = 1$) filters with 0.71 F-score and the Gaussian ($\sigma = 1.5$) filter with 0.72 F-score produced results closer to the initial value.

According to the SRG result sample images shown in Figure 13, the average filter applied to the Gaussian noise decreases the F-score value of the second seed selection group, and the Gaussian ($\sigma = 1$) filter decreases the F-score value of the third seed selection group. However, in the general of examples, it seems that there is not a significant change in the F-Score values. When the third group seed selection examples were examined, there was no change in the F-score result, although there were some visible changes in the segmentation results. This is because of the change in the precision and recall values of the F-Score calculation. Due to Equation (3), the F-score value does not change when one of the precision and recall values increases while the other decreases in a similar way.

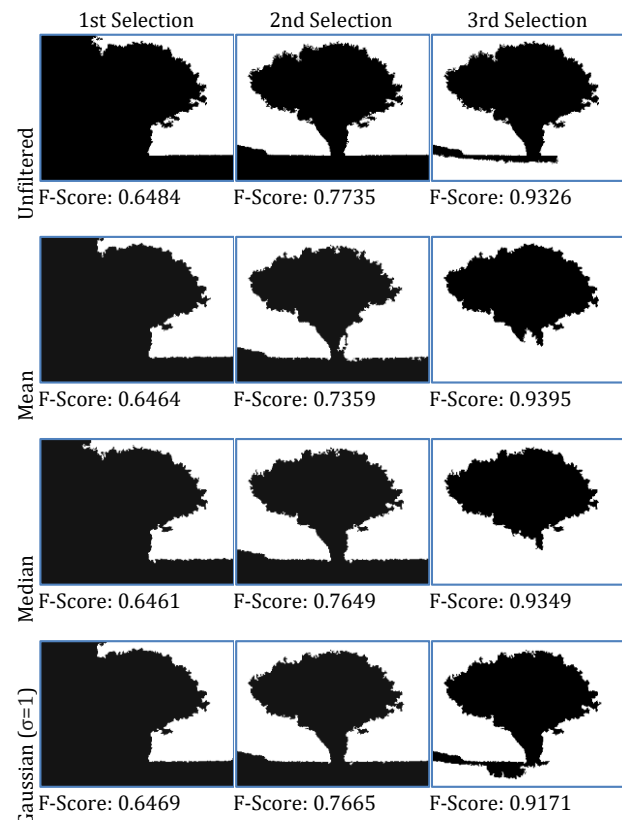


Figure 13. Examples of SRG results for Gaussian noise with 0.10 level

Figure 14 shows the graphs of the F-Score results obtained from filtered speckle noisy images. The results of unfiltered images of speckle noise show the lowest F-score values. All the filters used for the first and second seed selection group in Figure 14 (a) and (b) produce similar results. It is seen that the filters applied to the unfiltered images with low F-score value from 0.05 noise level produce the results close to the initial value. The

initial F-score value of 0.66 for the first seed selection group was increased from 0.55 to 0.65 using the filters at the 0.40 noise level. For the second seed selection group, the initial F-score value of 0.67 was increased from 0.53 to 0.66 at 0.40 noise level in the same way.

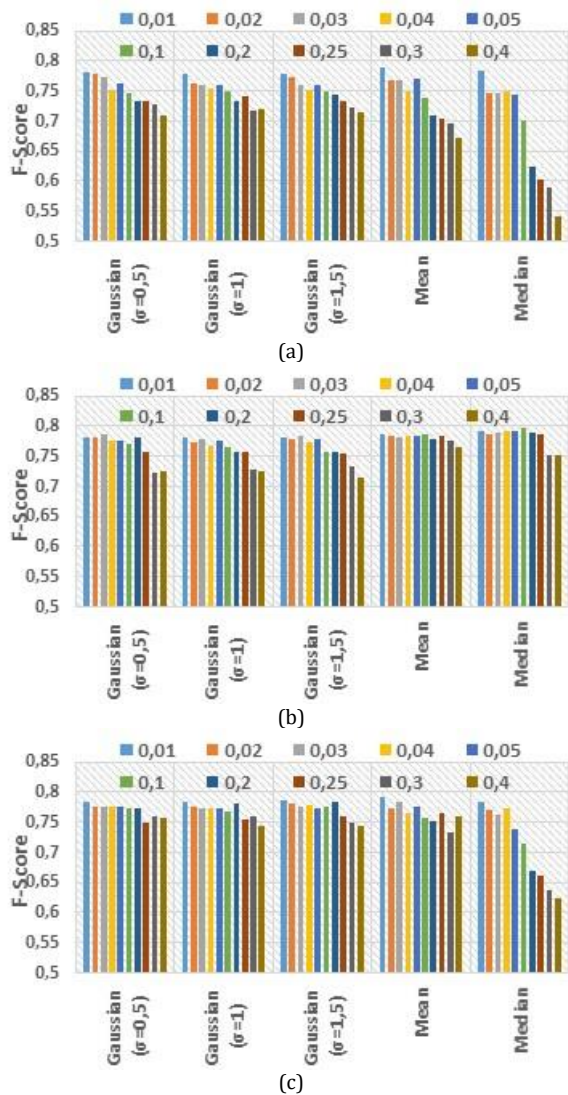


Figure 14. SRG segmentation F-Score results of filtered images added Speckle noise for three seed selection group (a) First group, (b) Second group, (c) Third group

The difference in success between filters is seen more clearly for the results of the third seed selection group in Figure 14 (c). As the noise level increases, the improvement rates also increase for all filters. Gaussian ($\sigma = 0.5$) filter has the lowest improvement performance among the all filters. The initial F-score value of unfiltered noisy images decreased from 0.79 to 0.62 at 0.40 noise level. The Gaussian ($\sigma = 0.5$) filter improved to 0.70 F-score while the other filters improved to 0.75 F-score. Although the median filter gives the best result at some noise levels, it is generally observed that its success is lower than other filters. It is seen that Gaussian ($\sigma = 1$), Gaussian ($\sigma = 1.5$) and mean filters produce the best results similar to each other for all seed selection groups.

Figure 15 shows example segmentation and F-score results for the speckle noise. It is seen that the average and Gaussian ($\sigma = 1$) filters reduces the F-score value in all seed selection groups. The median filter results showed a decrease for the first seed selection group and an increase for the third selection group but no change for the second seed selection group.

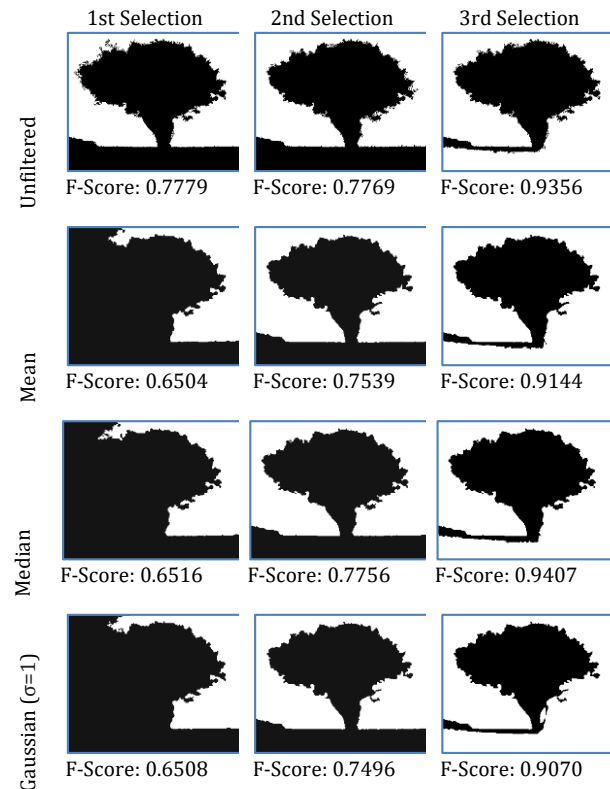


Figure 15. Examples of SRG results for speckle noise with 0.10 level

4. Conclusion

Image segmentation is an important part of the image analysis and image processing. Segmentation is also affected by noise like most steps in image processing. Many filter are used to reduce the noise effect. It is also expected that these filters reduce the negative effects of noise in processing such as segmentation. In this study, the effects of noise filters on SRG which is one of the most known of the region-based segmentation algorithms have been investigated.

The results obtained showed that the position and the number of seeds has a great influence on the success of SRG segmentation and correctly selected seeds increased the success. If the background around the object has more than one part with different gray level values, the object has more than one part with different gray level values, or the gray level values of the background and object are very close to each other, then the success of SRG method reduce. Selecting the background with the gray level values closest to the object as the seed field and selecting more than one seed for both the object and the

background seemed to increase the success of the SRG method. Selecting the background seed which has the closest gray level values to object and selecting more than one seed for both the object and the background increase the SRG success.

Experiments on noisy images have shown that noise with 0.05 level or less change the segmentation success, while the success rate is greatly reduced at higher noise level. It is also seen that SRG is less resistant against Gaussian and speckle noise and its success rate decreases significantly from 0.04 noise level. On the other hand, it has been determined that the SRG method is most resistant to salt-pepper noise and produces successful results even at the 0.40 noise level. Therefore, it appears that the negative effect of salt-pepper noise on SRG method is less than expected. It has been observed that the effects of the filters for the seed selections with low segmentation success are close to each other, while the differences between the filters become more apparent for seed selections with high success. In addition, there is not noise or filter effect on the success of SRG method when the noise level is low (level \leq 0.05). As the noise level increases, all filters applied to the speckle and Gaussian noises provide some improvement.

Since there was no significant reduction in the SRG success for salt-pepper noisy images, there was no significant decrease or increase in the F-score value for the filtered images accordingly. Nevertheless, it has been observed that the median filter gives slightly better results than other filters, as is known in literature. Since SRG is already resistant to salt-pepper noise and filters are not affected, it eliminates the necessity of using filters in salt-pepper noisy images. Gaussian ($\sigma = 1$), Gaussian ($\sigma = 1.5$), and average filters achieved the highest success rates for speckle and Gaussian noisy images. It is clearly visible that the using of these filters against the speckle and the Gaussian noises increases success of SRG, since they don't reduce the SRG segmentation results.

This study quantitatively demonstrated the effect of the noise filters against different noise types on SRG method. Thus, a reference source for filters that can be used before the SRG process to be performed on images with known noises has been established. The obtained data can be used to examine the effects of different filters on the segmentation in the future.

Conflict of Interest

No conflict of interest was declared by the authors.

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