An Accelerated Super Resolve Stood on Manufactured Edge Component and An Adaptive Leclerc Function

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***METHODAbstract*—Because the algorithm has less complexity and fast executed time, the Super Resolve algorithm, which is one of the famous Super Resolution algorithms, for applying on single image (so called SISR or Single Image Super Resolve) is extremely wanted in the image processing field hence this analytic paper aims to propose the spatial expanding algorithm is formed on the Super Resolve algorithm employed by a robust adaptive Leclerc function and manufactured edge component. Although this Super Resolve algorithm can create an image with superior spatial resolution, the SR performance is extremely hang on the control function, which is controlled by three constants (b, h, k) and the constant adjustment for finding optimized values is demanding computational step for creating a superior spatial resolution image with the highest PSNR. In consideration of fixing of this issue, the robust adaptive Leclerc function, which is theoretically controlled by only one constant (T), instead of three constants of the ingenious function, is substituted in the SISR framework. Under testing on 14 traditional standard images with many noise templates, the proposed accelerated super resolve algorithm can create the high spatial resolution image with superior quality (PSNR) to the original super resolve algorithm in the experimental testing section however the constant alteration procedure of the proposed accelerated super resolve algorithm (using one constant) is more ease and rapid than the original super resolve algorithm (using three constants) thereby the proposed accelerated super resolve algorithm can be easily implemented.**

Keywords—Adaptive Leclerc Function, SISR, Image Enlargment

I. THE SUPER RESOLVE WITH MANUFACTURED EDGE COMPONENT

This part quickly announces the algebraically theory of image enlarging method founded on SISR [1] utilizing synthesize high-band frequency, which is constituted by synthesize high-band frequency and the obliged function.

A. The Synthesize Of High-Band Frequency Procedure

The objective of this procedure [1] (in the figure 1) is for synthesizing the high-band frequency of the enriched resolution image. Early, the captured poor resolution image ($G_0(x,y)$ at $m\times n$), is made less in spatial resolution at copious sub-procedures in consideration of synthesis of a set of poor-resolution images: $G_1(x,y)$ at $\frac{m}{2}\times\frac{n}{2}$

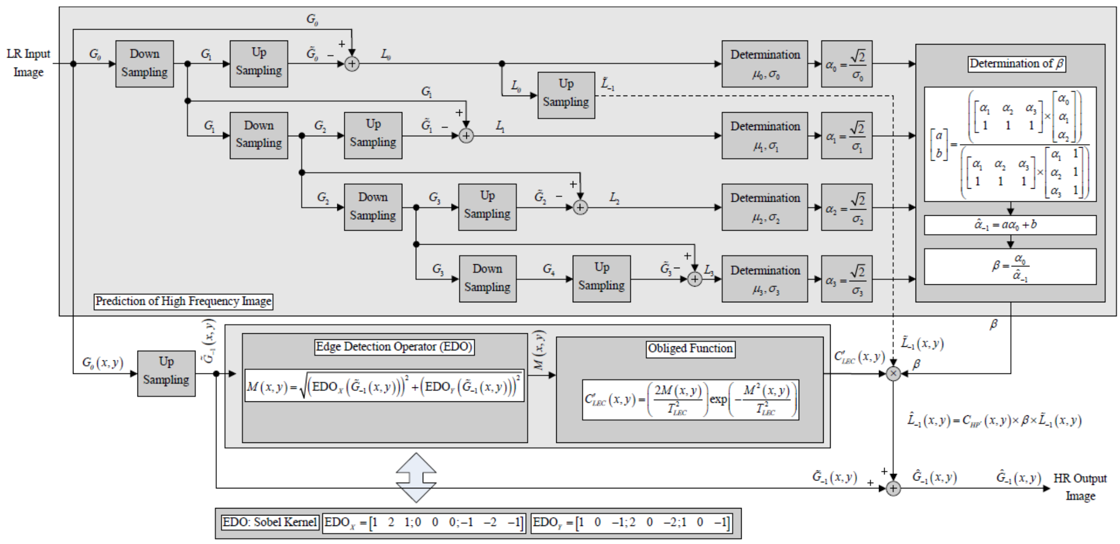

Fig. 2. The fast image enlarging founded on SISR using synthesize high-band frequency and an adaptive Leclerc function

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, $G_2(x,y)$ at $\frac{m}{4}\times\frac{n}{4}$, $G_3(x,y)$ at $\frac{m}{8}\times\frac{n}{8}$ and $G_4(x,y)$ at $\frac{m}{16}\times\frac{n}{16}$. Later, a set of high-band frequency image of each poor-resolution images is computed from a set of poor-resolution images: $L_0(x,y)$ at $m\times n$, $L_1(x,y)$ at $\frac{m}{2}\times\frac{n}{2}$, $L_2(x,y)$ at $\frac{m}{4}\times\frac{n}{4}$ and $L_3(x,y)$ at $\frac{m}{8}\times\frac{n}{8}$. Next, by utilizing histogram conversion, the mean and variance at each resolution of the high-band frequency image is computed by utilizing Gaussain statistical model in consideration of theoretical analysis: (μ_0,σ_0) at $m\times n$, (μ_1,σ_1) at $\frac{m}{2}\times\frac{n}{2}$, (μ_2,σ_2) at $\frac{m}{4}\times\frac{n}{4}$ and (μ_3,σ_3) at $\frac{m}{8}\times\frac{n}{8}$. In consideration of fast computing, a Laplacian statistical parameter (α) is computed by utilizing Laplacian statistical model from Gaussain statistical parameters (μ,σ): α_0 at $m\times n$, α_1 at $\frac{m}{2}\times\frac{n}{2}$, α_2 at $\frac{m}{4}\times\frac{n}{4}$ and α_3 at $\frac{m}{4}\times\frac{n}{4}$. At last, the high-band frequency image of the enriched resolution image $\tilde{L}_{-1}(x,y)$ at $2m\times 2n$ is computed by LS fitting technique.

B. *The Obliged Function Procedure*

The objective of this procedure (in the figure 1) [1] is for confining the bound-area of the synthesized magnitude ($\beta\cdot C(x,y)$), which is computed by the synthesis of high-band frequency procedure by the conventional obliged function $C(x,y)=\frac{(M(x,y)+b)}{(k(M(x,y)M(x,y))+h)}$ where b, k and h are a suitable number. At last, the enriched resolution image can be computed by combining of the synthesized high-band frequency image and the obliged function ($\hat{L}_{-1}(x,y)=\beta\cdot C(x,y)\cdot\tilde{L}_{-1}(x,y)$) and the low-band frequency image ($\tilde{G}_{-1}(x,y)$) at $2m\times 2n$ resolution.

II. Leclerc Obliged Function For The Image Enlarging Method Founded On The SISR

As announced in the obliged function procedure part, the obliged function $C(x,y)=\left(M(x,y)+b\right)\left(k\left(M(x,y)M(x,y)\right)+h\right)^{-1}$ [1] is controlled by 3 parameters (b, h, k) thereby it is difficult task for estimating these suitable values of these three parameters for reconstructing the superior enriched resolution image with the peak PSNR. In order to solve this problem, the Leclerc function relied upon wholly one parameter (T) instead of three parameters is comprised into SISR method. The Leclerc stochastic function is its first derivative can be announced as the upcoming Eq. (1) and Eq. (2), respectively.

$$C_{LEC}(x,y)=1-e^{\left(-M(x,y)^2/T^2\right)} \quad (1)$$

$$C'_{LEC}(x,y)=\left(2M(x,y)/T^2\right)e^{\left(-M(x,y)^2/T^2\right)} \quad (2)$$

Thus, the SISR founded on Leclerc stochastic function can also build a superior enriched resolution image by fast parameter selecting procedure as shown in figure 1.

III. All-Inclusive Theoretical Verification

In this part, copious computed images constitute up to 14 classic images: Lena, Tiffany, Baboon, House, Resolution chart, Peppers, F-16, Pentagon, Aerial, Tree, Sailboat, Cameraman, Stream and bridge, Mobile Frame10 [3-4]. All images are 2x2 resided down and added noise for building the captured images. Later, the fast Leclerc SISR, the conventional SISR and other 3 interpolation methods (for instance, nearest, bilinear and bicubic) are used for demonstrating its efficacy in PSNR.

A. *The Noiseless Status*

The first analytical verification discovers the optimized value of Leclerc constant, which is shift from 0 to 2000 for obtaining the highest PSNR results of the proposed SISR algorithm. The verification of noiseless status can be illustrated in figure 2. From the analytical verification result in figure 2, it can be inferred that the Leclerc constant is set to be optimized at 650-950 for common pattern and the Leclerc constant is set to be optimized at 1250-1400 for strong border region.

The overall analytical verification in PSNR can be illustrated in Table I for noiseless. The efficacy of the fast Leclerc is almost nearly to the conventional SISR nevertheless there is efficacy and undemanding in parameter turning.

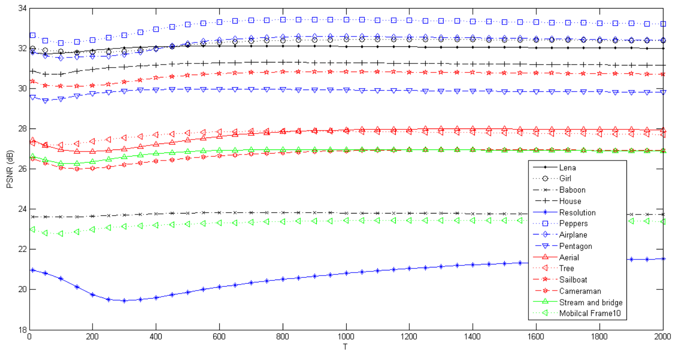

Fig. 2. The impact of the Leclerc constant (T) on the PSNR performance of the proposed SI-SR under the noiseless status

TABLE I. Anaalytical Verification For Noiseless Status

Efficacy (in dB)	**Convention Enlarging Technique**			**SISR Enlarging Technique**	
	nearest	***bilinear***	***bicubic***	***Original***	***Leclerc***
Lena 256	30.7847	31.0305	31.8281	32.1163	32.1184
Girl 256	30.9354	31.4602	31.9997	32.4382	32.4326
Baboon 256	23.2556	23.0546	23.6142	23.8230	23.8217
House 128	29.5053	30.1135	30.8944	31.3150	31.2925
Resolution chart 128	19.5643	20.0143	20.9699	21.5146	21.5161
Peppers 256	30.9254	31.7835	32.6814	33.4564	33.4231
Airplane 256	30.2861	31.0802	31.8515	32.6135	32.5823
Pentagon 512	28.8039	28.8569	29.6345	29.9707	29.9749
Aerial 512	25.6730	26.2025	27.4839	27.9839	27.9855
Tree 128	25.5058	26.2121	27.3201	27.8764	27.8810
Sailboat on lake	28.7881	29.3006	30.3990	30.8233	30.8247
Cameraman	25.4884	25.6590	26.5267	26.9492	26.9494
Stream & bridge	25.6787	25.8533	26.6535	26.9658	26.9673
Mobilcal Frame	22.0863	22.1223	23.0333	23.4345	23.4363

B. The Noisy Status (Gaussian Noise)

The verification of noisy status at SNR=15dB and SNR=20dB can be illustrated in figure 3 and figure 4, respectively. From the analytical verification result in figure 3 and figure 4, it can be inferred that the Leclerc constant is set to be optimized at 50-100 for common pattern and strong border region. The verification of noisy status at SNR=25dB can be illustrated in figure 5. From the analytical verification result in figure 5, it can be inferred that the Leclerc constant is set to be optimized at 2000 for common pattern and strong border region.

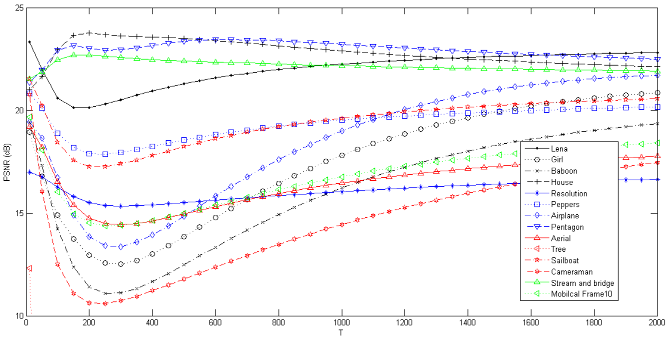

Fig. 3. The impact of the Leclerc constant (T) on the PSNR performance of the proposed SI-SR under the noisy at SNR=15 dB status

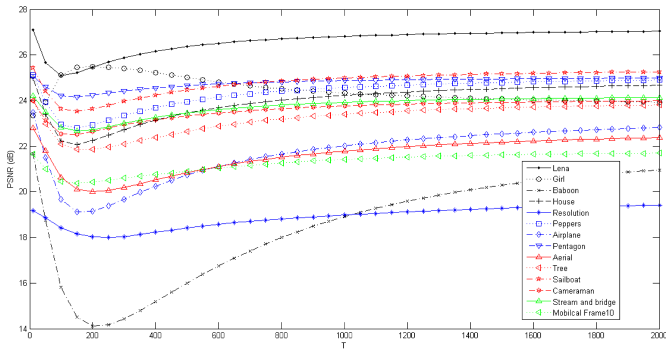

Fig. 4. The impact of the Leclerc constant (T) on the PSNR performance of the proposed SI-SR under the noisy at SNR=20 dB status

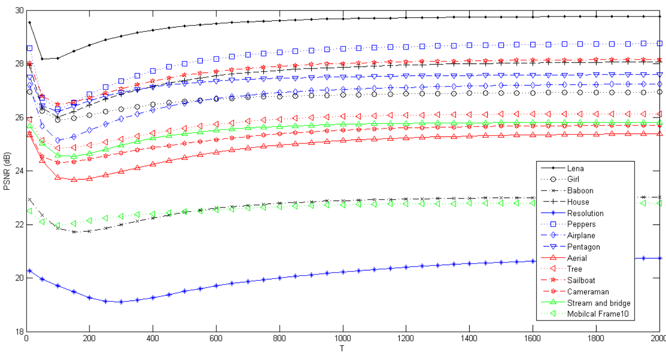

Fig. 5. The impact of the Leclerc constant (T) on the PSNR performance of the proposed SI-SR under the noisy at SNR=25 dB status

The verification of noisy status at SNR=30dB can be illustrated in figure 6. From the analytical verification result in figure 6, it can be inferred that the Leclerc constant is set to be optimized at 1050-1350 for common pattern and the Leclerc constant is set to be optimized at 1550-1800 for strong border region. The verification of noisy status at SNR=35dB can be illustrated in figure 7. From the analytical verification result in figure 7, it can be inferred that the Leclerc constant is set to be optimized at 750-1050 for common pattern and the Leclerc constant is set to be optimized at 1400-1500 for strong border region.

The overall analytical verification in PSNR can be illustrated in Table II-VI for noisy status (SNR=15dB, SNR=20dB, SNR=25dB, SNR=30dB and SNR=35dB). The efficacy of the fast Leclerc is almost nearly to the conventional SISR nevertheless there is efficacy and undemanding in parameter turning.

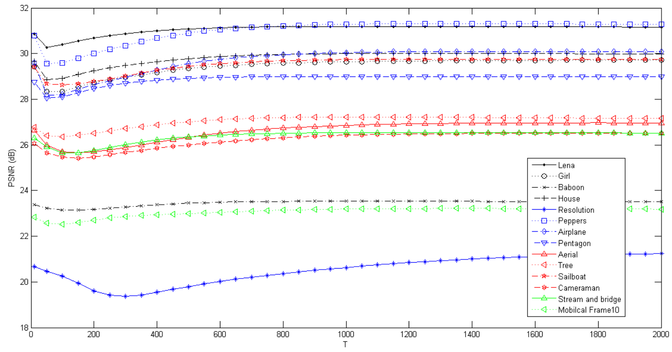

Fig. 6. The impact of the Leclerc constant (T) on the PSNR performance of the proposed SI-SR under the noisy at SNR=30 dB status

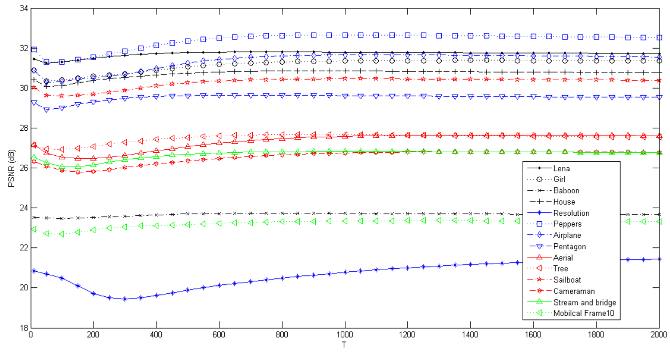

Fig. 7. The impact of the Leclerc constant (T) on the PSNR performance of the proposed SI-SR under the noisy at SNR=35 dB status

TABLE II. ANALYTICAL VERIFICATION FOR NOISY STATUS (15 DB)

Efficacy (in dB)	**Convention Enlarging Technique**			**SISR Enlarging Technique**	
	nearest	***bilinear***	***bicubic***	***Original***	***Leclerc***
Lena 256	21.6865	25.0304	23.3984	22.8143	23.3213
Girl 256	17.5919	20.5463	19.0607	20.8470	20.8638
Baboon 256	18.2870	20.4709	19.5803	19.3502	19.4454
House 128	19.2021	22.7441	20.9777	23.8707	23.7575
Resolution chart 128	15.8312	17.1004	17.0132	16.7247	17.0011
Peppers 256	19.0530	22.8168	20.8799	20.1654	20.8411
Airplane 256	17.6337	21.4275	19.4532	21.6973	21.7080
Pentagon 512	19.6055	22.9523	21.3112	23.4009	23.4386
Aerial 512	17.4295	20.7166	19.2504	17.9395	19.1982
Tree 128	19.0209	21.9996	20.8054	20.8054	20.8054
Sailboat on lake	19.7894	23.1942	21.5877	20.5746	21.5143
Cameraman	19.6661	22.2601	21.2392	17.4478	20.7578
Stream & bridge	19.9226	22.5555	21.5059	22.7491	22.7004
Mobilcal Frame	18.3270	20.2034	19.7472	18.4057	19.6574

TABLE III. ANALYTICAL VERIFICATION FOR NOISY STATUS (20 DB)

Efficacy (in dB)	Convention Enlarging Technique			SISR Enlarging Technique	
	nearest	*bilinear*	*bicubic*	*Original*	*Leclerc*
Lena 256	25.6564	28.1626	27.2344	27.0392	27.1052
Girl 256	21.8777	24.6240	23.3290	24.9774	25.4792
Baboon 256	20.9703	22.0453	21.8670	20.9569	21.6765
House 128	23.3918	26.2827	25.0868	24.6741	24.9794
Resolution chart 128	17.9745	18.7310	19.1978	19.4069	19.4087
Peppers 256	23.4069	26.6798	25.2104	24.9032	25.1305
Airplane 256	21.8144	25.2239	23.6010	22.8124	23.4781
Pentagon 512	23.5947	26.0207	25.1014	24.9881	25.0697
Aerial 512	21.0291	23.5342	22.8592	22.3751	22.8020
Tree 128	22.2373	24.3882	24.0573	23.8088	23.9904
Sailboat on lake	23.7172	26.3543	25.4907	25.2591	25.4206
Cameraman	22.6552	24.2765	24.0628	23.9895	23.9991
Stream & bridge	22.9163	24.4829	24.2592	24.1324	24.2150
Mobilcal Frame	20.4761	21.4132	21.6812	21.6926	21.6929

TABLE IV. ANALYTICAL VERIFICATION FOR NOISY STATUS (25 DB)

Efficacy (in dB)	Convention Enlarging Technique			SISR Enlarging Technique	
	nearest	*bilinear*	*bicubic*	*Original*	*Leclerc*
Lena 256	28.4337	29.8840	29.7845	29.7683	29.7683
Girl 256	25.6196	27.8846	27.0131	26.9386	26.9489
Baboon 256	22.3835	22.7094	22.9807	23.0185	23.0185
House 128	26.5383	28.5195	28.1402	28.0728	28.0727
Resolution chart 128	18.9763	19.5031	20.2865	20.7360	20.7376
Peppers 256	26.9869	29.4634	28.7941	28.7553	28.7551
Airplane 256	25.6092	28.2721	27.3511	27.2471	27.2472
Pentagon 512	26.4092	27.7381	27.6345	27.5956	27.5956
Aerial 512	23.5987	25.1536	25.4107	25.3921	25.3923
Tree 128	24.1746	25.5459	25.9950	26.1296	26.1301
Sailboat on lake	26.4762	28.1148	28.1716	28.1581	28.1582
Cameraman	24.3387	25.1270	25.5263	25.7021	25.7008
Stream & bridge	24.5930	25.3655	25.7363	25.8133	25.8134
Mobilcal Frame	21.5043	21.8787	22.5487	22.7896	22.7900

TABLE V. ANALYTICAL VERIFICATION FOR NOISY STATUS (30 DB)

Efficacy (in dB)	Convention Enlarging Technique			SISR Enlarging Technique	
	nearest	*bilinear*	*bicubic*	*Original*	*Leclerc*
Lena 256	29.8834	30.6228	31.0558	31.1859	31.1861
Girl 256	28.3650	29.9100	29.6382	29.7120	29.7121
Baboon 256	22.9560	22.9394	23.3984	23.5359	23.5358
House 128	28.3219	29.5568	29.8302	30.0055	30.0038
Resolution chart 128	19.3609	19.8073	20.7091	21.2386	21.2400
Peppers 256	29.2480	30.8899	31.0236	31.3112	31.3087
Airplane 256	28.2036	29.9570	29.8565	30.0975	30.0961
Pentagon 512	27.8858	28.4586	28.8821	29.0009	29.0015
Aerial 512	24.8993	25.8372	26.7127	26.9680	26.9684
Tree 128	25.0357	25.9789	26.8435	27.2191	27.2222
Sailboat on lake	27.9077	28.8840	29.5562	29.7565	29.7568
Cameraman	25.0797	25.4869	26.1808	26.5104	26.5106
Stream & bridge	25.3003	25.6880	26.3351	26.5466	26.5471
Mobilcal Frame	21.8914	22.0470	22.8758	23.2144	23.2155

TABLE VI. ANALYTICAL VERIFICATION FOR NOISY STATUS (35 DB)

Efficacy (in dB)	Convention Enlarging Technique			SISR Enlarging Technique	
	nearest	*bilinear*	*bicubic*	*Original*	*Leclerc*
Lena 256	29.8834	30.6228	31.0558	31.7766	31.8012
Girl 256	28.3650	29.9100	29.6382	31.6288	31.3790
Baboon 256	22.9560	22.9394	23.3984	23.7324	23.7278
House 128	28.3219	29.5568	29.8302	30.6766	30.8522
Resolution chart 128	19.3609	19.8073	20.7091	21.3702	21.4357
Peppers 256	29.2480	30.8899	31.0236	32.2512	32.6523
Airplane 256	28.2036	29.9570	29.8565	31.7989	31.6607
Pentagon 512	27.8858	28.4586	28.8821	29.5919	29.6383
Aerial 512	24.8993	25.8372	26.7127	27.5565	27.6420
Tree 128	25.0357	25.9789	26.8435	27.6981	27.6656
Sailboat on lake	27.9077	28.8840	29.5562	30.3552	30.4577
Cameraman	25.0797	25.4869	26.1808	26.7378	26.8088
Stream & bridge	25.3003	25.6880	26.3351	26.7787	26.8272
Mobilcal Frame	21.8914	22.0470	22.8758	23.2646	23.3655

C. The Blurring Status (Gaussian Blurring)

The verification of Gaussian blurring status can be illustrated in figure 8 therefore it can be inferred that the Leclerc constant is set to be optimized at 150-350 for common pattern and the Leclerc constant is set to be optimized at 450-600 for strong border region. The overall analytical verification in PSNR can be illustrated in Table VII for noiseless and the efficacy of the fast Leclerc is nearly to the conventional SISR.

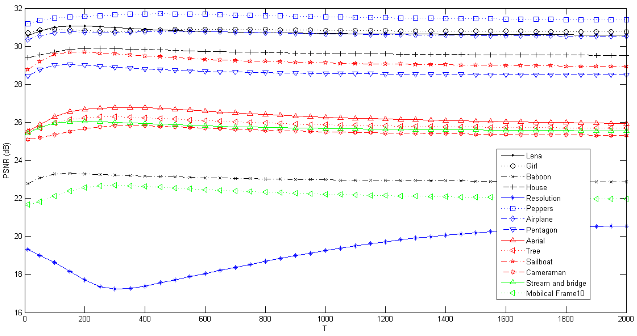

Fig. 8. The impact of the Leclerc constant (T) on the PSNR performance of the proposed SI-SR under the blurring status

TABLE VII. ANAALYTICAL VERIFICATION FOR BLURRING STATUS

Efficacy (in dB)	Convention Enlarging Technique			SISR Enlarging Technique	
	nearest	*bilinear*	*bicubic*	*Original*	*Leclerc*
Lena 256	30.0380	29.8434	30.5045	31.1895	31.0722
Girl 256	30.0060	30.2589	30.6625	30.9394	30.8954
Baboon 256	22.7067	22.2646	22.7420	23.4005	23.3176
House 128	28.5948	28.6986	29.3834	29.9856	29.8902
Resolution chart 128	18.8097	18.5600	19.4261	20.5435	20.5535
Peppers 256	30.1123	30.3825	31.1269	31.8157	31.7031
Airplane 256	29.4545	29.7184	30.3379	30.8805	30.7790
Pentagon 512	28.1090	27.7764	28.4035	29.1642	29.0476
Aerial 512	24.7733	24.5300	25.4756	26.6213	26.7769
Tree 128	24.6571	24.6232	25.4944	26.4663	26.2838
Sailboat on lake	28.0071	27.8400	28.7182	29.9100	29.6981
Cameraman	24.6746	24.3546	25.0812	25.9308	25.8233
Stream & bridge	25.0165	24.7138	25.4004	26.2157	26.0459
Mobilcal Frame	21.3858	20.9279	21.6672	22.8347	22.6794

IV. SUMMARY

This analytic paper aims to propose the spatial expanding algorithm is formed on the Super Resolve algorithm employed by a robust adaptive Leclerc function and manufactured edge component. Under testing on 14 traditional standard images, the proposed accelerated super resolve algorithm can create the high spatial resolution image with superior quality (PSNR) to the original super resolve algorithm in the experimental testing section however the constant alteration procedure of the proposed accelerated super resolve algorithm is more ease and rapid than the original super resolve algorithm

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