

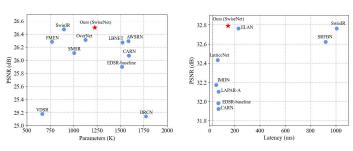
## Lightweight Image Super-Resolution with Scale-wise Network

Approach



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## Problem



- Current CNN-based super-resolution (SR) network depends on a significant number of model parameters, which results in increased computational requirements and memory consumption during the training process.
- Most conventional upsampling modules utilize single-layer PixelShuffle or Bicubic, which leads to a loss of feature information. And the missing information is also crucial for reconstructing high quality image networks.

## Contribution

- A lightweight recursive feature extractor that improves performance even in the most advanced models.
- A Scale-wise Upsample module (SUM) to retain multi-scale information that helps restore HR images accurately.
- SUM favors lightweight model design. Based on this, we construct a lightweight SwiseNet, using the multi-scale information fusion strategy to extract multi-scale context information.
- Replacing the upsampling operation with our SUM produces better SR results for the baseline model.

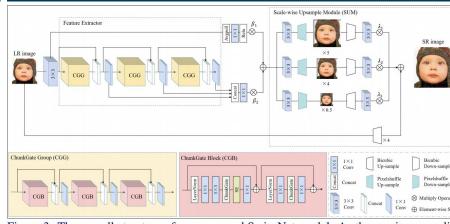


Figure 3: The overall structure of our proposed SwiseNet model. As the maximum scaling factor in this example is set to N = 4, the required scaling-factors are  $\times 4$ ,  $\times 5$  and  $\times 0.5$ .

- To deal with all the mentioned challenges, we proposed a lightweight SR model that includes several continuous feature extractors and a novel upsampling module.
- Our proposed method, called multi-scale fusion, utilizes feature information from multiple scales simultaneously for up-sampling. This approach has the advantage of integrating information from different scales to provide a more comprehensive understanding of the image features, leading to improved performance and network robustness.
- After many ablation experiments, we have the following findings: multiple upsampled information of different scales can make the model produce better SR results, but at the same time, it will sacrifice some computational efficiency.

Based on these findings, we employed a scale transformation approach with the target scale as the reference in three different directions, including magnification, equivalence, and reduction. Subsequently, we adjusted them to the target scale, thereby providing additional information for the same pixel and enhancing the effectiveness of SR.

## **Experimental Results**

Table 1: Average PSNR/SSIM for  $2\times$ ,  $3\times$ ,  $4\times$  SR. The best results are highlighted in red color and the second best is in blue.

#Params[K]   #F     -   -     57   -     585   -     985   -     748   -     878   -     1077   -     -	52.7 222.8 224.1 153.2 172.0 195.6 212.7 236.5 52.7 118.8 100.5 68.4 77.2 87.2 112.8	PSNR/SSIM 33.66 / 0.9299 36.66 / 0.9542 37.76 / 0.9500 38.00 / 0.9601 38.10 / 0.9600 38.14 / 0.9610 33.39 / 0.8682 32.75 / 0.9000 34.29 / 0.9255 34.40 / 0.9270 34.47 / 0.9277 34.45 / 0.9277 34.45 / 0.9278	PSNR/SSIM 30.24 / 0.8688 32.45 / 0.9067 33.52 / 0.9166 33.64 / 0.9179 33.75 / 0.9192 33.86 / 0.9206 33.86 / 0.9207 33.89 / 0.9207 33.89 / 0.9217 30.29 / 0.8407 30.33 / 0.8412 30.38 / 0.8417 30.49 / 0.8443 30.54 / 0.8443	PSNR/SSIM 29,56 / 0.8431 31,36 / 0.8879 32,09 / 0.8978 32,16 / 0.8994 32,26 / 0.9007 32,31 / 0.9012 32,22 / 0.9008 23,228 / 0.9012 27,21 / 0.7385 28,41 / 0.7863 29,06 / 0.8034 29,10 / 0.8050 29,13 / 0.8061 29,17 / 0.8062	PSNR/SSIM 26.88 / 0.8403 29.50 / 0.8946 31.92 / 0.9256 32.19 / 0.9284 32.30 / 0.9291 32.41 / 0.9311 32.76 / 0.9338 32.64 / 0.9349 26.24 / 0.7349 26.24 / 0.7349 26.24 / 0.7349 28.06 / 0.8493 28.26 / 0.8536
57 1592 985 731 748 878 1035 1075 - 57 1592 993 736 757 886 1044 1064 1044 1064	52.7 222.8 224.1 153.2 172.0 195.6 212.7 236.5 52.7 118.8 100.5 68.4 77.2 87.2 112.8 128.0	36.66 / 0.9542 37.76 / 0.9590 38.00 / 0.9601 38.05 / 0.9607 38.10 / 0.9609 38.14 / 0.9610 38.10 / 0.9605 38.18 / 0.9610 33.39 / 0.8682 32.75 / 0.9090 34.29 / 0.9255 34.40 / 0.9270 34.47 / 0.9277 34.45 / 0.9275 34.61 / 0.9289	$\begin{array}{c} 32.45  /  0.9067 \\ 33.52  /  0.9166 \\ 33.54  /  0.9179 \\ 33.65  /  0.9179 \\ 33.55  /  0.9192 \\ 33.86  /  0.9206 \\ 33.86  /  0.9206 \\ 33.86  /  0.9207 \\ 33.84  /  0.9216 \\ 33.80  0.9206$	31.36 / 0.8879 32.09 / 0.8978 32.17 / 0.8990 32.16 / 0.8994 32.26 / 0.9007 32.22 / 0.9008 32.22 / 0.9008 32.22 / 0.9012 32.22 / 0.9018 32.28 / 0.9012 32.22 / 0.9018 32.28 / 0.9012 29.12 / 0.8050 29.13 / 0.8051 29.17 / 0.8061	$\begin{array}{c} 29.50 \ / \ 0.8946 \\ 31.92 \ / \ 0.9256 \\ 32.19 \ / \ 0.9281 \\ 32.30 \ / \ 0.9291 \\ 32.41 \ / \ 0.9311 \\ 32.76 \ / \ 0.9338 \\ 32.64 \ / \ 0.9339 \\ 24.46 \ / \ 0.9339 \\ 24.46 \ / \ 0.7349 \\ 26.24 \ / \ 0.7849 \\ 28.06 \ / \ 0.8493 \\ 28.25 \ / \ 0.8556 \\ 28.42 \ / \ 0.8559 \end{array}$
1592   985     731   748     878   1035     1077   -     -   -     57   1592     993   736     757   886     10444   10644	222.8 224.1 153.2 172.0 195.6 212.7 236.5 52.7 118.8 100.5 68.4 77.2 87.2 112.8 112.8	37.76 / 0.9590 38.00 / 0.9601 38.05 / 0.9607 38.10 / 0.9609 38.14 / 0.9610 33.39 / 0.8682 32.75 / 0.9090 34.29 / 0.9255 34.40 / 0.9270 34.47 / 0.9277 34.67 / 0.9278 34.43 / 0.9289	33.52 / 0.9166 33.64 / 0.9179 33.75 / 0.9192 33.86 / 0.9206 33.86 / 0.9206 33.85 / 0.9207 33.84 / 0.9217 27.55 / 0.7142 29.30 / 0.8215 30.29 / 0.8407 30.33 / 0.8412 30.38 / 0.8417 30.48 / 0.8435 30.54 / 0.8442	32.09 / 0.8978 32.17 / 0.8990 32.26 / 0.8994 32.26 / 0.9007 32.31 / 0.9012 32.22 / 0.9008 32.28 / 0.9012 27.21 / 0.7385 28.41 / 0.7863 29.96 / 0.8034 29.10 / 0.8050 29.13 / 0.8061 29.17 / 0.8062	$\begin{array}{c} 31.92 \ / \ 0.9256\\ 32.19 \ / \ 0.9284\\ 32.30 \ / \ 0.9291\\ 32.41 \ / \ 0.9318\\ 32.76 \ / \ 0.9338\\ 32.64 \ / \ 0.9338\\ 32.64 \ / \ 0.9339\\ 24.46 \ / \ 0.7349\\ 26.24 \ / \ 0.7849\\ 28.06 \ / \ 0.8493\\ 28.25 \ / \ 0.8556\\ 28.42 \ / \ 0.8559\\ \end{array}$
985 731 748 878 1035 1077 57 57 592 993 736 757 886 1044 1064	224.1 153.2 172.0 195.6 212.7 236.5 52.7 118.8 100.5 68.4 77.2 87.2 112.8 128.0	38.00 / 0.9601 38.05 / 0.9607 38.10 / 0.9609 38.14 / 0.9609 38.14 / 0.9609 38.18 / 0.9609 33.37 / 0.9602 33.37 / 0.9020 34.29 / 0.9255 34.40 / 0.9275 34.45 / 0.9275 34.45 / 0.9275 34.45 / 0.9289	33.64 / 0.9179 33.65 / 0.9177 33.85 / 0.9172 33.86 / 0.9206 33.85 / 0.9207 33.94 / 0.9217 27.55 / 0.7742 29.30 / 0.8215 30.29 / 0.8407 30.33 / 0.8412 30.38 / 0.8412 30.34 / 0.8433 30.54 / 0.8443	32.17 / 0.8990 32.16 / 0.8994 32.26 / 0.9007 32.32 / 0.9002 32.22 / 0.9008 32.28 / 0.9012 27.21 / 0.7863 29.41 / 0.7863 29.10 / 0.8034 29.13 / 0.8061 29.17 / 0.8063 29.17 / 0.8063	$\begin{array}{c} 32.19 \ / \ 0.9284 \\ 32.30 \ / \ 0.9291 \\ 32.41 \ / \ 0.9318 \\ 32.64 \ / \ 0.9326 \\ 32.67 \ / \ 0.9328 \\ 32.64 \ / \ 0.9326 \\ 32.64 \ / \ 0.9329 \\ 24.46 \ / \ 0.7349 \\ 26.24 \ / \ 0.7989 \\ 28.06 \ / \ 0.8493 \\ 28.25 \ / \ 0.8556 \\ 28.42 \ / \ 0.8559 \end{array}$
731 748 878 1035 1077 57 1592 993 736 757 886 1044 1068	153.2 172.0 195.6 212.7 236.5 52.7 118.8 100.5 68.4 77.2 87.2 112.8 128.0	38.05 / 0.9607 38.10 / 0.9609 38.14 / 0.9610 38.14 / 0.9610 33.39 / 0.8682 32.75 / 0.9090 34.29 / 0.9255 34.40 / 0.9277 34.45 / 0.9277 34.45 / 0.9275 34.61 / 0.9289	$\begin{array}{r} 33.65 / 0.9177 \\ 33.75 / 0.9192 \\ 33.86 / 0.9206 \\ 33.85 / 0.9207 \\ 33.94 / 0.9217 \\ 27.55 / 0.7742 \\ 29.30 / 0.8215 \\ 30.29 / 0.8407 \\ 30.33 / 0.8412 \\ 30.33 / 0.8411 \\ 30.34 / 0.8435 \\ 30.54 / 0.8443 \\ 30.54 / 0.8442 \\ \end{array}$	$\begin{array}{c} 32.16 \ / \ 0.8994 \\ 32.26 \ / \ 0.9007 \\ 32.31 \ / \ 0.9012 \\ 32.22 \ / \ 0.9008 \\ 32.22 \ / \ 0.9008 \\ 32.22 \ / \ 0.9012 \\ 27.21 \ / \ 0.7385 \\ 28.41 \ / \ 0.7863 \\ 29.06 \ / \ 0.8034 \\ 29.10 \ / \ 0.8061 \\ 29.17 \ / \ 0.8063 \\ 29.19 \ / \ 0.8062 \end{array}$	$\begin{array}{c} 32.30  /  0.9291 \\ 32.41  /  0.9311 \\ 32.76  /  0.9338 \\ 32.64  /  0.9326 \\ 32.79  /  0.9339 \\ 24.46  /  0.7349 \\ 26.24  /  0.7989 \\ 28.06  /  0.8493 \\ 28.25  /  0.8536 \\ 28.42  /  0.8559 \end{array}$
748     878     1035     1077     57     1592     993     736     757     886     1044     1064	172.0 195.6 212.7 236.5 52.7 118.8 100.5 68.4 77.2 87.2 112.8 128.0	38.10 / 0.9609 38.14 / 0.9610 38.18 / 0.9605 38.18 / 0.9605 33.39 / 0.8682 32.75 / 0.9090 34.29 / 0.9275 34.40 / 0.9270 34.47 / 0.9277 34.45 / 0.9275 34.61 / 0.9268 34.61 / 0.9268	$\begin{array}{r} 33.75 \ / \ 0.9192 \\ 33.86 \ / \ 0.9206 \\ 33.85 \ / \ 0.9207 \\ 33.94 \ / \ 0.9217 \\ 27.55 \ / \ 0.7742 \\ 29.30 \ / \ 0.8215 \\ 30.29 \ / \ 0.8407 \\ 30.33 \ / \ 0.8412 \\ 30.38 \ / \ 0.8412 \\ 30.38 \ / \ 0.8415 \\ 30.54 \ / \ 0.8463 \\ 30.44 \ / \ 0.8442 \\ \end{array}$	32.26 / 0.9007 32.31 / 0.9012 32.22 / 0.9008 32.28 / 0.9012 27.21 / 0.7385 28.41 / 0.7385 29.40 / 0.8034 29.10 / 0.8061 29.17 / 0.8063 29.19 / 0.8082	$\begin{array}{c} 32.41 / 0.9311 \\ 32.76 / 0.9338 \\ 32.64 / 0.9326 \\ 32.79 / 0.9339 \\ 24.46 / 0.7349 \\ 26.24 / 0.7989 \\ 28.06 / 0.8493 \\ 28.25 / 0.8536 \\ 28.42 / 0.8559 \end{array}$
878     1035     107     57     1592     993     736     757     886     1044     1068	195.6     212.7     236.5     -     52.7     118.8     100.5     68.4     77.2     87.2     112.8     128.0	38.14 / 0.9610 38.10 / 0.9605 38.18 / 0.9610 33.39 / 0.8682 32.75 / 0.9090 34.29 / 0.9255 34.40 / 0.9270 34.47 / 0.9277 34.45 / 0.9275 34.60 / 0.9289 34.43 / 0.9268 34.61 / 0.9289	33.86 / 0.9206 33.85 / 0.9207 33.94 / 0.9217 27.55 / 0.7742 29.30 / 0.8215 30.29 / 0.8407 30.33 / 0.8412 30.38 / 0.8417 30.40 / 0.8435 30.54 / 0.8463 30.54 / 0.8442	32.31 / 0.9012 32.22 / 0.9008 32.28 / 0.9012 27.21 / 0.7385 28.41 / 0.7863 29.06 / 0.8034 29.10 / 0.8061 29.17 / 0.8063 29.19 / 0.8082	32.76 / 0.9338 32.64 / 0.9326 32.79 / 0.9339 24.46 / 0.7349 26.24 / 0.7989 28.06 / 0.8493 28.25 / 0.8536 28.42 / 0.8559
1035 1077 57 1592 993 736 757 886 1044 1068	212.7 236.5 52.7 118.8 100.5 68.4 77.2 87.2 112.8 128.0	38.10 / 0.9605 38.18 / 0.9610 33.39 / 0.8682 32.75 / 0.9090 34.29 / 0.9255 34.40 / 0.9270 34.47 / 0.9277 34.45 / 0.9275 34.60 / 0.9289 34.43 / 0.9268 34.61 / 0.9289	$\begin{array}{c} 33.85 \ / \ 0.9207 \\ \hline 33.94 \ / \ 0.9217 \\ \hline 27.55 \ / \ 0.7742 \\ 29.30 \ / \ 0.8215 \\ 30.29 \ / \ 0.8407 \\ \hline 30.33 \ / \ 0.8412 \\ \hline 30.38 \ / \ 0.8412 \\ \hline 30.40 \ / \ 0.8435 \\ \hline 30.54 \ / \ 0.8463 \\ \hline 30.44 \ / \ 0.8442 \end{array}$	32.22 / 0.9008 32.28 / 0.9012 27.21 / 0.7385 28.41 / 0.7863 29.06 / 0.8034 29.10 / 0.8050 29.13 / 0.8061 29.17 / 0.8063 29.19 / 0.8082	32.64 / 0.9326 32.79 / 0.9339 24.46 / 0.7349 26.24 / 0.7989 28.06 / 0.8493 28.25 / 0.8536 28.42 / 0.8559
1077 57 1592 993 736 757 886 1044 1068	236.5 52.7 118.8 100.5 68.4 77.2 87.2 112.8 128.0	38.18 / 0.9610     33.39 / 0.8682     32.75 / 0.9090     34.29 / 0.9255     34.40 / 0.9270     34.47 / 0.9277     34.60 / 0.9289     34.61 / 0.9289     34.61 / 0.9289	33.94 / 0.9217 27.55 / 0.7742 29.30 / 0.8215 30.29 / 0.8407 30.33 / 0.8412 30.38 / 0.8417 30.40 / 0.8435 30.54 / 0.8463 30.44 / 0.8442	32.28 / 0.9012 27.21 / 0.7385 28.41 / 0.7863 29.06 / 0.8034 29.10 / 0.8050 29.13 / 0.8061 29.17 / 0.8063 29.19 / 0.8082	32.79 / 0.9339 24.46 / 0.7349 26.24 / 0.7989 28.06 / 0.8493 28.25 / 0.8536 28.42 / 0.8559
57 1592 993 736 757 886 1044 1068	52.7 118.8 100.5 68.4 77.2 87.2 112.8 128.0	33.39 / 0.8682 32.75 / 0.9090 34.29 / 0.9255 34.40 / 0.9270 34.47 / 0.9277 34.45 / 0.9289 34.60 / 0.9289 34.61 / 0.9289	27.55 / 0.7742 29.30 / 0.8215 30.29 / 0.8407 30.33 / 0.8412 30.38 / 0.8417 30.40 / 0.8435 30.54 / 0.8463 30.44 / 0.8442	27.21 / 0.7385 28.41 / 0.7863 29.06 / 0.8034 29.10 / 0.8050 29.13 / 0.8061 29.17 / 0.8063 29.19 / 0.8082	24.46 / 0.7349 26.24 / 0.7989 28.06 / 0.8493 28.25 / 0.8536 28.42 / 0.8559
57 1592 993 736 757 886 1044 1068	52.7 118.8 100.5 68.4 77.2 87.2 112.8 128.0	32.75 / 0.9090 34.29 / 0.9255 34.40 / 0.9270 34.47 / 0.9277 34.45 / 0.9275 34.60 / 0.9289 34.43 / 0.9268 34.61 / 0.9289	29.30 / 0.8215 30.29 / 0.8407 30.33 / 0.8412 30.38 / 0.8417 30.40 / 0.8435 30.54 / 0.8463 30.44 / 0.8442	28.41 / 0.7863 29.06 / 0.8034 29.10 / 0.8050 29.13 / 0.8061 29.17 / 0.8063 29.19 / 0.8082	26.24 / 0.7989 28.06 / 0.8493 28.25 / 0.8536 28.42 / 0.8559
1592 993 736 757 886 1044 1068	118.8 100.5 68.4 77.2 87.2 112.8 128.0	34.29 / 0.9255 34.40 / 0.9270 34.47 / 0.9277 34.45 / 0.9275 34.60 / 0.9289 34.43 / 0.9268 34.61 / 0.9289	30.29 / 0.8407 30.33 / 0.8412 30.38 / 0.8417 30.40 / 0.8435 <b>30.54 / 0.8463</b> 30.44 / 0.8442	29.06 / 0.8034 29.10 / 0.8050 29.13 / 0.8061 29.17 / 0.8063 29.19 / 0.8082	28.06 / 0.8493 28.25 / 0.8536 28.42 / 0.8559
993 736 757 886 1044 1068	100.5 68.4 77.2 87.2 112.8 128.0	34.40 / 0.9270 34.47 / 0.9277 34.45 / 0.9275 34.60 / 0.9289 34.43 / 0.9268 34.61 / 0.9289	30.33 / 0.8412 30.38 / 0.8417 30.40 / 0.8435 30.54 / 0.8463 30.44 / 0.8442	29.10 / 0.8050 29.13 / 0.8061 29.17 / 0.8063 29.19 / 0.8082	28.25 / 0.8536 28.42 / 0.8559
736 757 886 1044 1068	68.4 77.2 87.2 112.8 128.0	34.47 / 0.9277 34.45 / 0.9275 34.60 / 0.9289 34.43 / 0.9268 34.61 / 0.9289	30.38 / 0.8417 30.40 / 0.8435 30.54 / 0.8463 30.44 / 0.8442	29.13 / 0.8061 29.17 / 0.8063 29.19 / 0.8082	28.42/0.8559
757 886 1044 1068	77.2 87.2 112.8 128.0	34.45 / 0.9275 34.60 / 0.9289 34.43 / 0.9268 34.61 / 0.9289	30.38 / 0.8417 30.40 / 0.8435 30.54 / 0.8463 30.44 / 0.8442	29.13 / 0.8061 29.17 / 0.8063 29.19 / 0.8082	28.42/0.8559
886 1044 1068	87.2 112.8 128.0	34.60 / 0.9289   34.43 / 0.9268   34.61 / 0.9289	<b>30.54 / 0.8463</b> 30.44 / 0.8442	29.19 / 0.8082	28.33/0.8562
1044 1068	112.8 128.0	34.43 / 0.9268 34.61 / 0.9289	30.44 / 0.8442		
1044 1068	112.8 128.0	34.43 / 0.9268 34.61 / 0.9289	30.44 / 0.8442		28.66/0.8624
- 1068	128.0	34.61 / 0.9289		29.11/0.8066	28.45 / 0.8590
-			30.52/0.8453	29.20 / 0.8079	28.63/0.8615
		28.42/0.8104	26.00 / 0.7027	25.96 / 0.6675	23.14/0.6577
	52.7	30.48 / 0.8628	27.50 / 0.7513	26.90 / 0.7101	24.52 / 0.7221
1592		32.13 / 0.8937	28.60 / 0.7806	27.58 / 0.7349	26.07 / 0.7837
1006		32.12 / 0.8932	28.55 / 0.7808	27.55 / 0.7351	26.11/0.7868
742		32.29 / 0.8960	28.68 / 0.7832	27.62 / 0.7382	26.27 / 0.7906
769		32.24 / 0.8955	28.70 / 0.7839	27.63 / 0.7379	26.28 / 0.7908
897		32.42 / 0.8976	28.77 / 0.7858	27.68 / 0.7406	26.47 / 0.7980
1056		32.31 / 0.8955	28.65 / 0.7829	27.57 / 0.7363	26.35 / 0.7928
1227		32.43 / 0.8979	28.72 / 0.7844	27.68 / 0.7396	26.48 / 0.7969
HR I PSNR/SSIM 21.	Bicubic .10/0.5470	SRCNN 23.21/0.6719	FSRCNN 23.28/0.6771	VDSR 23.44/0.6961	DRCN 23.49/0.6987
	SMSR	LBNET 23.86/0.7329	FMEN 23.83/0.7288	SwinIR 23.91/0.7338	SwiseNet 24.00/0.7345
CARN 23.48/0.6985 23.	.82/0.7263			and the second se	-
23.48/0.6985 23.	.82/0.7263 Bicubic .96/0.4001	SRCNN 17.56/0.5413	FSRCNN 17.70/0.5528	VDSR 18.13/0.6004	DRCN 18.20/0.6069
The second se	3.48/0.6985 23.				