Image Fusion in Bayer Domain using a Monochrome and Bayer Sensor

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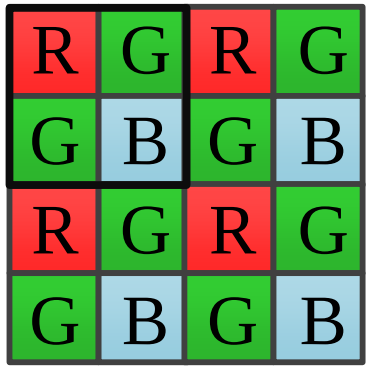
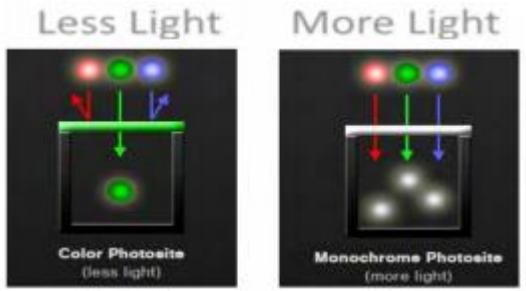
Why dual sensor?



Bayer Pattern



- Smartphones - physical limit on the size of sensors
- Large number of pixels in a small area
- Lowlight photography performance issue
- No color filters in Mono -> captures ~3x light
- High resolution compared to same megapixel Bayer sensor

Fusion of Mono and Color Image to take advantage of lower noise, high sensitivity and high resolution of Mono

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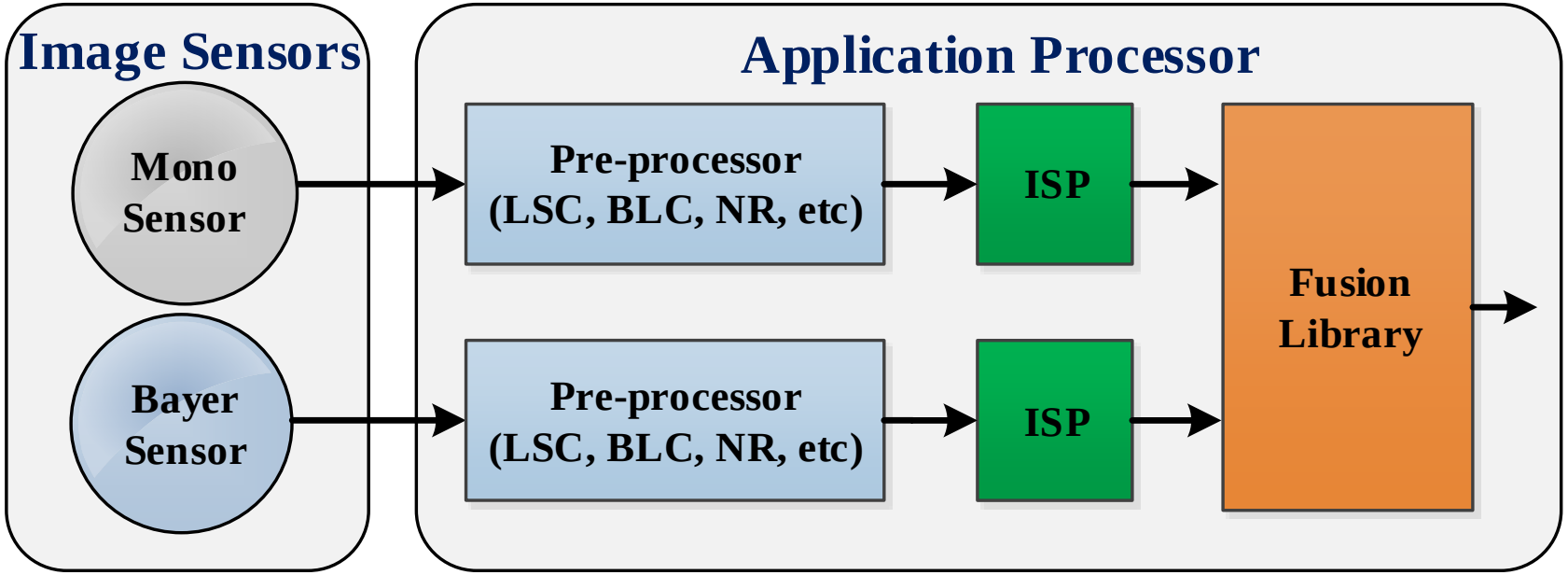
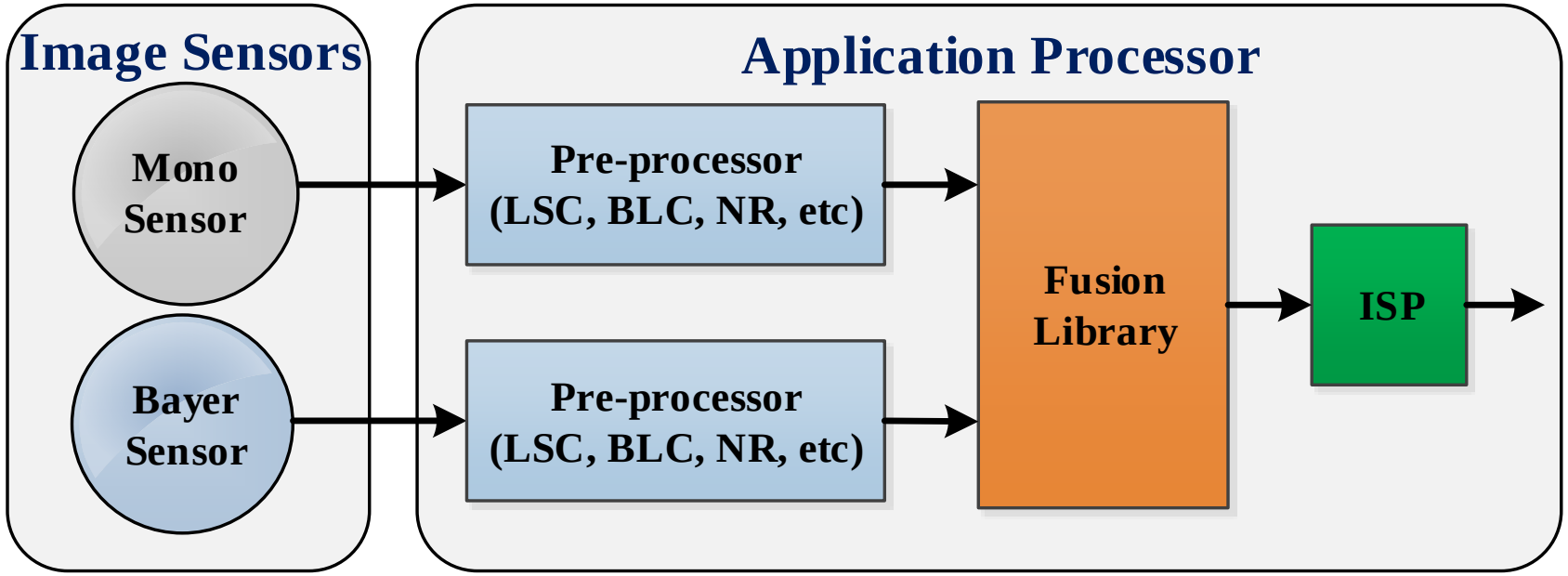
Conventional Fusion System



Conventional (Bayer + Mono) Fusion System

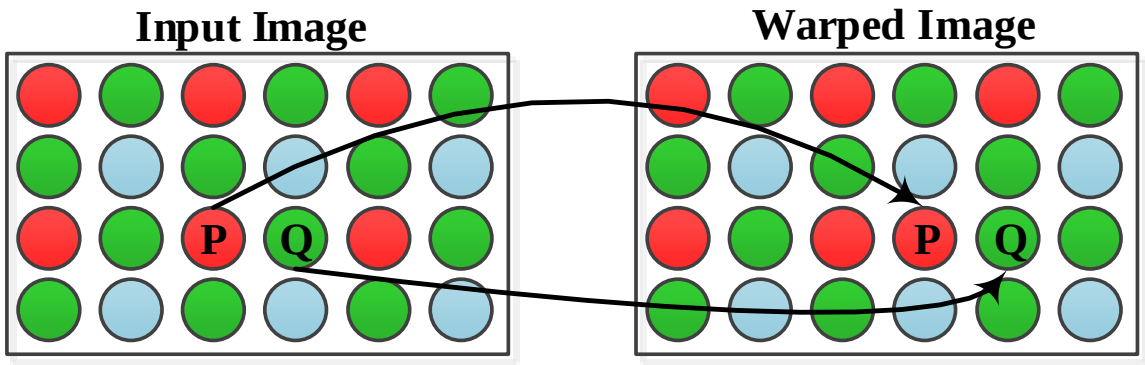
~~Conventional~~ Fusion System



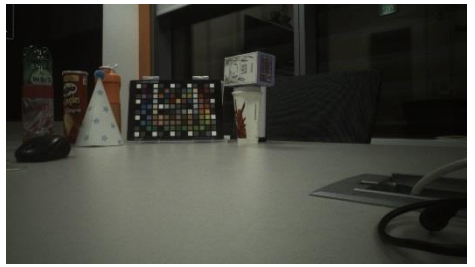
Bayer Domain (Bayer + Mono) Fusion System

Challenges in Bayer Domain Fusion

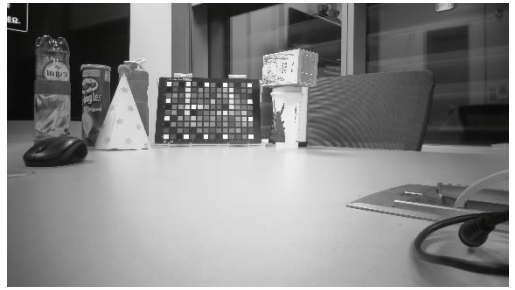
1



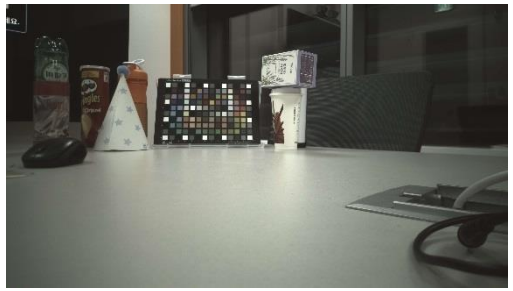
2



Color (YUV Domain)

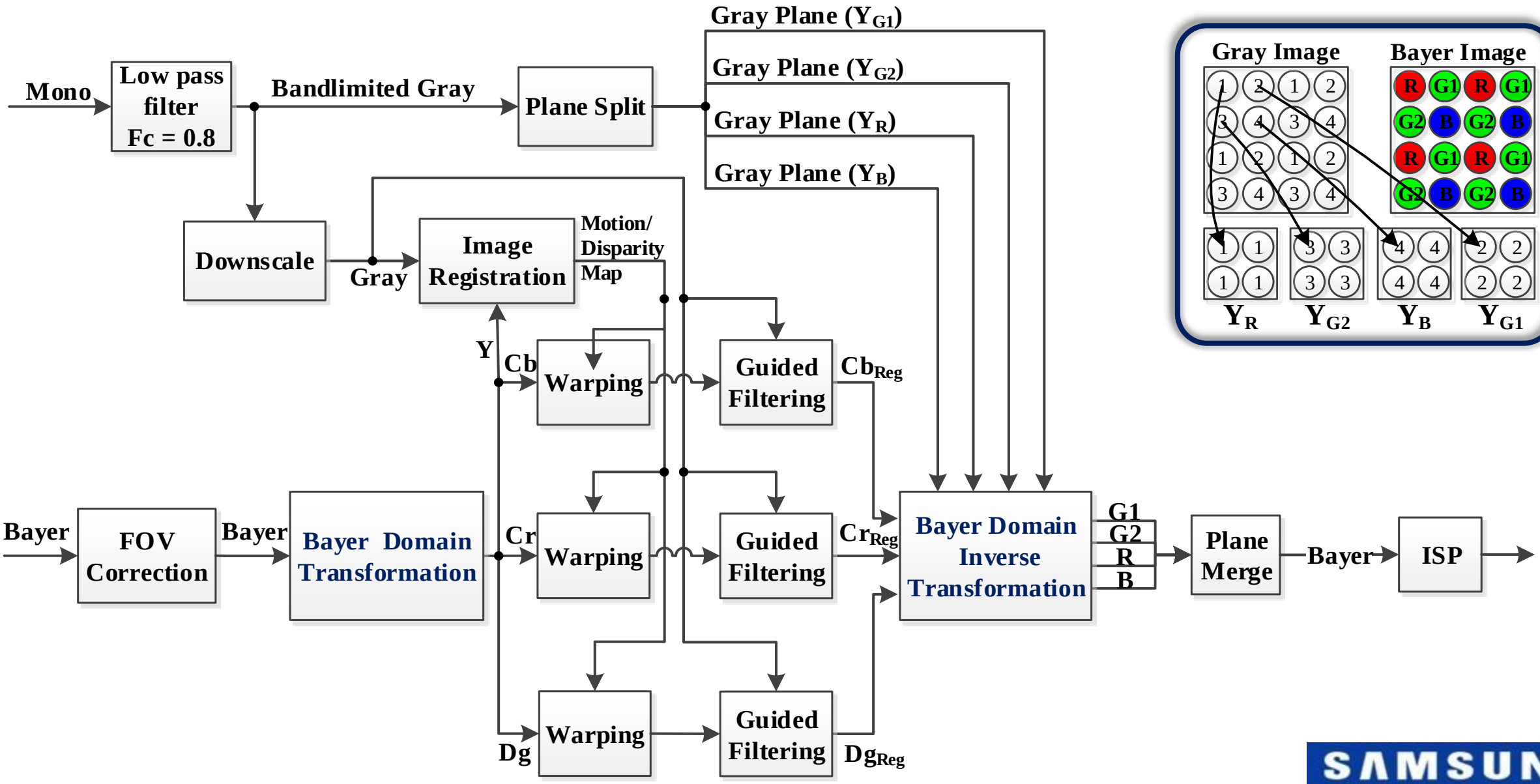


Monochrome



Fused Image

Proposed System



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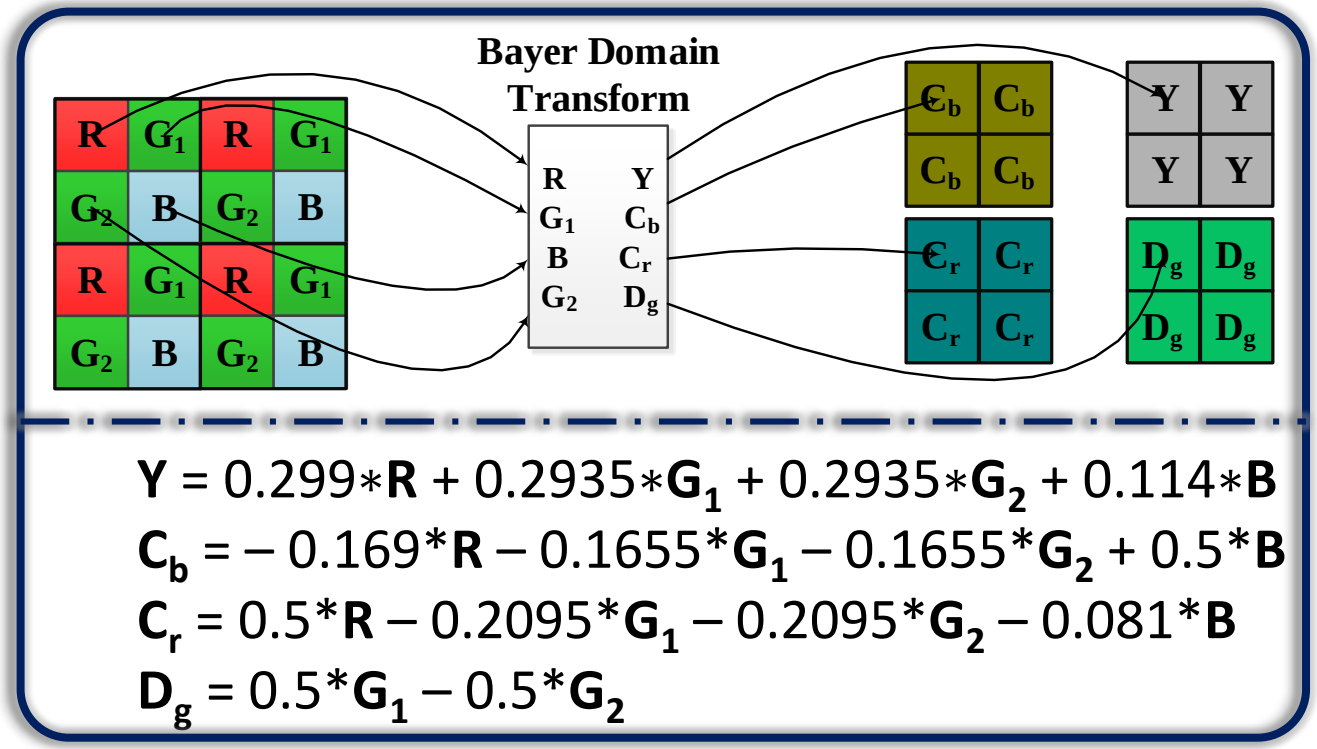
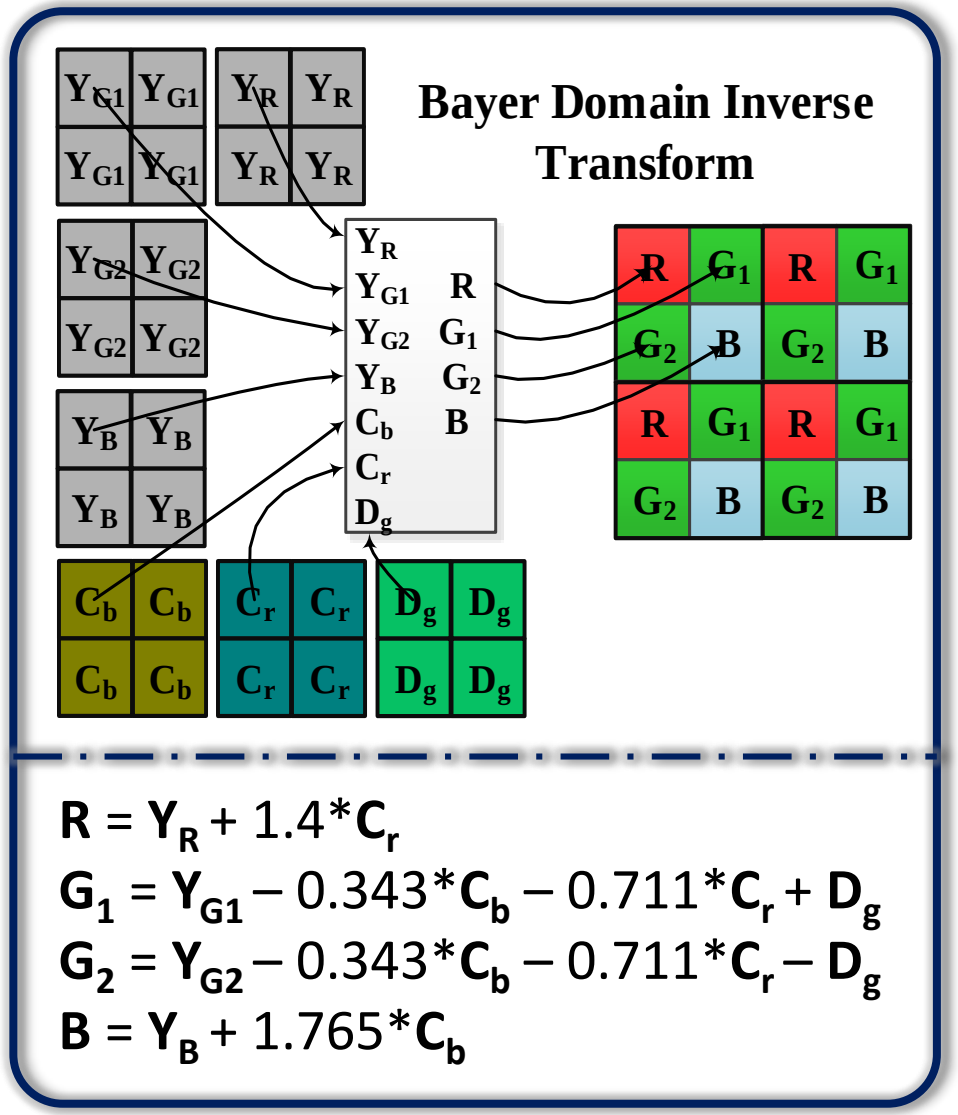
Transform



$$Y = 0.299*R + 0.2935*G_1 + 0.2935*G_2 + 0.114*B$$
$$C_b = -0.169*R - 0.1655*G_1 - 0.1655*G_2 + 0.5*B$$
$$C_r = 0.5*R - 0.2095*G_1 - 0.2095*G_2 - 0.081*B$$
$$D_g = 0.5*G_1 - 0.5*G_2$$



$$R = Y_R + 1.4*C_r$$
$$G_1 = Y_{G1} - 0.343*C_b - 0.711*C_r + D_g$$
$$G_2 = Y_{G2} - 0.343*C_b - 0.711*C_r - D_g$$
$$B = Y_B + 1.765*C_b$$

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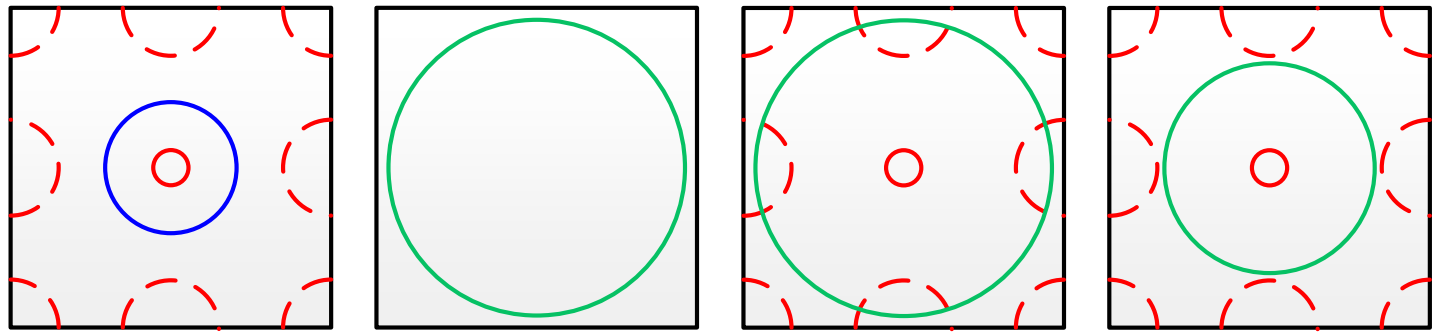
Challenges in Fusing Mono in Bayer Domain

Fused Image

without LPF of Mono

with LPF of Mono



(a) **(b)** **(c)** **(d)**

Idealized frequency spectrum of images from 2D-FFT of

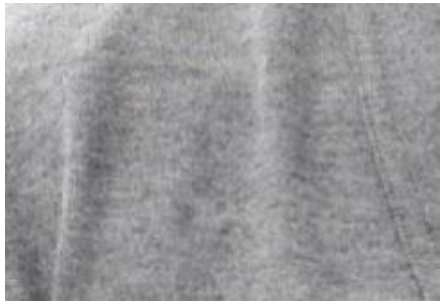
(a) Bayer image

(b) Mono image

(c) Fused image without low pass filtering of mono image

(d) Fused image with low pass filtering of mono image.

With downscaled mono



With phase-aligned mono

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Advantages

	Pixel operation required in	
	Conventional System	Proposed System
Feature Detection & Matching, Motion map generation etc.	$W\ x\ H$	$\frac{W\ x\ H}{4}$
Warping & guided filtering	$2\ x\ W\ x\ H$	$(3\ x\ \frac{W\ x\ H}{4})$
Total	$\boldsymbol{3\ x\ W\ x\ H}$	$\boldsymbol{W\ x\ H}$

Galaxy S6 device	Conventional system	Proposed system
Power consumed by ISPs	0.48 W	0.24 W
Total power consumed	2.96 W	2.72W

- Reduces required computations in fusion library by **~66.67%**
- Requires only one ISP as compared to requirement of two ISPs in conventional system, **~50%** savings at ISP IP-level
- No need of replicating blocks like white balance after fusion which is required in conventional system

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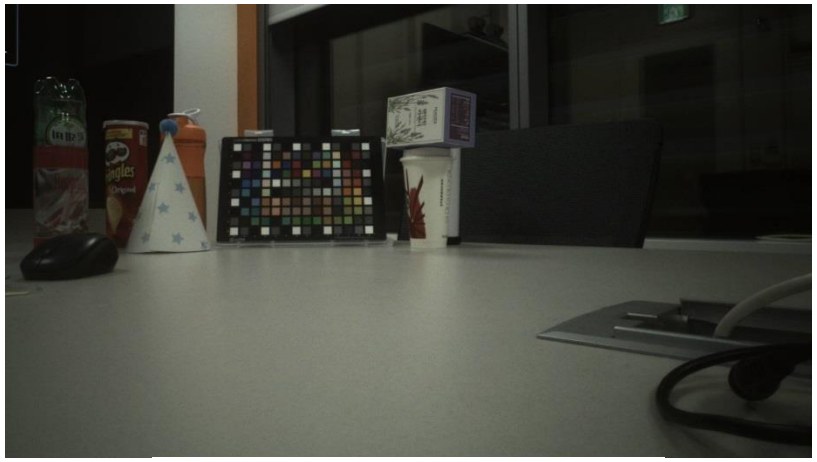
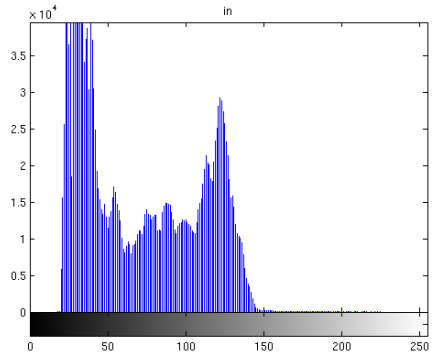
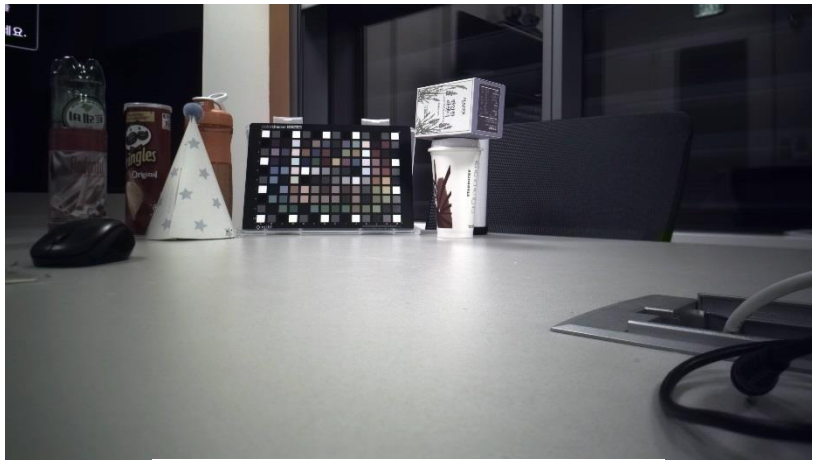
Results

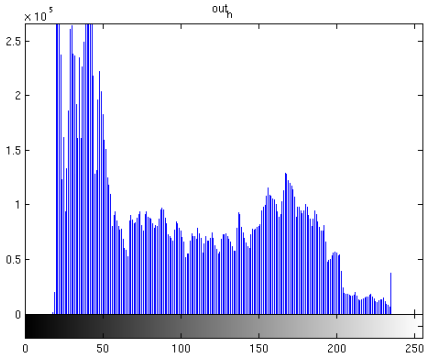
Our experimental dual camera setup has 16 MP Mono and 3.7 MP Bayer sensor with different FOV and 9 mm of baseline.



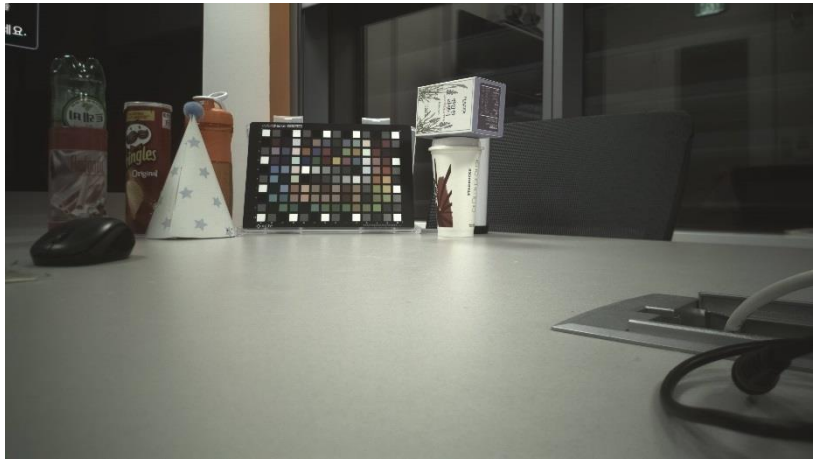


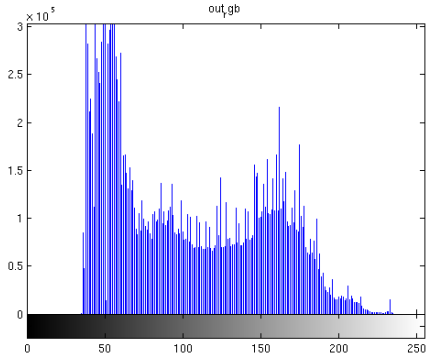
ISP processed Bayer sensor image





Proposed system output





Conventional system output

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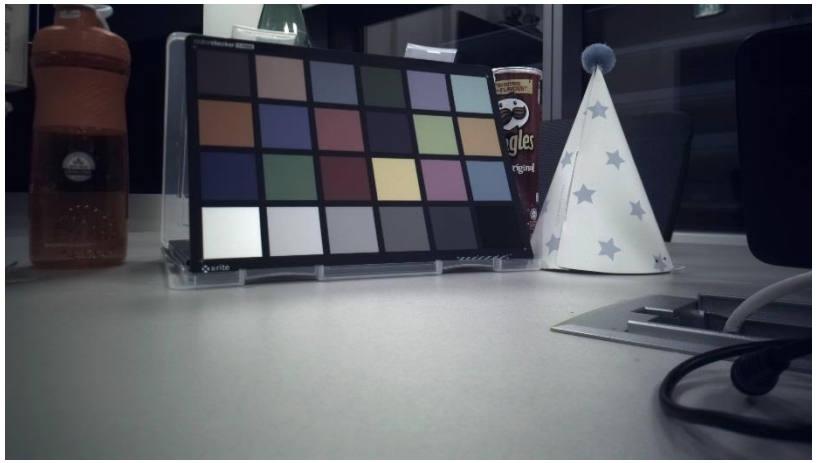
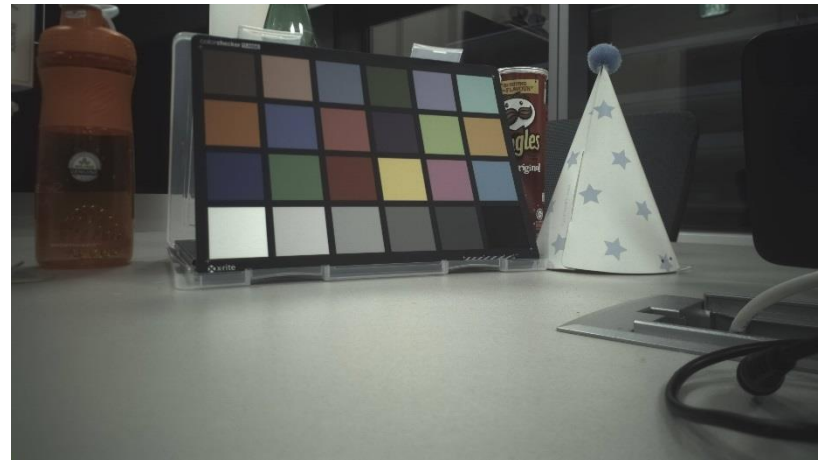
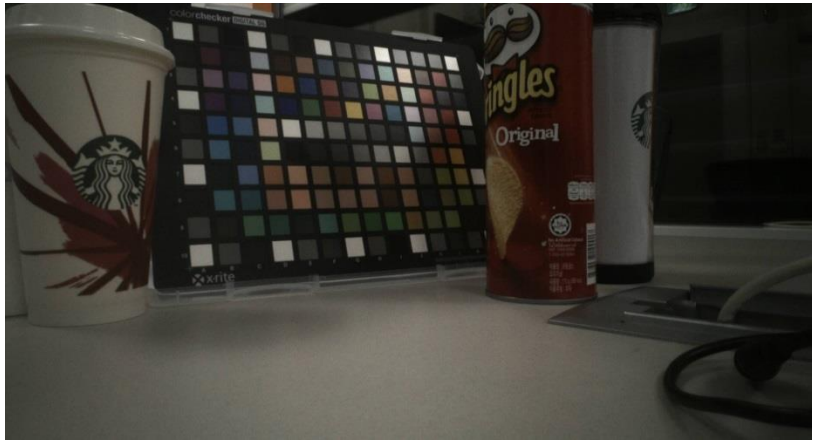
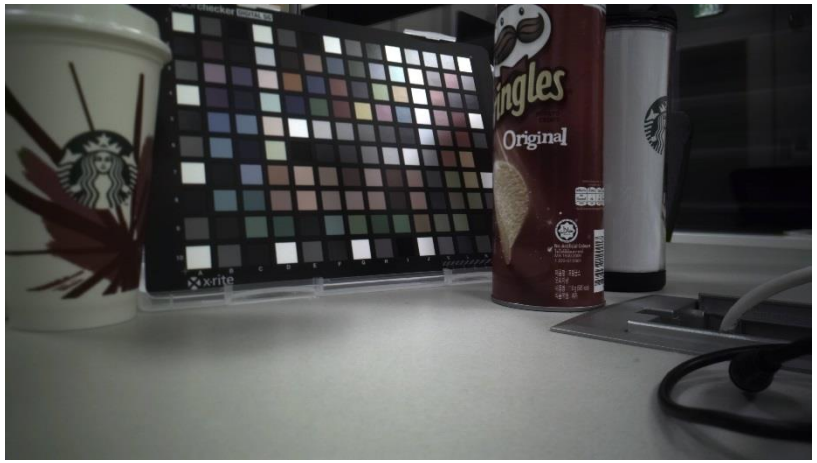
Results









ISP processed Bayer sensor image

Proposed system output

Conventional system output

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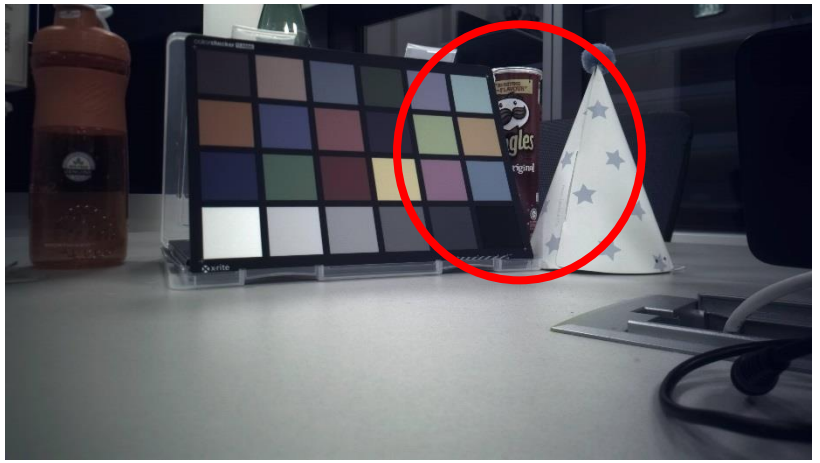
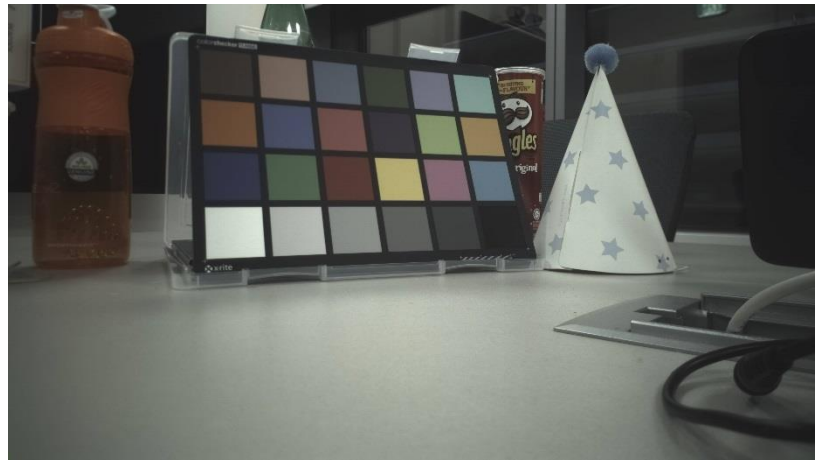
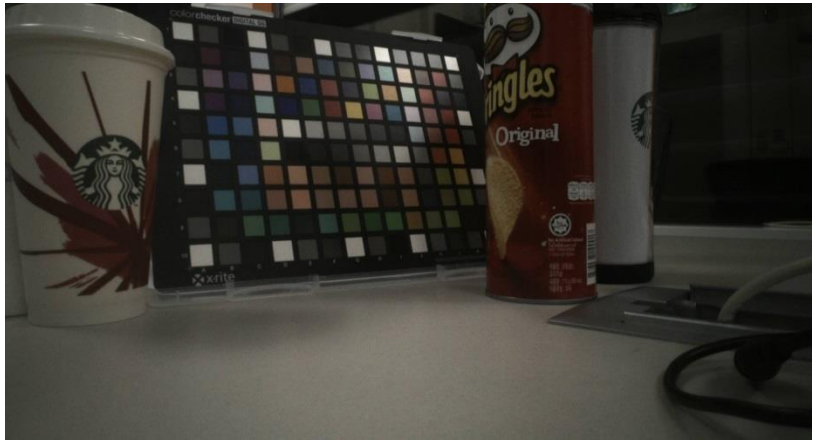
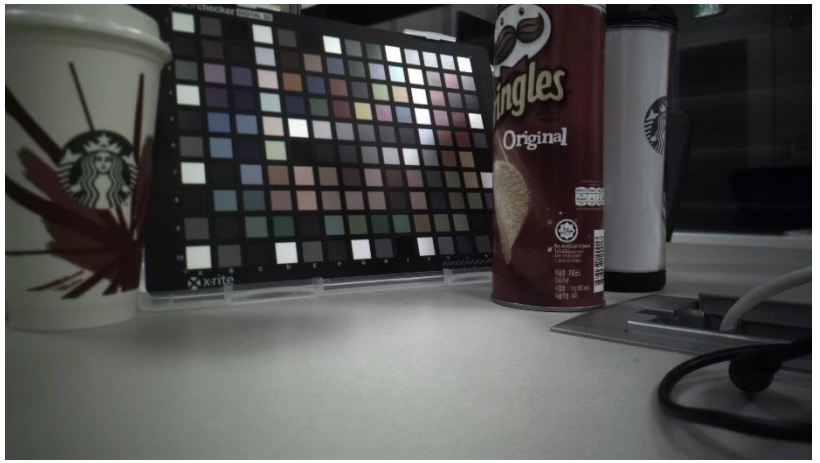
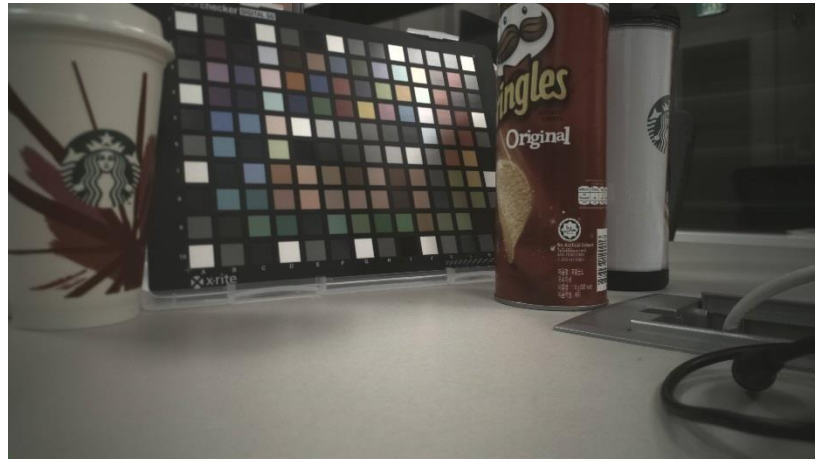
Results











ISP processed Bayer sensor image

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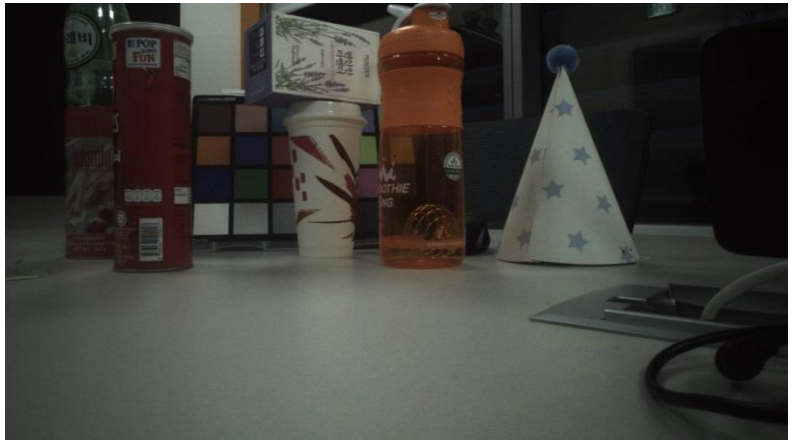

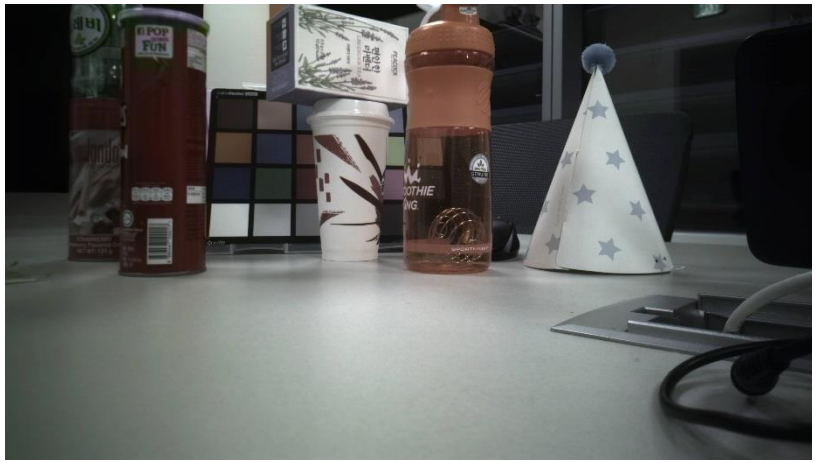

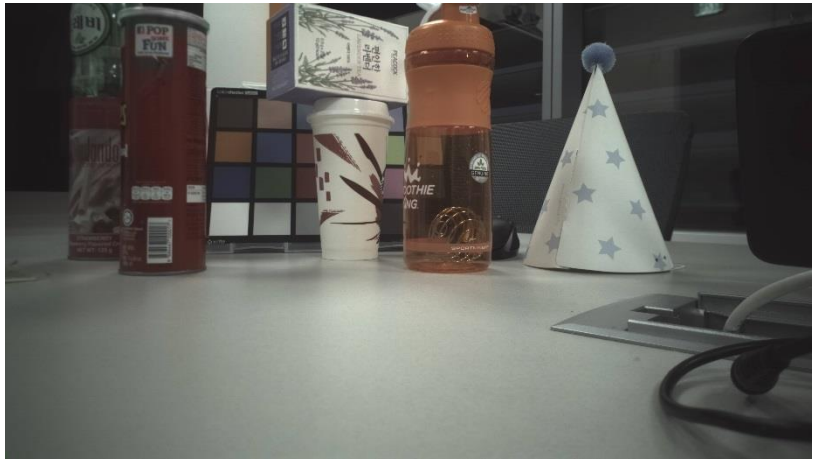

ISP processed Bayer sensor image

Proposed system output

Conventional system output

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THANK YOU