Zigzag Ordered Walsh Matrix for Compressed Sensing Image Sensor

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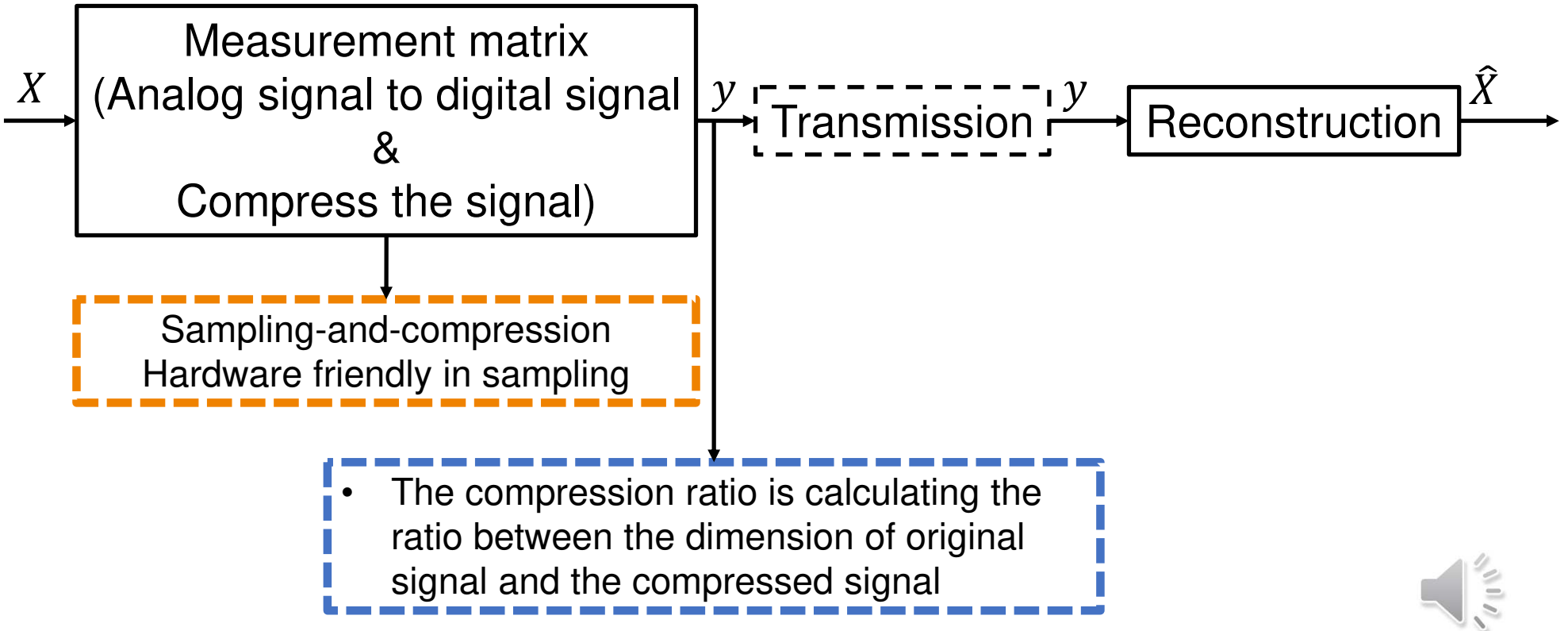
Guideline

- Introduction
- Proposals
- Experimental results

Introduction

I Introduction

The codec based on Compressed Sensing:



I Introduction

Classic measurement matrix：Hadamard and Walsh

they provide good sensing performance, fast reconstruction, and are hardware friendly

Problems of Hadamard and Walsh：

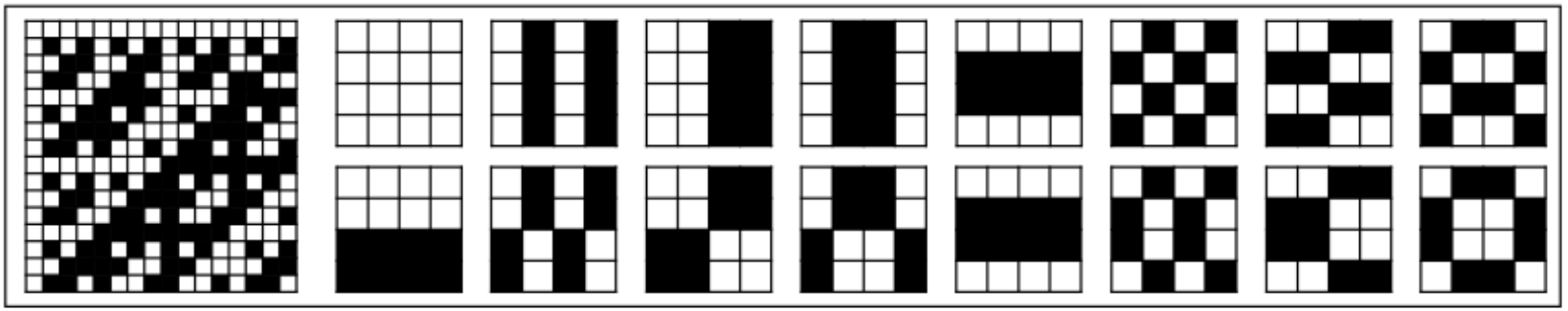
pretty poor image quality when further reduced sampling rates lower than 60%

To solve problems ：

related work: Russian-doll, Cake-cutting, GCS+S method

I Related work

example of Hadamard matrix patterns



Related work: Russian-doll, Cake-cutting, GCS+S method ：

investigate the effect of Hadamard and Walsh projection order selection on image reconstruction quality by simply reordering orthogonal matrices

Existing Problems ：

do not achieve better reconstructed image performance, especially at low SR

Proposals

Ⅱ Proposals

To solve problems ：

we design a measurement matrix that is hardware friendly and provides high-quality results under low sampling rates.

Hardware friendly → chose Walsh matrix

Provides high-quality results under low SR:

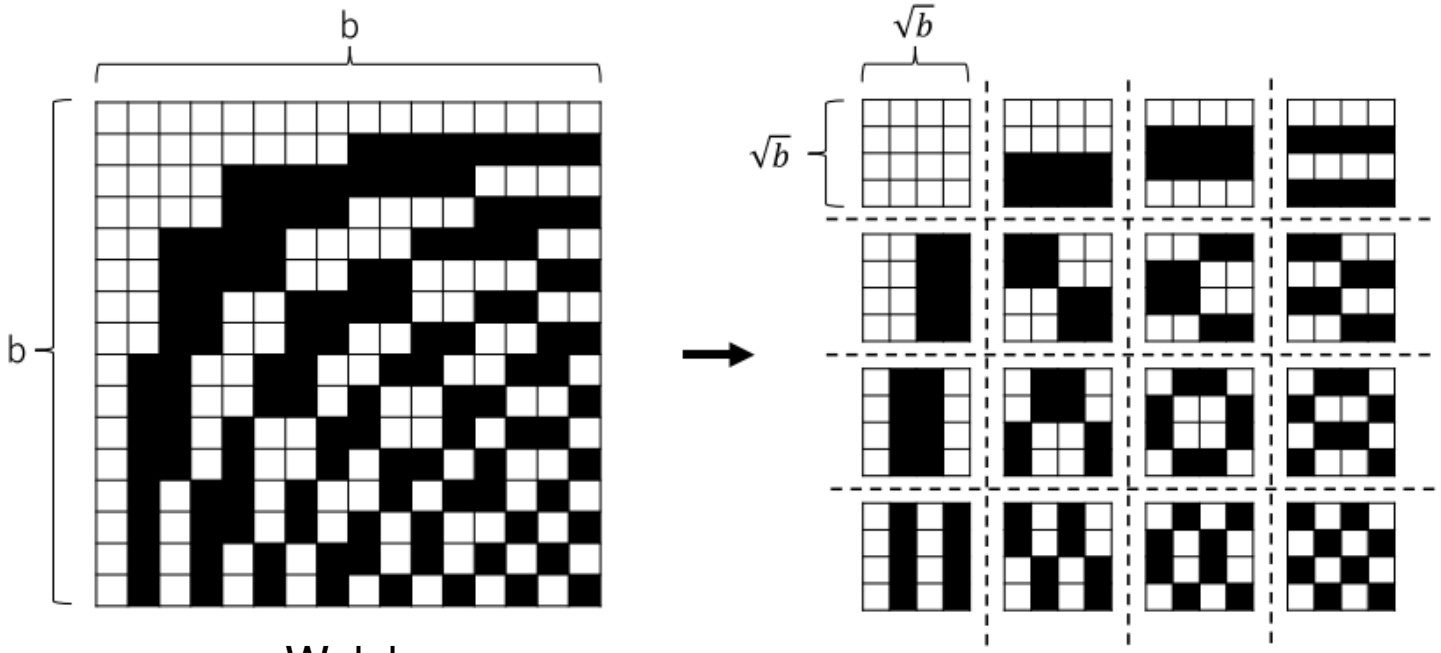
under various SR, remains the lowest frequency patterns which are the most critical patterns for determining the image quality

↓

Using zigzag to reorder the patterns of Walsh

The proposed matrix named Zigzag ordered Walsh (ZoW)

Ⅱ Proposals

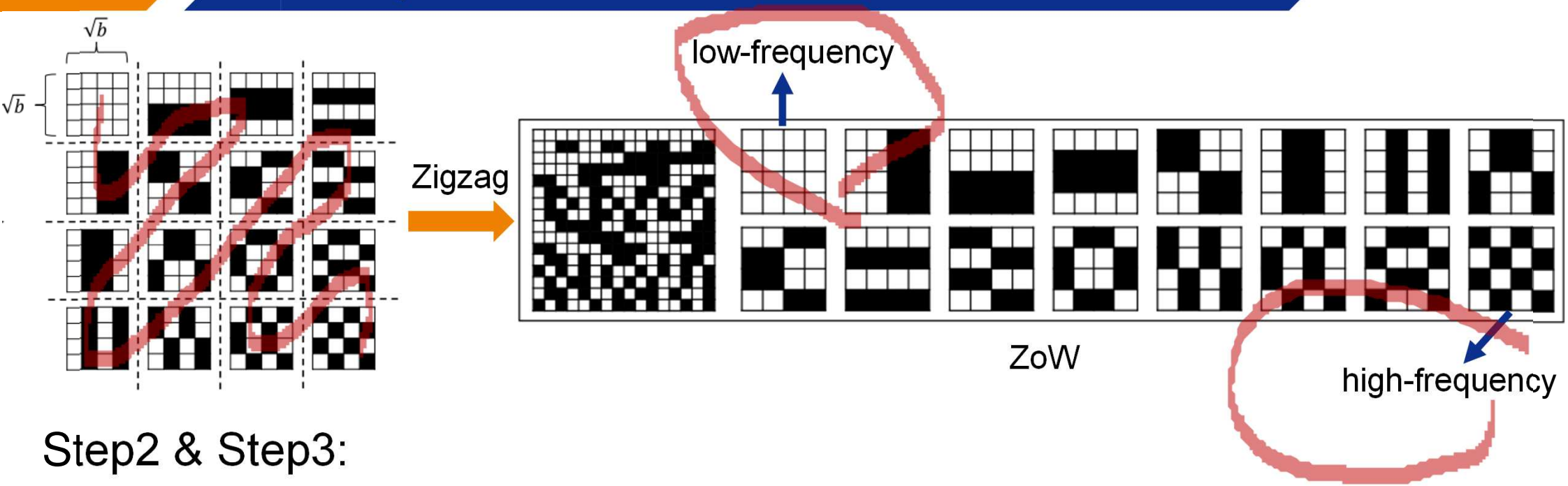


Walsh

Step1:

we partition the Walsh matrix into several measurement patterns, where the size of each piece is equal to $\sqrt{b} \times \sqrt{b}$

Ⅱ Proposals



Step2 & Step3:

apply zigzag scramble to the multiple pieces of Walsh matrix and vectorize each piece and stack it back into ZoW matrix

so that ZoW can extract features from low frequency components to high frequency components

Experimental Results

Ⅲ Experimental Results

Table 1: Recovery error via PSNR and SSIM comparisions of Toeplitz, Hadamard, Walsh, PoW and ZoW (this work), where $b = 16$ and SR $= 5\%$

Images	Toeplitz		Hadamard		Walsh		PoW		this work	
SR=5%	PSNR	SSIM	PSNR	SSIM	PSNR	SSIM	PSNR	SSIM	PSNR	SSIM
Monarch	15.54	0.11	16.98	0.27	17.31	0.30	17.33	0.30	**20.51**	**0.46**
Parrots	19.19	0.12	20.94	0.28	20.68	0.25	20.68	0.24	**23.62**	**0.39**
barbara	19.04	0.11	21.16	0.33	20.07	0.21	20.08	0.22	**22.74**	**0.39**
boats	18.22	0.07	19.83	0.26	20.87	0.24	20.90	0.25	**23.57**	**0.37**
cameraman	17.66	0.08	19.65	0.19	18.87	**0.29**	18.86	0.28	**21.44**	**0.29**
foreman	21.80	0.11	22.80	0.23	24.63	0.32	24.67	0.33	**28.01**	**0.41**
house	20.42	0.08	21.80	0.19	22.93	0.25	22.93	0.24	**25.64**	**0.28**
lena	19.09	0.12	21.78	0.36	19.74	0.17	19.74	0.17	**23.66**	**0.42**
Average	18.87	0.10	20.62	0.26	20.64	0.25	20.65	0.25	**23.65**	**0.38**

Ⅲ Experimental Results

Table 2: Recovery error via PSNR and SSIM comparisions of Toeplitz, Hadamard, Walsh, PoW and ZoW (this work), where $b = 16$ and SR $= 10\%$

Images	Toeplitz		Hadamard		Walsh		PoW		this work	
SR=10%	PSNR	SSIM	PSNR	SSIM	PSNR	SSIM	PSNR	SSIM	PSNR	SSIM
Monarch	16.01	0.17	17.06	0.29	17.49	0.33	19.83	0.47	**22.36**	**0.58**
Parrots	19.72	0.18	21.02	0.31	20.85	0.28	22.88	0.39	**25.15**	**0.49**
barbara	19.58	0.19	21.29	0.36	20.14	0.24	22.05	0.36	**23.48**	**0.50**
boats	18.95	0.16	20.02	0.31	21.01	0.27	23.13	0.38	**25.59**	**0.50**
cameraman	18.23	0.14	19.86	0.25	19.00	0.35	20.64	0.40	**23.01**	**0.42**
foreman	22.06	0.16	22.84	0.25	24.84	0.37	27.79	0.47	**29.59**	**0.52**
house	20.93	0.15	22.02	0.25	23.22	0.35	25.62	0.38	**27.80**	**0.41**
lena	20.04	0.21	21.96	0.41	19.81	0.19	21.88	0.32	**25.17**	**0.53**
Average	19.44	0.17	20.76	0.30	20.80	0.30	22.98	0.40	**25.27**	**0.49**

Ⅲ Experimental Results

Table 3: Recovery error via PSNR and SSIM comparisions of Toeplitz, Hadamard, Walsh, PoW and ZoW (this work), where $b = 16$ and SR $= 15\%$

Images	Toeplitz		Hadamard		Walsh		PoW		this work	
SR=15%	PSNR	SSIM	PSNR	SSIM	PSNR	SSIM	PSNR	SSIM	PSNR	SSIM
Monarch	16.22	0.21	17.13	0.30	21.67	0.57	20.70	0.55	**23.98**	**0.68**
Parrots	20.08	0.22	21.10	0.32	24.33	0.46	23.90	0.48	**26.47**	**0.60**
barbara	19.93	0.24	21.36	0.37	22.78	0.43	22.69	0.44	**24.46**	**0.62**
boats	19.47	0.20	20.09	0.32	24.31	0.46	24.00	0.45	**27.28**	**0.61**
cameraman	18.57	0.19	19.96	0.28	21.94	0.47	21.44	0.47	**24.29**	**0.51**
foreman	22.12	0.18	22.94	0.26	29.23	0.54	29.05	0.55	**31.29**	**0.62**
house	21.60	0.20	22.09	0.27	27.11	0.49	26.61	0.48	**29.42**	**0.51**
lena	20.50	0.26	22.03	0.42	23.51	0.43	22.78	0.42	**26.82**	**0.66**
Average	19.81	0.21	20.84	0.32	24.36	0.48	23.90	0.48	**26.75**	**0.60**


SR=5%
SR= 10%
SR= 15%
SR=5%
SR= 10%
SR= 15%
Toeplitz
PSNR: 20.42
SSIM: 0.08
PSNR: 20.93
SSIM: 0.15
PSNR: 21.60
SSIM: 0.20
PSNR: 21.80
SSIM: 0.11
PSNR: 22.06
SSIM: 0.16
PSNR: 22.12
SSIM: 0.18
Hadamard
PSNR: 21.80
SSIM: 0.19
PSNR: 22.02
SSIM: 0.25
PSNR: 22.09
SSIM: 0.27
PSNR: 22.80
SSIM: 0.23
PSNR: 22.84
SSIM: 0.25
PSNR: 22.94
SSIM: 0.26
Walsh
PSNR: 22.93
SSIM: 0.25
PSNR: 23.22
SSIM: 0.35
PSNR: 27.11
SSIM: 0.49
PSNR: 24.63
SSIM: 0.32
PSNR: 24.84
SSIM: 0.37
PSNR: 29.23
SSIM: 0.54
PoW
PSNR: 22.93
SSIM: 0.24
PSNR: 25.62
SSIM: 0.38
PSNR: 26.61
SSIM: 0.48
PSNR: 24.67
SSIM: 0.33
PSNR: 27.79
SSIM: 0.47
PSNR: 29.05
SSIM: 0.55
this work
PSNR: 25.64
SSIM: 0.28
PSNR: 27.80
SSIM: 0.41
PSNR: 29.42
SSIM: 0.51
PSNR: 28.01
SSIM: 0.41
PSNR: 29.59
SSIM: 0.52
PSNR: 31.29
SSIM: 0.62

Ⅲ Experimental Results

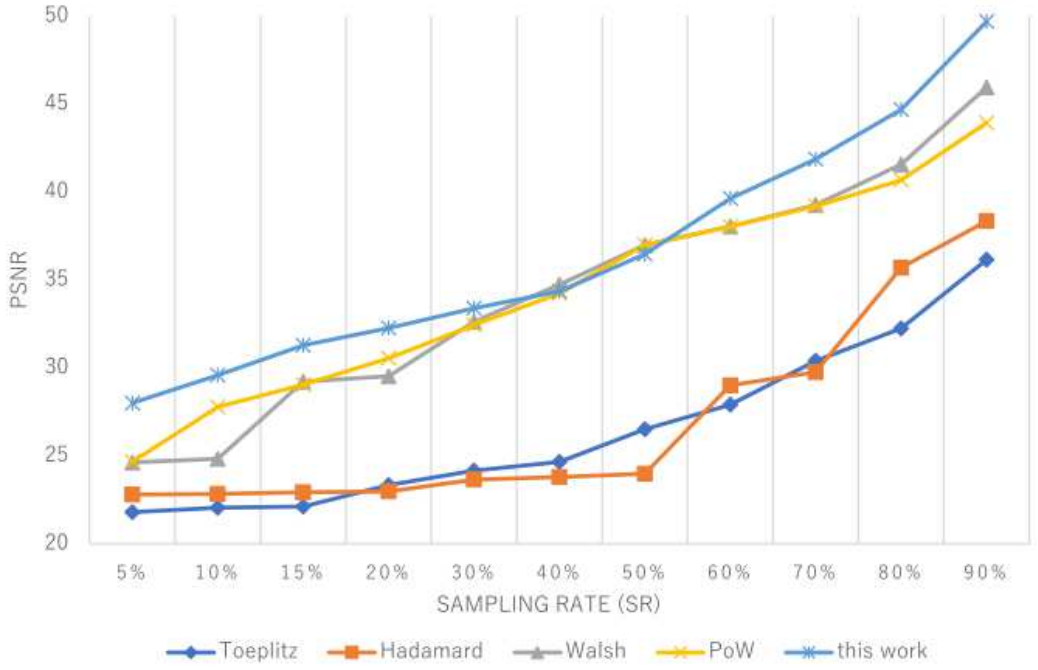


Figure 5: Comparison of recovery error via PSNR of Torplitz, Hadamard, Walsh, PoW and ZoW (this work), where $b = 16, n = b \times b = 256$, and $SR \in \{5\%, 10\%, 15\%, .., 90\%\}$.

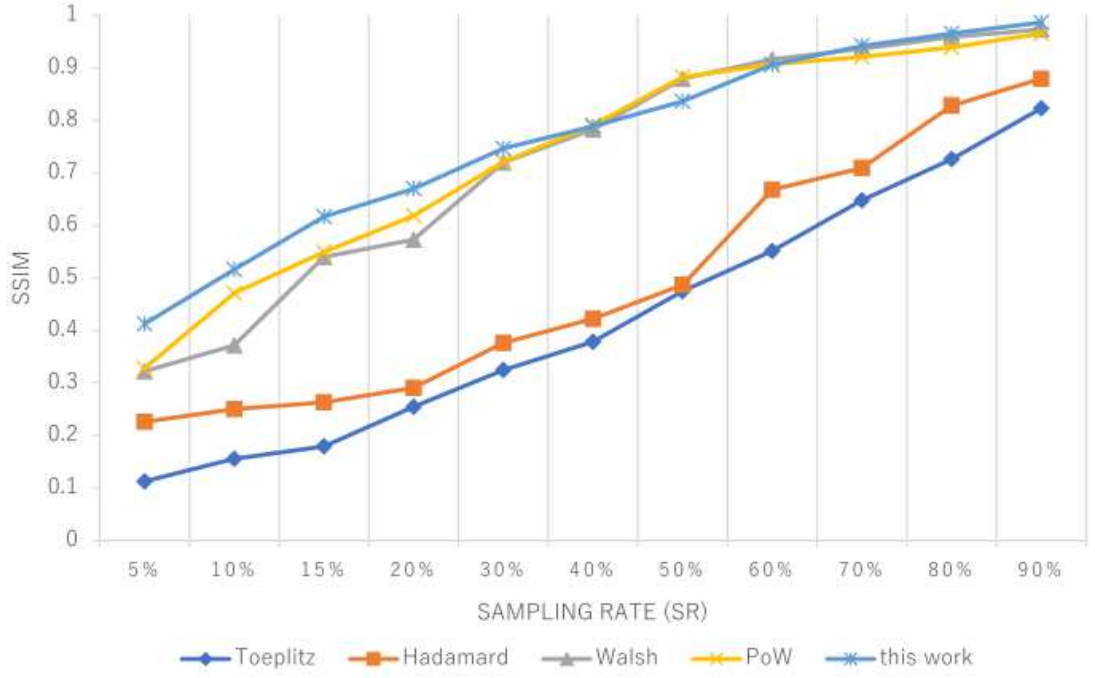


Figure 6: Comparison of recovery error via SSIM of Torplitz, Hadamard, Walsh, PoW and ZoW (this work), where $b = 16, n = b \times b = 256$, and $SR \in \{5\%, 10\%, 15\%, .., 90\%\}$.

Conclusion

Ⅳ Conclusion

- The Walsh matrix provides good sensing performance and high reconstruction efficiency with hardware friendly

- we proposed a new structured measurement matrix called the Zigzag ordered Walsh matrix (ZoW) by using zigzag to reorder the patterns of Walsh

- the low-frequency patterns are in the upper-left corner, and the frequency increases according to the zigzag scan order so that under various sampling rates ZoW can extract features from low frequency components to high frequency components.

Thank you

For your listening

法政大学
HOSEI University