

## Wavefront shaping with a Hadamard basis for scattering soil imaging: supplement

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During the adaptive stochastic parallel gradient descent (ASPGD) optimization, the learning rate  $\alpha$  and the amplitude of random perturbations  $|\delta u^k|$  are critical to the optimization performance. They must be carefully chosen in order to obtain the optimal optimization performance. A value that is too small leads to painfully slow convergence, while a value that is too large can hinder convergence or even cause divergence. The parameter setting for the experimental results in Fig. 6 is listed in Table S1.

**Table S1. Parameter setting for the experimental results in Fig. 6**

Modes	$\alpha$	$ \delta u^k $
Hadamard 0-60	5	2
Hadamard 61-120	3	2
Hadamard 121-180	3	2
Hadamard 181-240	2	2
Hadamard 241-300	2	1.6
Pixel basis	0.06	0.05

To verify the repeatability of our method, we repeated the experiments for multiple times on the similar soil mineral samples, whose optimization evolution curves are plotted in Fig. S1. It successfully demonstrates the repeatability of our method with majority of the experimental results showing the obvious advantages of using Hadamard basis. For the results from repeated experiment 1 shown in Fig. S1(a), optimization with pixel basis performs unexpectedly well and the optimization with Hadamard basis just shows a marginal advantage. One of the possible reasons is that the phase map of the soil mineral sample in repeated experiment 1 contains less low spatial frequencies thus optimizing Hadamard modes with low spatial frequencies doesn't provide a rapid progress of the improvement of the performance metric. It can also be due to the sub-optimal parameter setting for Hadamard basis.

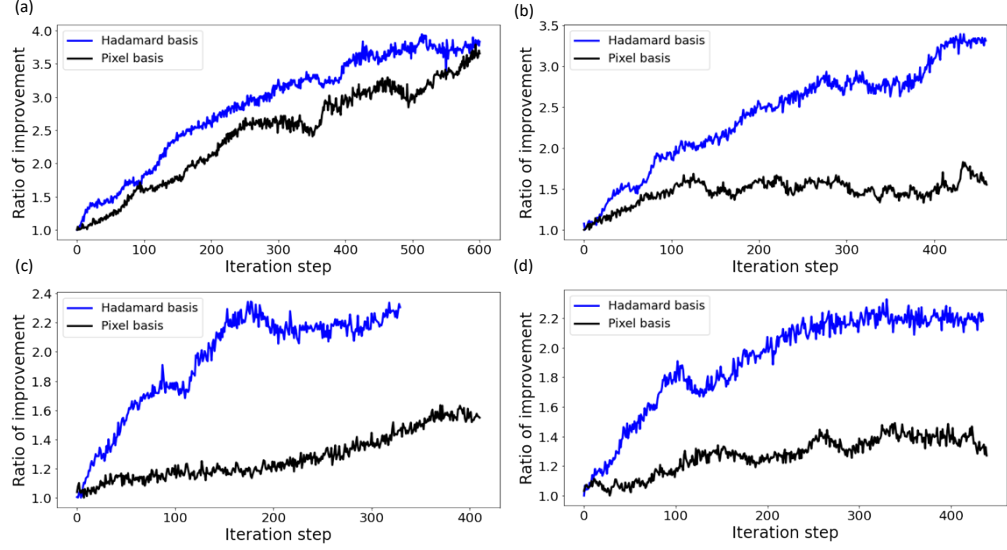


Fig. S1. The optimization evolution curves. (a). Repeated experiment 1. (b). Repeated experiment 2. (c). Repeated experiment 3. (d). Repeated experiment 4.

The found optimal parameter setting for the repeated experimental results in Fig. S1 is listed in Table S2. The optimal parameter setting varies for each experiment, which depend on the initial intensity distribution before optimization, the soil mineral sample under test and its optical aberration and scattering characteristics.

**Table S2. Parameter setting for the repeated experimental results in Fig. S1**

Modes	Repeated Exp 1		Repeated Exp 2		Repeated Exp 3		Repeated Exp 4	
	$\alpha$	$ \delta u^k $	$\alpha$	$ \delta u^k $	$\alpha$	$ \delta u^k $	$\alpha$	$ \delta u^k $
Hadamard 0-60	6	3	8	3	7	3	5	3
Hadamard 61-120	4	3	4	4	3	3	2	3
Hadamard 121-180	2.8	2.4						
Hadamard 181-240	2	2						
Hadamard 241-300	1.6	1.6	1.6	4.5	0.8	3	1	3
Pixel basis	0.06	0.05	0.07	0.05	0.04	0.05	0.05	0.05