

Supplementary Material

Inversion Model of GPR Imaging Characteristics of Point Objects and Fracture Detection of Heritage building

Gao Lv¹, Ning Li^{1,2}, Jie Yang^{1,3}, Xianchun Yao², Dexiu Hu^{1,3}, Rixuan Pang⁴

(1. Institute of Water Resources and Hydro-electric Engineering, Xi'an University of Technology, Xi'an, 710048, China.

2. Institute of Geotechnical Engineering, Xi'an university of Technology, Xi'an, 710048, China.

3. State Key Laboratory Base of Eco-hydraulic Engineering in Arid Area, Xi'an University of Technology, Xi'an, Shaanxi 710048, China.

4. Geochemical exploration team of Shaanxi geological mineral survey group, Xi'an, 710023, China)

According to the radius and depth of the object in the forward model and the imaging depth information, the depth of the object and two-way travel time could be converted as Formula S1.

Formula S1.
$$h = \frac{c}{\sqrt{\epsilon_r}} \cdot \frac{t}{2}$$

Where: c is the propagation speed of light. t is two-way travel time of electromagnetic wave. h is depth of object. ϵ_r is relative permittivity of geological background.

Figure S1

GETDATA obtains the key point coordinates by taking points continuously at the maximum amplitude of the reflection curve in the image as shown in Figure S1.

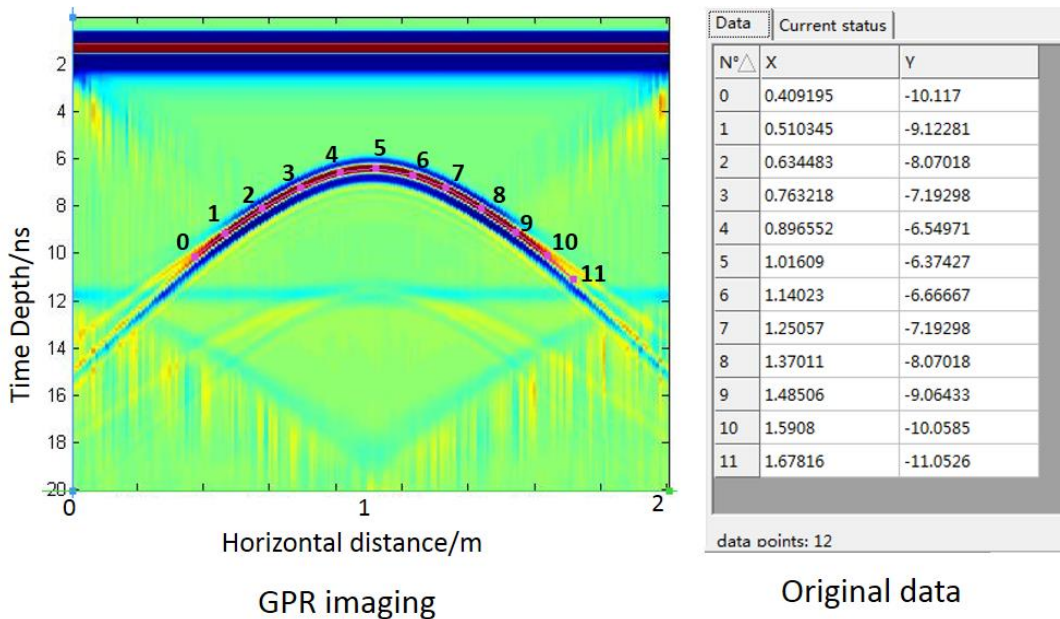


Figure S1. Node extraction of hyperbolic imaging by GetData

GetData Graph Digitizer 2.24 software (<http://getdata-graph-digitizer.com/>) was applied to digitize and extract data. It's a convenient and efficient way to extract data precisely.

After the manual sampling, the coordinates of the objects with different radius are obtained as shown in Table S1:

Table S1. Data of the GPR imaging with different object radius

r=0.005 m		r=0.025 m		r=0.050 m		r=0.100 m	
horizontal /m	vertical/ns	horizontal /m	vertical/ ns	horizontal /m	vertical/ ns	horizontal /m	vertical/ ns
0.597	7.894	0.597	7.485	0.514	8.011	0.413	9.181
0.661	7.076	0.670	6.725	0.593	7.309	0.550	7.543
0.749	6.256	0.744	6.022	0.694	6.432	0.684	6.432
0.831	5.613	0.818	5.496	0.781	5.730	0.795	5.613
0.919	5.204	0.926	5.145	0.882	5.204	0.882	5.028
0.952	5.087	0.988	4.912	0.956	4.912	0.974	4.912
0.979	4.997	1.006	4.763	0.996	4.822	1.093	4.880
1.098	5.028	1.108	4.853	1.080	4.970	1.117	4.911
1.218	5.555	1.204	5.262	1.158	5.321	1.209	5.145
1.310	6.315	1.278	5.847	1.250	5.906	1.287	5.789
1.379	7.193	1.351	6.608	1.347	6.666	1.370	6.549
1.452	7.777	1.411	7.076	1.425	7.368	1.457	7.251
1.521	8.480	1.489	7.719	1.498	8.187	1.636	8.948

The coordinates of the objects with different radius are transformed by coordinate translation as shown in Table S2:

Table S2. Transfer data of the GPR imaging with different object radius

r=0.005 m		r=0.025 m		r=0.050 m		r=0.100 m	
horizontal /m	vertical/m	horizontal /m	vertical/ m	horizontal /m	vertical/ m	horizontal /m	vertical/ m
-0.40	-0.53	-0.40	-0.50	-0.49	-0.54	-0.59	-0.62
-0.34	-0.47	-0.33	-0.45	-0.41	-0.49	-0.45	-0.51
-0.25	-0.42	-0.26	-0.40	-0.31	-0.43	-0.32	-0.43
-0.17	-0.38	-0.18	-0.37	-0.22	-0.38	-0.21	-0.38
-0.08	-0.35	-0.07	-0.35	-0.12	-0.35	-0.12	-0.34
-0.05	-0.34	-0.01	-0.33	-0.04	-0.33	-0.03	-0.33
-0.02	-0.34	0.01	-0.32	0.00	-0.32	0.09	-0.33
0.10	-0.34	0.11	-0.33	0.08	-0.33	0.12	-0.33
0.22	-0.37	0.20	-0.35	0.16	-0.36	0.21	-0.35
0.31	-0.42	0.28	-0.39	0.25	-0.40	0.29	-0.39
0.38	-0.48	0.35	-0.44	0.35	-0.45	0.37	-0.44
0.45	-0.52	0.41	-0.47	0.43	-0.49	0.46	-0.49
0.52	-0.57	0.49	-0.52	0.50	-0.55	0.64	-0.60

After the manual sampling, the coordinates of the objects with different depth are obtained as shown in Table S3:

Table S3. Data of the GPR imaging with different object depth

h= 0.05 m		h= 0.1 m		h = 0.2 m		h = 0.3 m	
horizontal/m	vertical/ns	horizontal/m	vertical/ns	horizontal /m	vertical/ns	horizontal /m	vertical/ns
0.75	3.39	0.69	4.39	0.60	6.20	0.51	8.01
0.81	2.81	0.75	3.74	0.69	5.38	0.59	7.31
0.87	2.16	0.82	3.16	0.76	4.74	0.69	6.43
0.92	1.58	0.89	2.40	0.84	4.09	0.78	5.73
1.00	1.23	0.96	1.99	0.91	3.57	0.88	5.20
1.07	1.46	1.00	1.93	1.00	3.39	0.96	4.91
1.13	2.11	1.05	1.99	1.09	3.57	1.01	4.85

1.20	2.81	1.11	2.40	1.16	4.04	1.08	4.97
1.25	3.33	1.16	2.87	1.24	4.62	1.16	5.32
		1.20	3.27	1.31	5.26	1.25	5.91
		1.26	3.80	1.38	6.02	1.35	6.67
		1.31	4.39			1.43	7.37
						1.50	8.19

Table S3. Data of the GPR imaging with different object depth

h= 0.4 m		h= 0.5 m		h = 0.6 m	
horizontal/m	vertical/ns	horizontal/m	vertical/ns	horizontal /m	vertical/ns
0.41	10.12	0.34	11.87	0.21	14.15
0.51	9.12	0.41	11.11	0.34	12.86
0.63	8.07	0.51	10.23	0.45	11.92
0.76	7.19	0.61	9.47	0.57	11.05
0.90	6.55	0.73	8.71	0.70	10.23
1.02	6.37	0.86	8.13	0.86	9.53
1.14	6.67	0.97	7.89	1.00	9.36
1.25	7.19	1.03	7.84	1.12	9.47
1.37	8.07	1.13	8.07	1.26	10.00
1.49	9.06	1.24	8.48	1.40	10.82
1.59	10.06	1.32	8.95	1.51	11.58
1.68	11.05	1.40	9.53	1.61	12.46
0.41	10.12	1.48	10.12	1.78	13.92
		1.55	10.76		
		1.64	11.52		
		1.72	12.34		

The coordinates of the objects with different depth are transformed by coordinate translation as shown in Table S4:

Table S4. Transfer data of the GPR imaging with different object depth

h= 0.05 m		h= 0.1 m		h = 0.2 m		h = 0.3 m	
horizontal/m	vertical/m	horizontal/m	vertical/m	horizontal /m	vertical/m	horizontal /m	vertical/m
-0.25	-0.23	-0.31	-0.29	-0.40	-0.42	-0.49	-0.54
-0.19	-0.19	-0.25	-0.25	-0.32	-0.36	-0.41	-0.49
-0.13	-0.15	-0.18	-0.21	-0.24	-0.32	-0.31	-0.43
-0.08	-0.11	-0.11	-0.16	-0.16	-0.27	-0.22	-0.38
0.00	-0.08	-0.04	-0.13	-0.09	-0.24	-0.12	-0.35
0.07	-0.10	0.00	-0.13	0.00	-0.23	-0.04	-0.33
0.13	-0.14	0.05	-0.13	0.09	-0.24	0.01	-0.33
0.20	-0.19	0.11	-0.16	0.16	-0.27	0.08	-0.33
0.25	-0.23	0.16	-0.19	0.24	-0.31	0.16	-0.36
		0.20	-0.22	0.31	-0.35	0.25	-0.40
		0.26	-0.25	0.38	-0.40	0.35	-0.45
		0.31	-0.29			0.43	-0.49
						0.50	-0.55

Table S4. Transfer data of the GPR imaging with different object depth

h= 0.4 m		h= 0.5 m		h = 0.6 m	
horizontal/m	vertical/m	horizontal/m	vertical/m	horizontal /m	vertical/m
-0.59	-0.68	-0.67	-0.80	-0.79	-0.95
-0.49	-0.61	-0.59	-0.75	-0.67	-0.86
-0.37	-0.54	-0.49	-0.69	-0.56	-0.80
-0.24	-0.48	-0.39	-0.64	-0.43	-0.74
-0.10	-0.44	-0.27	-0.58	-0.30	-0.69
0.02	-0.43	-0.15	-0.55	-0.15	-0.64
0.14	-0.45	-0.04	-0.53	0.00	-0.63
0.25	-0.48	0.02	-0.53	0.12	-0.64
0.37	-0.54	0.13	-0.54	0.26	-0.67
		0.24	-0.57	0.40	-0.73
		0.32	-0.60	0.51	-0.78
		0.40	-0.64		
		0.48	-0.68		