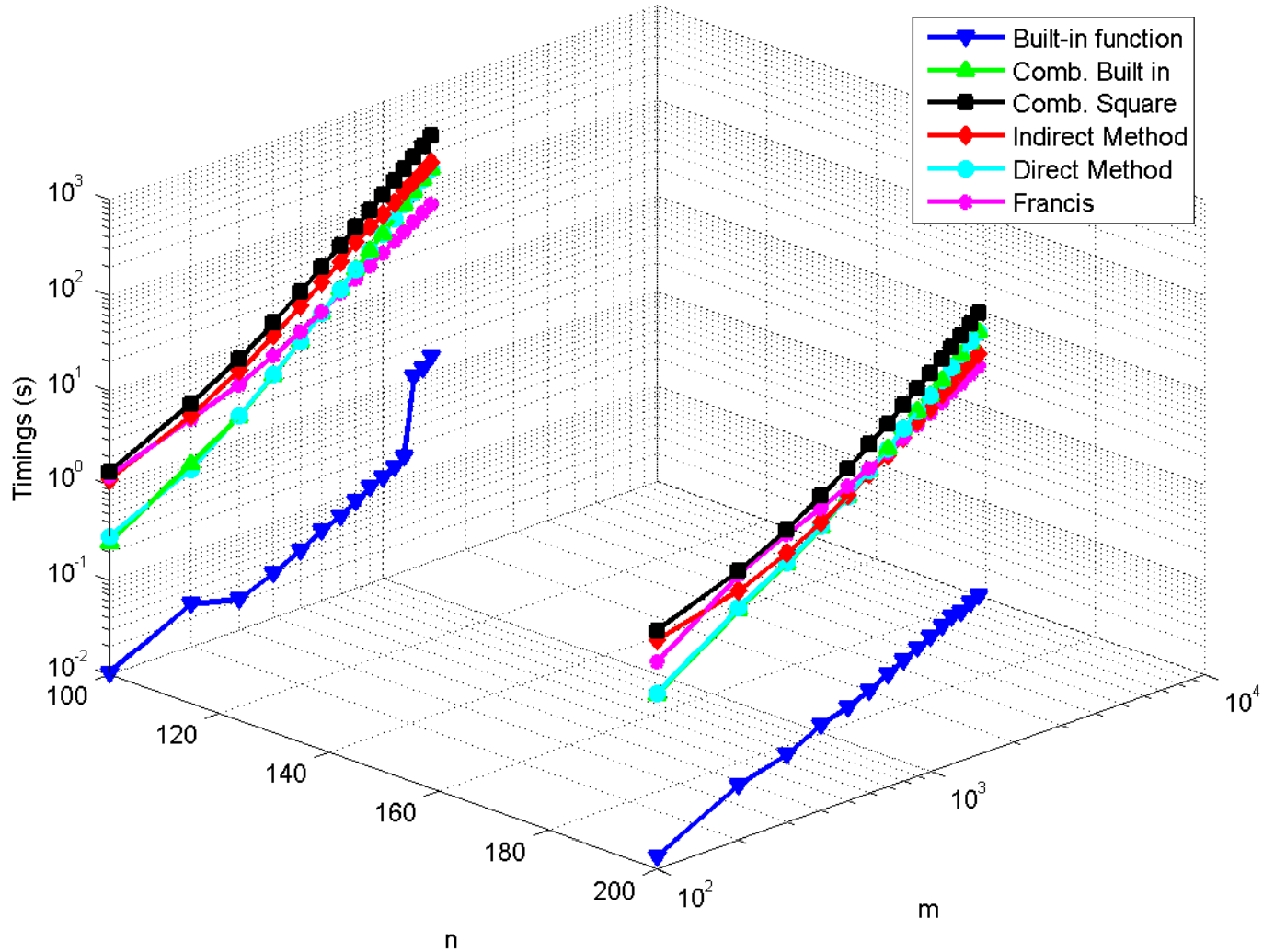


# Results for different matrices and comparisons

- Dense Matrices
  - Rectangular Matrices
  - Symmetric Matrices
- Sparse Matrices

# Dense Rectangular matrices

Comparison of timings when  $n$  is fixed and  $m$  is varied



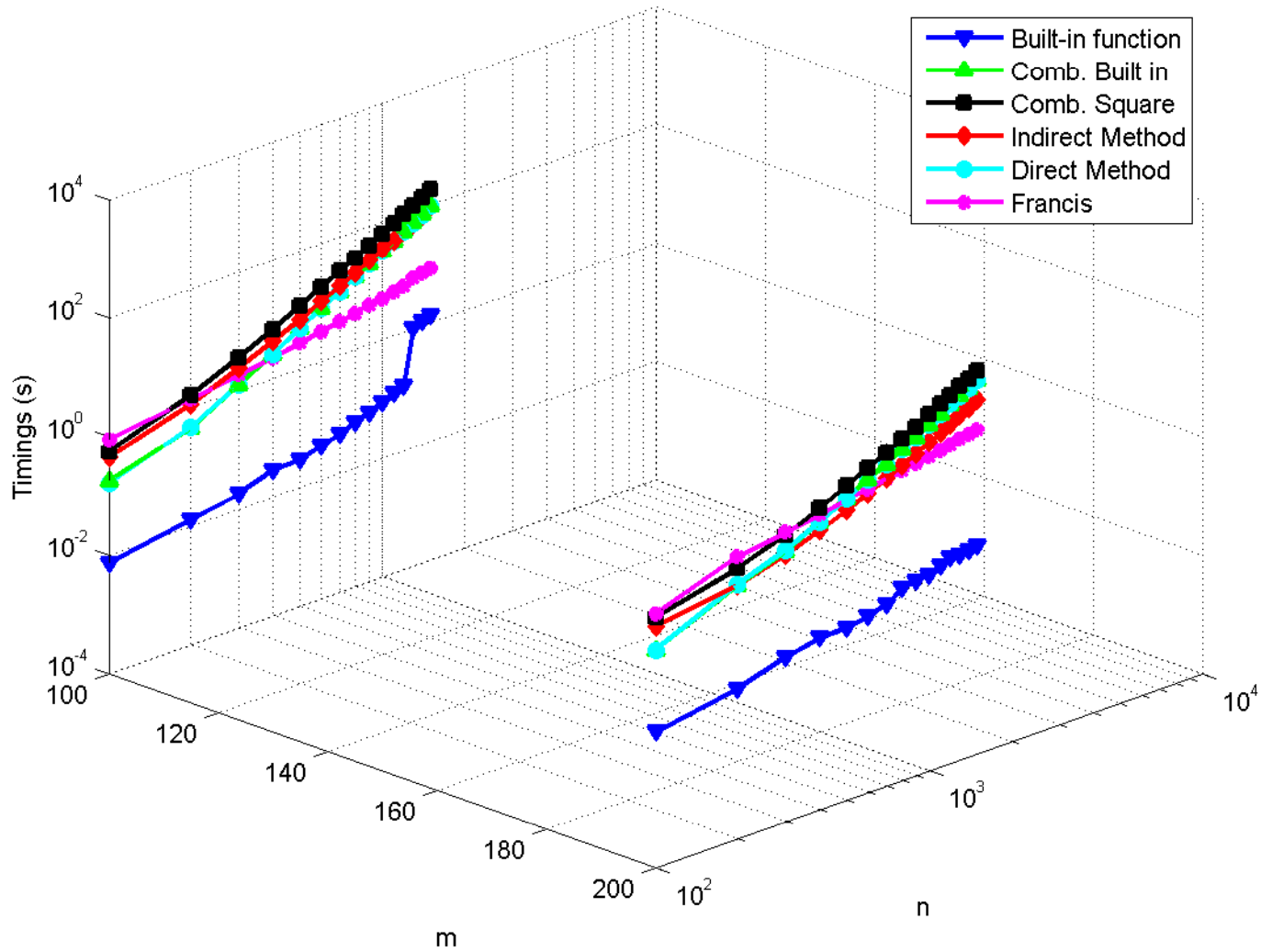
# Dense Rectangular matrices

- Comparison of timings when m is fixed and n is varied

n	m	Built in SVD	Comb. Built in	Comb. Square	Indirect Method	Direct Method	Francis
100	100	0.0073	0.1779	0.5651	0.4488	0.1616	0.8897
200		0.0129	0.4382	1.6292	1.1313	0.4599	1.3890
700		0.0451	11.4075	25.4917	14.3346	11.6559	3.6083
800		0.0589	16.5906	35.1912	19.3266	16.7657	3.9636
1400		1.1683	76.9117	147.1903	71.8148	75.7396	7.6926
1500		1.3396	96.2016	181.0894	93.1726	94.5906	8.2684
100	200	0.0191	0.4518	1.6380	1.1398	0.4642	1.8997
200		0.0331	1.7899	3.5367	1.8215	1.9187	5.5780
700		0.1123	26.2992	40.5601	14.7202	26.1704	14.6077
800		0.1689	37.0253	55.9529	19.7481	37.0049	16.2683
1400		0.2952	162.2110	236.5831	74.3360	162.2961	27.0306
1500		0.3177	200.9886	290.3429	89.6555	201.3425	28.6722

# Dense Rectangular matrices

Comparison of timings when m is fixed and n is varied



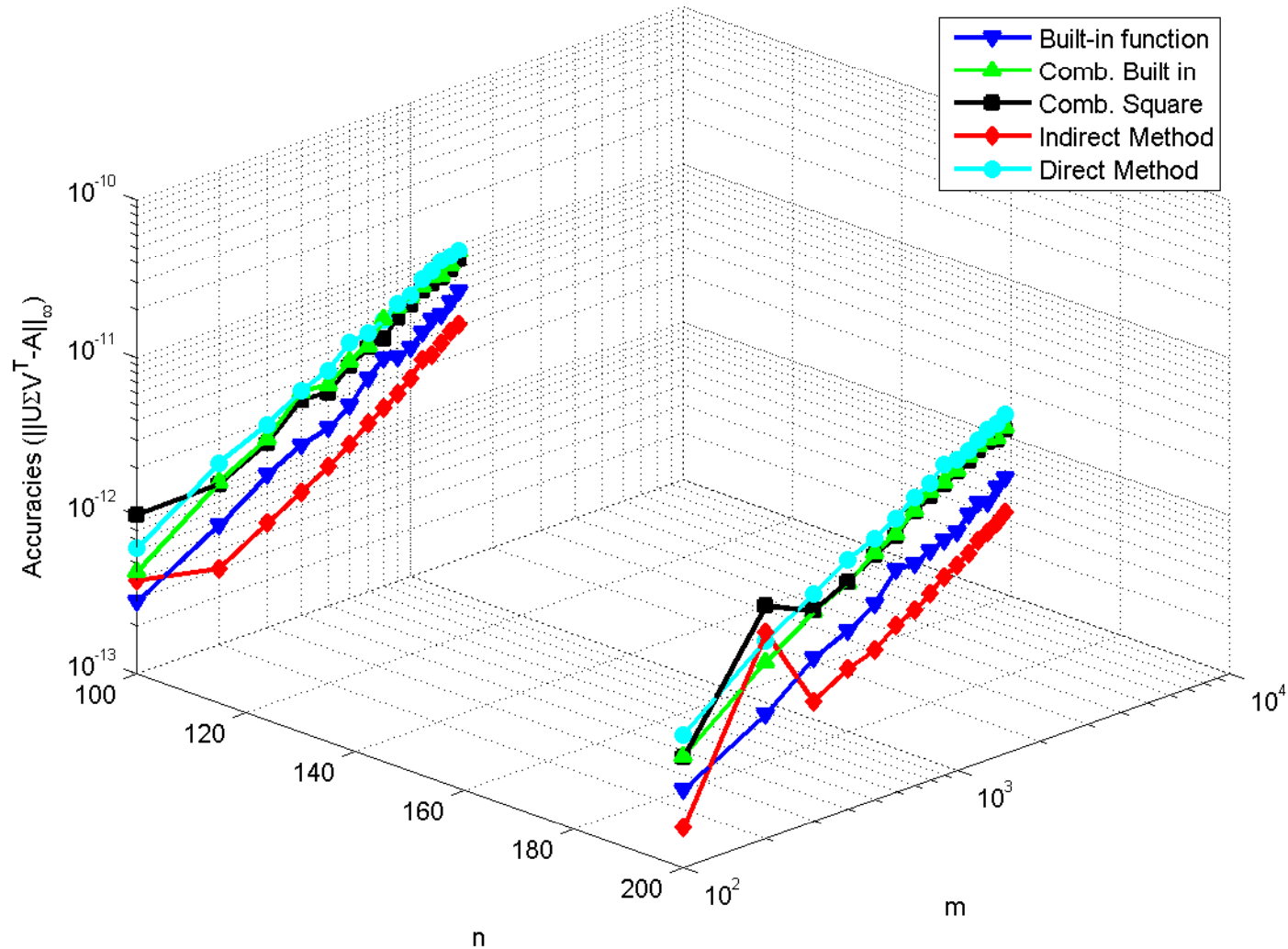
# Dense Rectangular matrices

- Comparison of accuracies when  $n$  is fixed and  $m$  is varied

n	m	Built in SVD	Comb. Built in	Comb. Square	Indirect Method	Direct Method
100	100	2.22e-13	3.8e-13	9e-13	9.3e-13	5.5e-13
	200	5.66e-13	8.1e-13	8e-13	3e-13	13.7e-13
	700	20.88e-13	30.04e-13	28e-13	10.2e-13	36.5e-13
	800	25.78e-13	37.6e-13	33e-13	12.1e-13	46.7e-13
	1400	40.33e-13	67.6e-13	61e-13	25.1e-13	82.3e-13
	1500	47.24e-13	70.9e-13	60e-13	27.6e-13	84.1e-13
200	100	3.54e-13	5.6e-13	5e-13	1.6e-13	7.3e-13
	200	5.69e-13	11.3e-13	1482e-13	247.6e-13	18e-13
	700	20.56e-13	43.9e-13	43e-13	12.1e-13	52.6e-13
	800	25.42e-13	50.8e-13	51e-13	14.3e-13	59.8e-13
	1400	44.68e-13	98.3e-13	98e-13	27.6e-13	115.5e-13
	1500	48.22e-13	107.3e-13	102e-13	30.1e-13	129.3e-13

# Dense Rectangular matrices

Comparison of accuracies when n is fixed and m is varied



# Dense Rectangular matrices

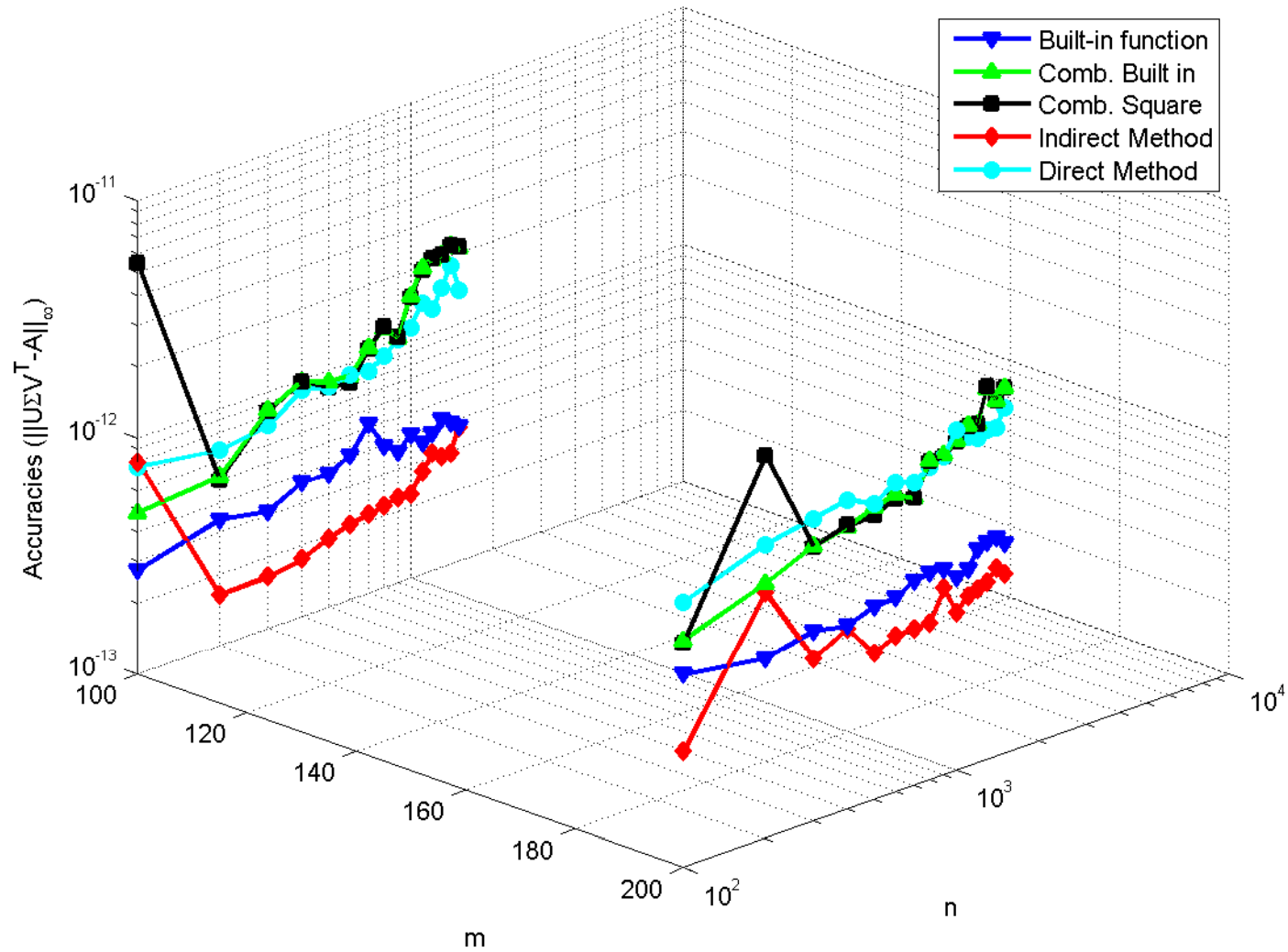
- Comparison of accuracies when m is fixed and n is varied

n	m	Built in SVD	Comb. Built in	Comb. Square	Indirect Method	Direct Method
100	100	2.62e-13	3.7e-13	8.2e-13	5.92e-13	5.8e-13
200		3.04e-13	5.26e-13	4.8e-13	1.55e-13	6.04e-13
700		2.93e-13	8.15e-13	8.2e-13	1.78e-13	7.87e-13
800		3.97e-13	9.8e-13	9.6e-13	1.99e-13	7.45e-13
1400		3.52e-13	12.34e-13	12e-13	2.39e-13	8.97e-13
1500		3.2e-13	17.57e-13	17.1e-13	2.31e-13	10.59e-13
100	200	6.04e-13	9.21e-13	8.1e-13	3.17e-13	14.07e-13
200		5.28e-13	11.53e-13	247.7e-13	16.71e-13	17.68e-13
700		6.51e-13	18.67e-13	18.4e-13	4.05e-13	20.09e-13
800		6.20e-13	19.55e-13	19.4e-13	4.03e-13	18.89e-13
1400		5.86e-13	21.5e-13	21.5e-13	4.38e-13	21.15e-13
1500		6.17e-13	27.02e-13	26.5e-13	4.9e-13	24.03e-13



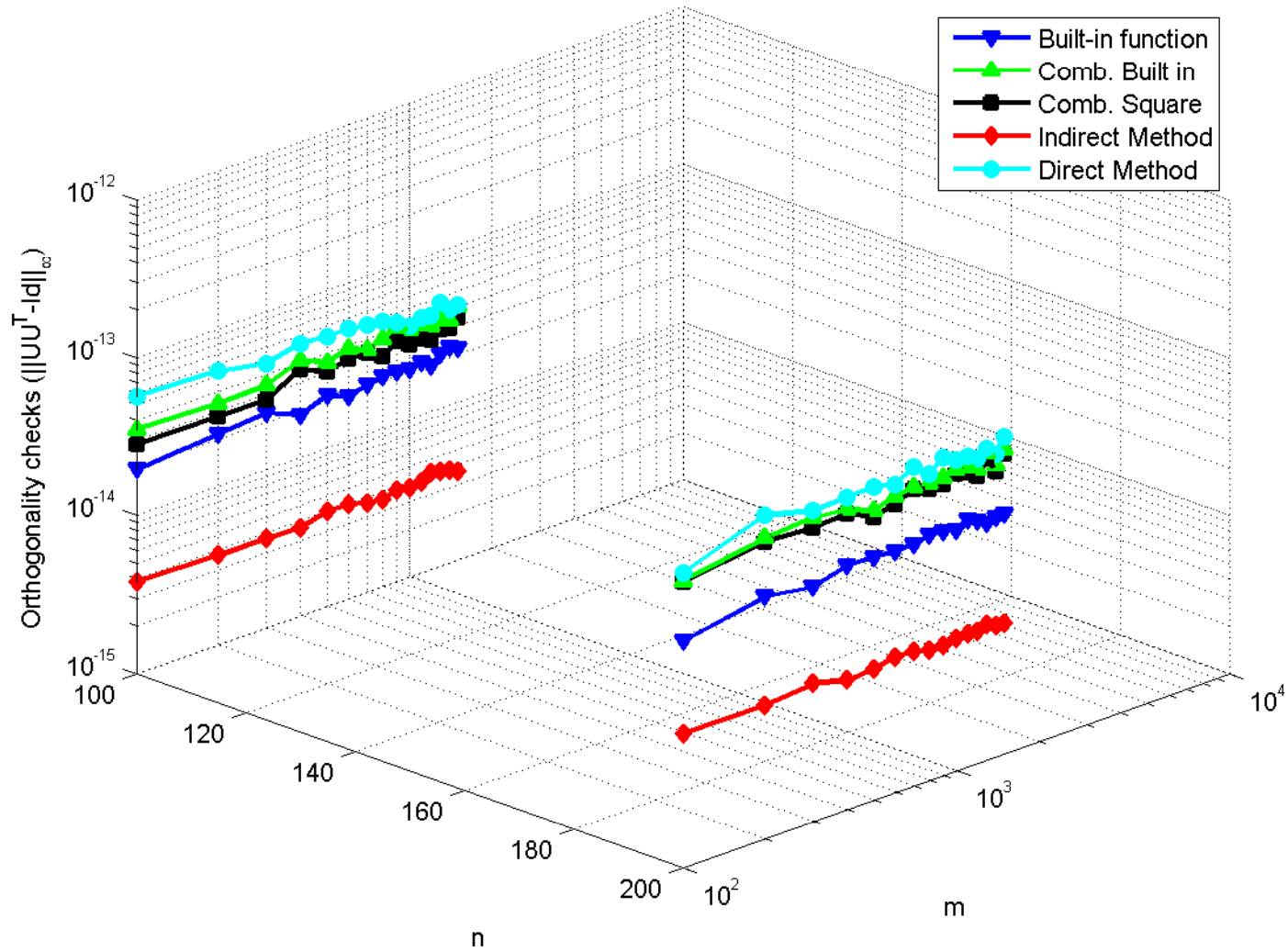
# Dense Rectangular matrices

Comparison of accuracies when m is fixed and n is varied



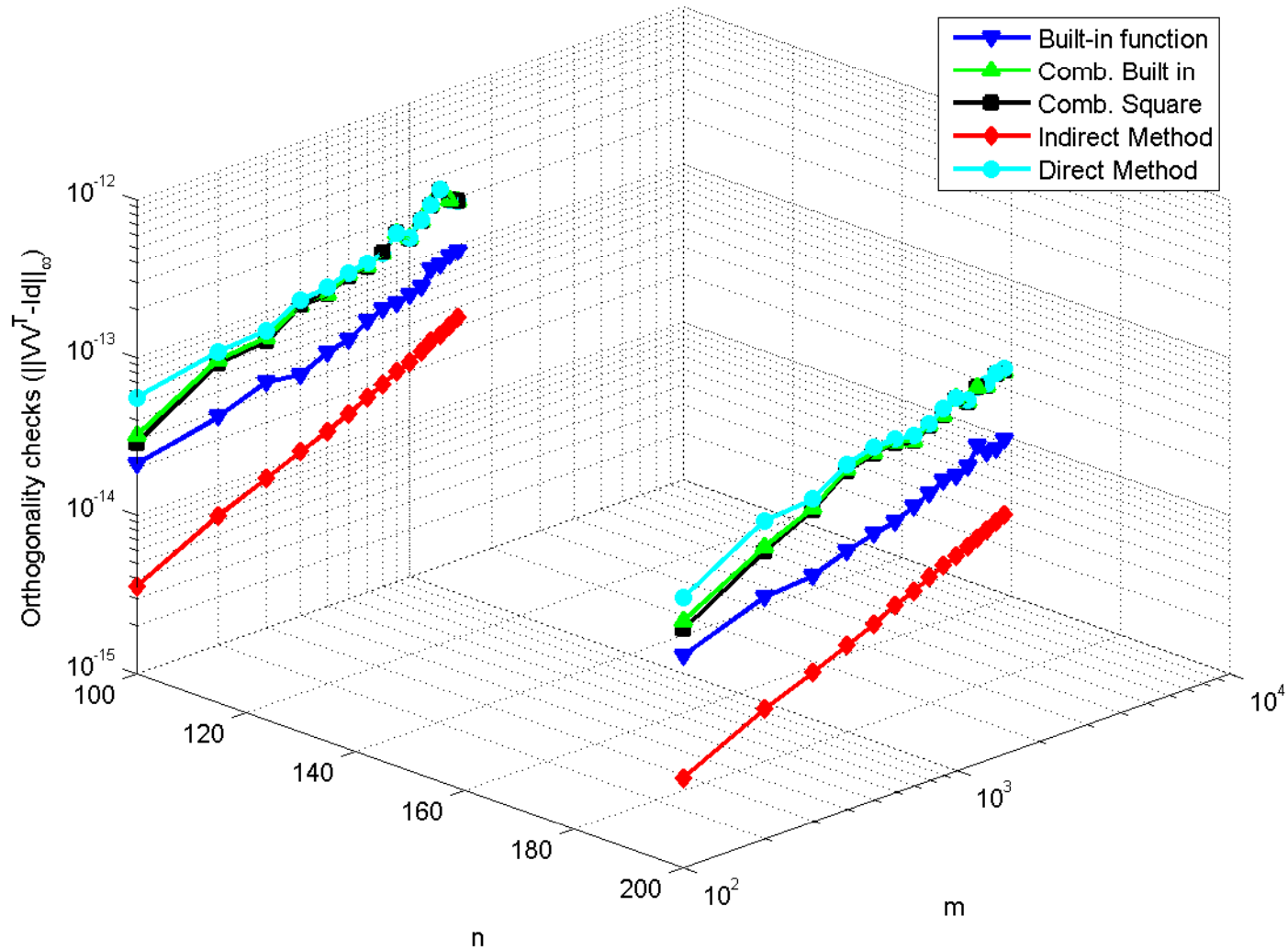
# Dense Rectangular matrices

Comparison of Orthogonality checks when  $n$  is fixed and  $m$  is varied



# Dense Rectangular matrices

Comparison of Orthogonality checks when  $n$  is fixed and  $m$  is varied



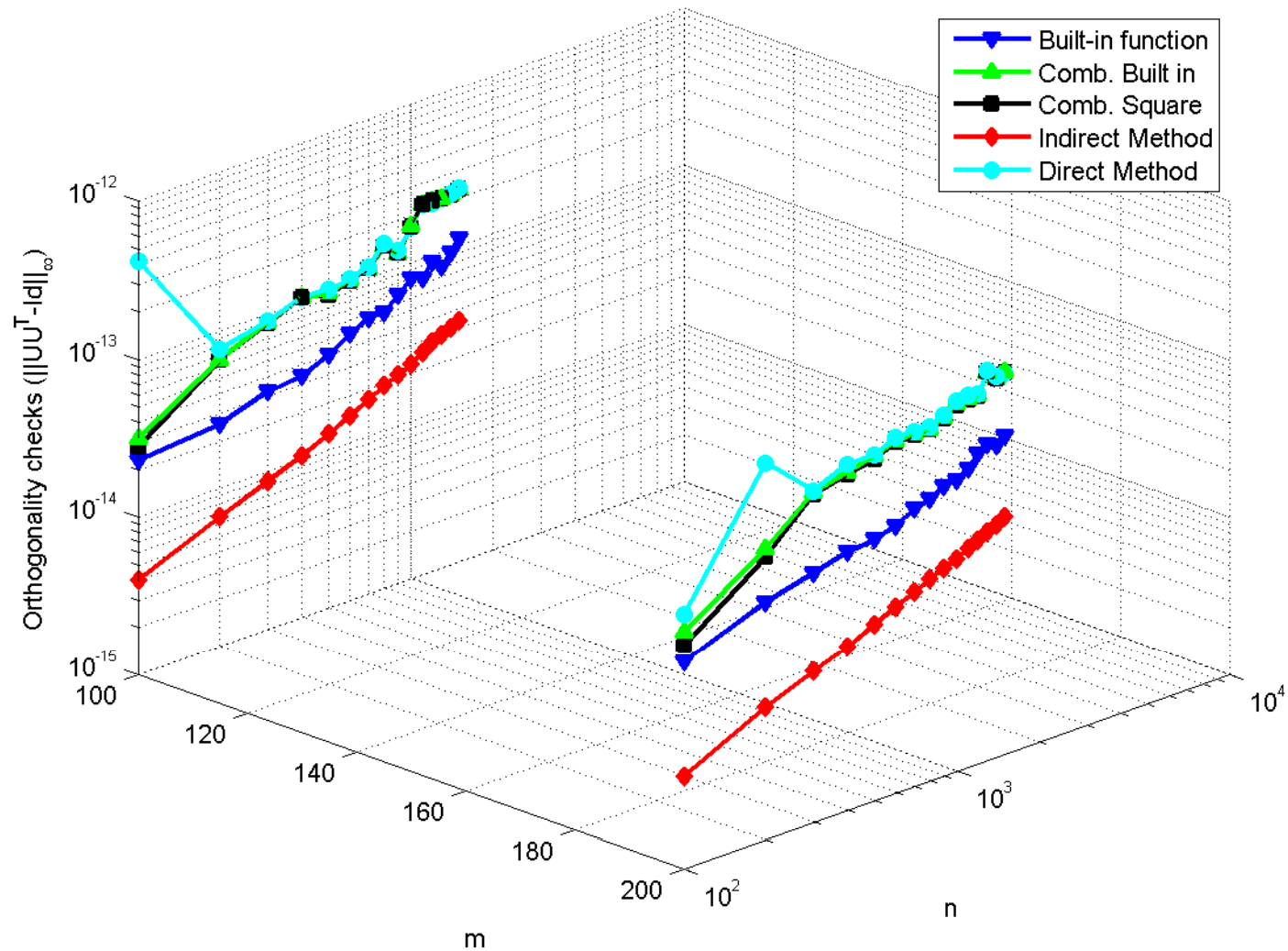
# Dense Rectangular matrices

- Orthogonality checks when m is fixed and n is varied

m	n	Built in SVD		Comb. Built in		Comb. Square		Indirect Method		Direct Method	
		UU <sup>T</sup> -Id	VV <sup>T</sup> -Id	UU <sup>T</sup> -Id	VV <sup>T</sup> -Id	UU <sup>T</sup> -Id	VV <sup>T</sup> -Id	UU <sup>T</sup> -Id	VV <sup>T</sup> -Id	UU <sup>T</sup> -Id	VV <sup>T</sup> -Id
100	100	0.19e-13	0.18e-13	0.28e-13	0.28e-13	0.22e-13	0.22e-13	0.03e-13	0.03e-13	0.77e-13	0.71e-13
	200	0.22e-13	0.18e-13	0.71e-13	0.33e-13	0.49e-13	0.24e-13	0.07e-13	0.04e-13	0.71e-13	0.42e-13
	700	0.37e-13	0.20e-13	1.45e-13	0.31e-13	1.05e-13	0.23e-13	0.17e-13	0.03e-13	1.44e-13	0.47e-13
	800	0.30e-13	0.19e-13	1.59e-13	0.28e-13	1.05e-13	0.21e-13	0.19e-13	0.03e-13	1.59e-13	0.34e-13
	1400	0.53e-13	0.21e-13	1.91e-13	0.30e-13	1.56e-13	0.21e-13	0.33e-13	0.03e-13	1.91e-13	0.46e-13
	1500	0.51e-13	0.19e-13	1.79e-13	0.31e-13	1.82e-13	0.22e-13	0.35e-13	0.03e-13	1.79e-13	0.37e-13
200	100	0.20e-13	0.21e-13	0.31e-13	0.70e-13	0.22e-13	0.48e-13	0.04e-13	0.06e-13	0.37e-13	0.70e-13
	200	0.32e-13	0.30e-13	0.62e-13	0.66e-13	0.53e-13	0.55e-13	0.08e-13	0.07e-13	4.66e-13	4.70e-13
	700	0.40e-13	0.31e-13	2.72e-13	0.64e-13	1.56e-13	0.54e-13	0.18e-13	0.07e-13	2.73e-13	0.74e-13
	800	0.43e-13	0.30e-13	2.92e-13	0.67e-13	1.47e-13	0.56e-13	0.20e-13	0.07e-13	2.92e-13	0.76e-13
	1400	0.57e-13	0.30e-13	3.06e-13	0.74e-13	1.97e-13	0.76e-13	0.32e-13	0.06e-13	3.05e-13	0.81e-13
	1500	0.61e-13	0.29e-13	3.56e-13	0.66e-13	2.16e-13	0.56e-13	0.34e-13	0.06e-13	3.55e-13	0.80e-13

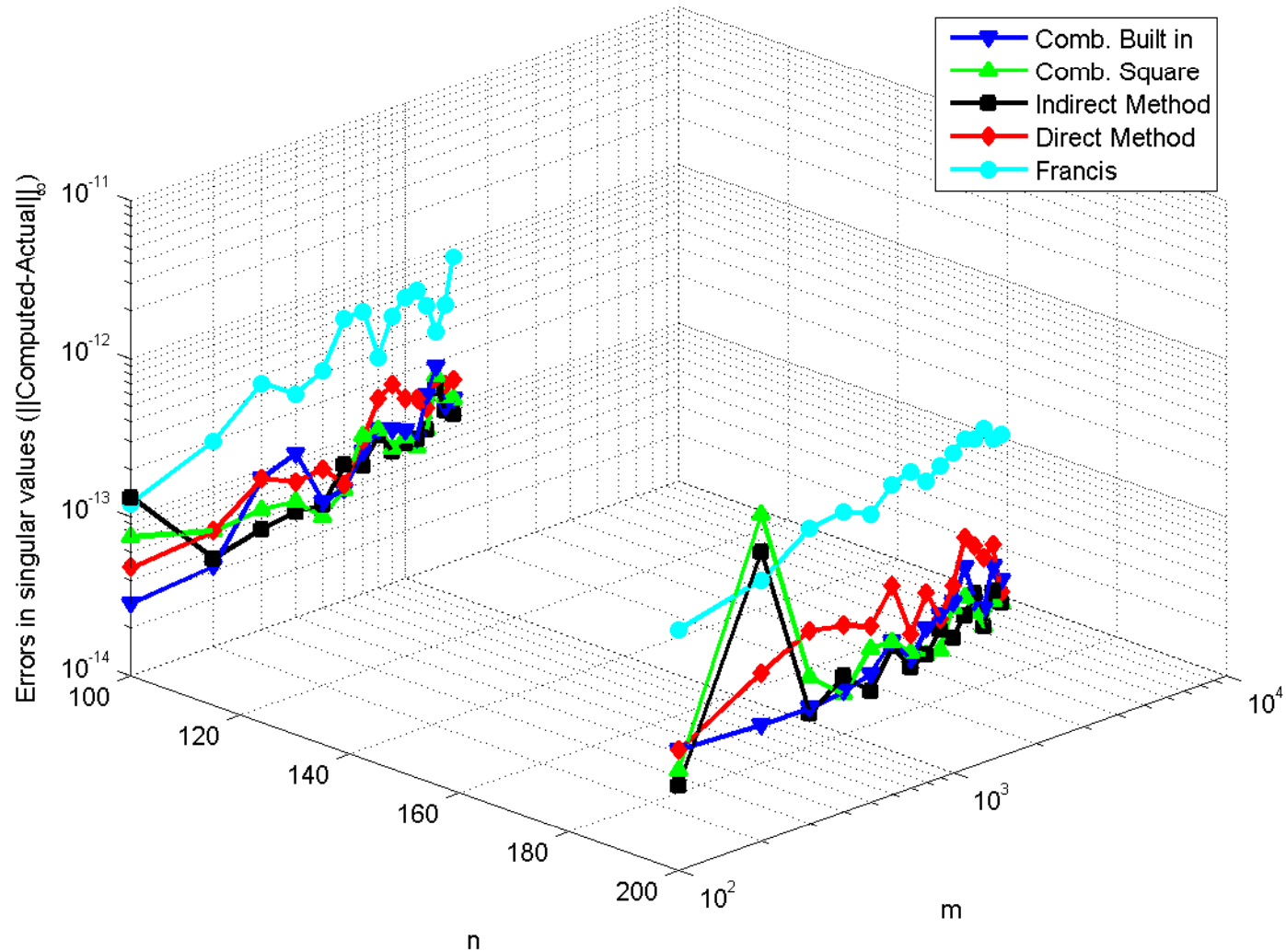
# Dense Rectangular matrices

Comparison of Orthogonality checks when  $m$  is fixed and  $n$  is varied



# Dense Rectangular matrices

Comparison of errors in singular values when  $n$  is fixed and  $m$  is varied



# Dense Rectangular matrices

- Error in singular values when m is fixed and n is varied

n	m	Comb. Built in	Comb. Square	Indirect Method	Direct Method	Francis
100	100	0.42e-13	2.96e-13	2.42e-13	0.92e-13	2.59e-13
200		0.56e-13	0.37e-13	0.24e-13	0.56e-13	1.53e-13
700		0.92e-13	0.64e-13	0.71e-13	1.06e-13	2.49e-13
800		0.71e-13	0.60e-13	0.67e-13	1.56e-13	2.42e-13
1400		0.99e-13	1.78e-13	1.20e-13	1.49e-13	2.98e-13
1500		0.71e-13	0.85e-13	0.63e-13	1.49e-13	5.76e-13
100	200	0.67e-13	0.43e-13	0.32e-13	0.74e-13	2.63e-13
200		0.56e-13	87e-13	3.34e-13	1.24e-13	5.51e-13
700		0.78e-13	0.71e-13	0.71e-13	1.70e-13	8.6e-13
800		0.99e-13	0.78e-13	0.56e-13	1.45e-13	11.65e-13
1400		0.85e-13	0.92e-13	0.92e-13	2.06e-13	9.73e-13
1500		0.71e-13	1.28e-13	1.13e-13	1.92e-13	15.49e-13

# Dense Symmetric matrices

- Comparison of timings

n	Built in SVD	Comb. Built in	Comb. Square	Indirect Method	Direct Method	Francis
100	0.1478	0.8	1.5	1.0154	0.3	1.1
200	0.0396	3.3	6.9	4.3111	3	6.3
700	1.1737	359.7	414.4	57.9199	366.7	210.8
800	1.6642	603.4	675.6	77.6638	622.2	313.4
1400	9.3720	5518.4	5761.6	73.7534	5655.7	1622.8
1500	11.2318	7256.0	7546.5	321.702	7405.2	1988.7



# Dense Symmetric matrices

- Comparison of Accuracies

n	Built in SVD	Comb. Built in	Comb. Square	Indirect Method	Direct Method
100	0.35e-12	0.62e-12	1.171e-12	0.258e-12	0.91e-12
200	0.83e-12	1.83e-12	8.027e-12	1.11e-12	2.59e-12
700	3.85e-12	12.88e-12	84.79e-12	24.28e-12	16.96e-12
800	4.66e-12	16.25e-12	75.42e-12	40.11e-12	20.10e-12
1400	10.53e-12	40.89e-12	781.6e-12	910.0e-12	51.26e-12
1500	10.92e-12	44.37e-12	133.4e-12	126.2e-12	55.05e-12

# Dense Symmetric matrices

- Comparison of Orthogonality checks  $||UU^T - Id||$

n	Built in SVD	Comb. Built in	Comb. Square	Indirect Method	Direct Method
100	0.19e-13	0.35e-13	0.29e-13	0.03e-13	0.53e-13
200	0.33e-13	0.69e-13	0.65e-13	0.06e-13	0.969e-13
700	0.89e-13	2.56e-13	2.52e-13	0.20e-13	3.40e-13
800	1.05e-13	2.87e-13	2.80e-13	0.22e-13	6.80e-13
1400	1.63e-13	5.94e-13	5.77e-13	0.36e-13	40.63e-13
1500	1.68e-13	7.04e-13	6.92e-13	0.38e-13	8.348e-13

# Dense Symmetric matrices

- Comparison of error in singular values

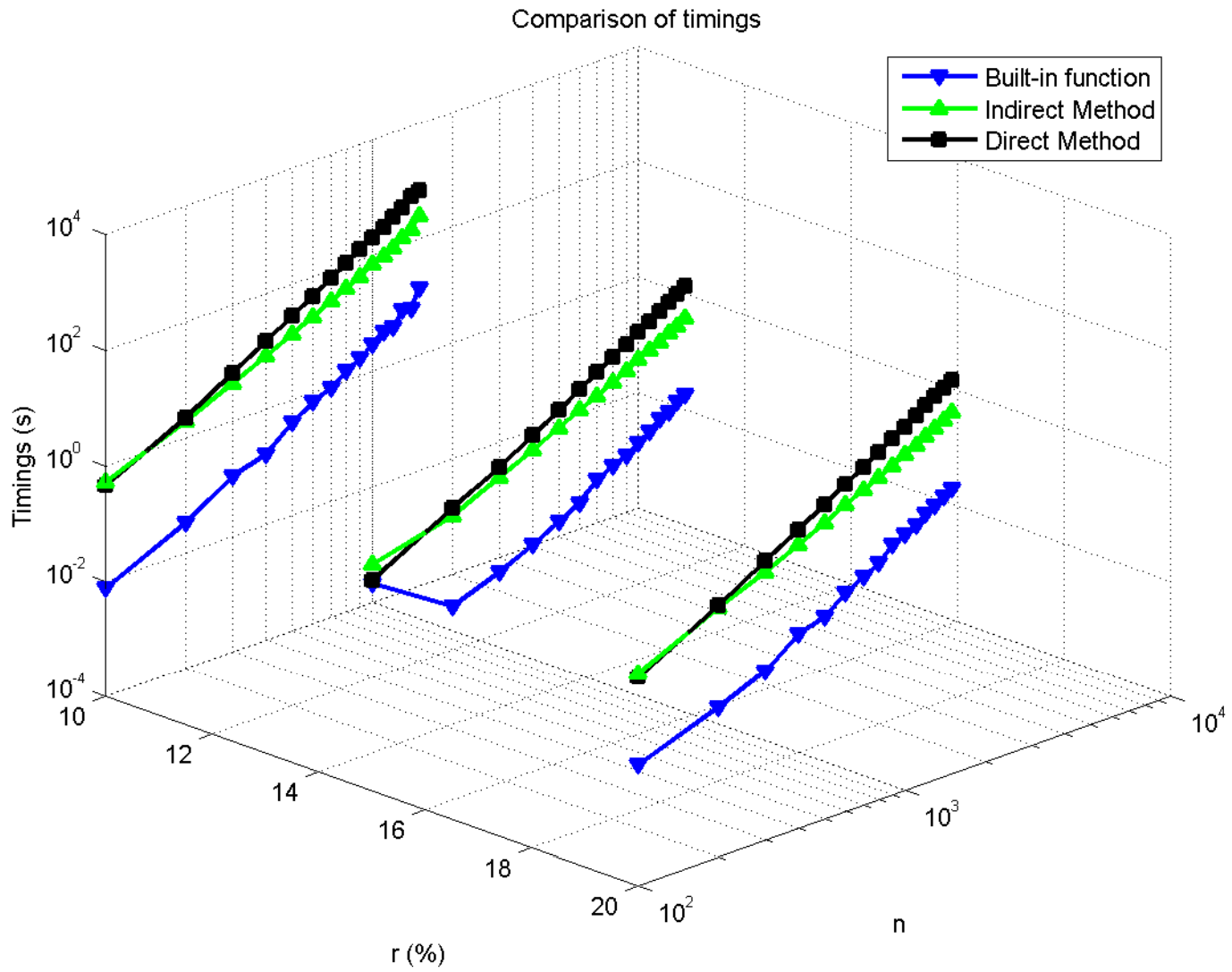
n	Built in SVD	Comb. Built in	Comb. Square	Indirect Method	Direct Method
100	0.03e-12	0.421e-12	0.29e-12	0.12e-12	0.13e-12
200	0.07e-12	2.999e-12	0.65e-12	0.25e-12	0.78e-12
700	0.15e-12	27.92e-12	2.52e-12	0.49e-12	4.59e-12
800	0.14e-12	22.87e-12	2.80e-12	0.76e-12	8.27e-12
1400	0.18e-12	226.2e-12	5.77e-12	1.25e-12	12.32e-12
1500	0.22e-12	34.41e-12	6.92e-12	1.13e-12	21.03e-12

# Sparse matrices

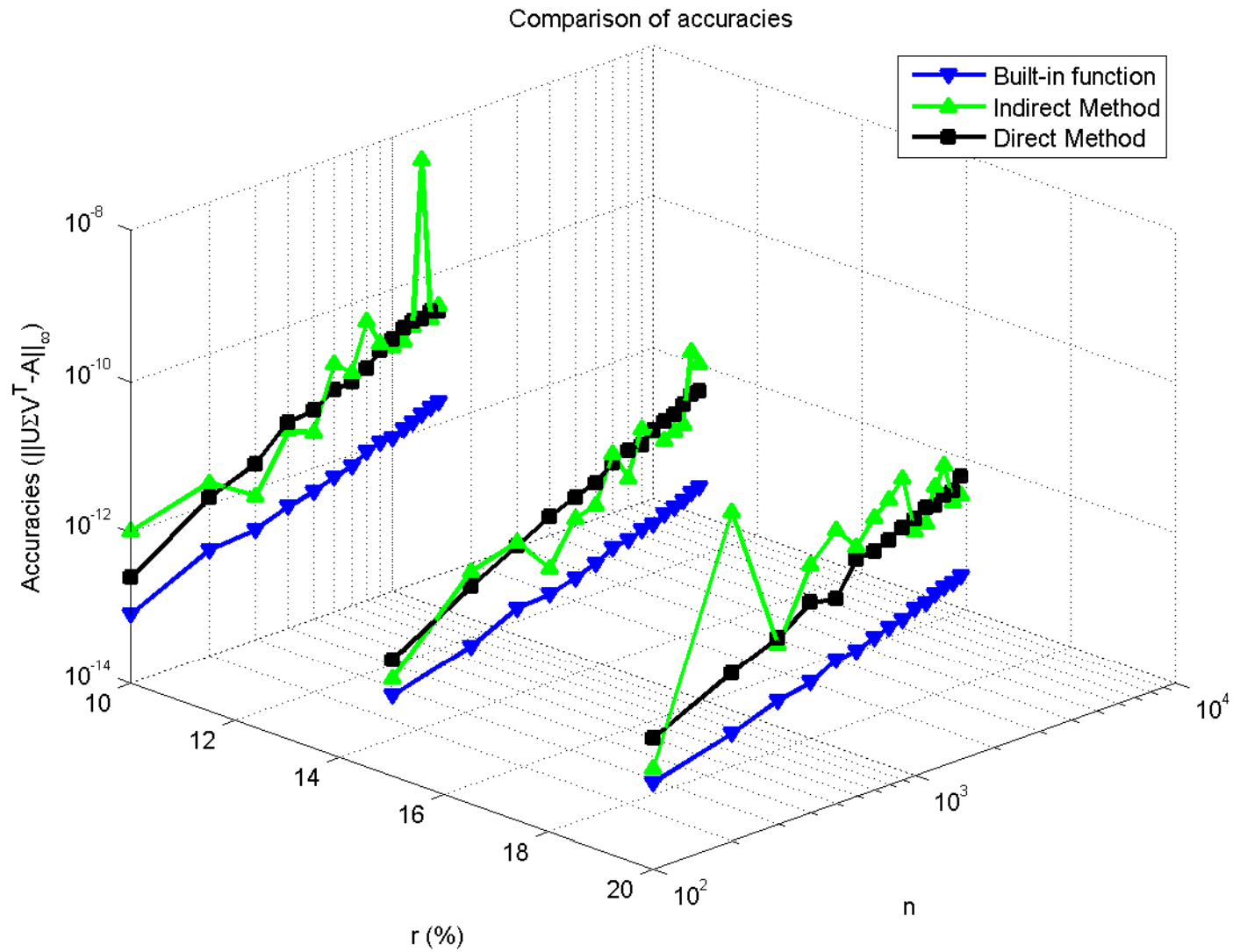
- Timings

R (%)	n	Built in SVD	Indirect Method	Direct Method	R (%)	Built in SVD	Indirect Method	Direct Method	R (%)	Built in SVD	Indirect Method	Direct Method
10	100	0.0076	0.5285	0.4531	15	0.3907	0.8333	0.4507	20	0.0116	0.4647	0.3947
	200	0.0333	1.9142	2.2428		0.0508	1.8609	2.5580		0.0376	2.0297	2.2426
	700	0.9298	29.3478	73.0620		1.0218	29.4391	74.0069		0.9093	29.4586	74.6328
	800	1.4618	39.9833	108.9375		1.4118	39.7951	108.4363		1.2709	40.0569	108.3989
	1400	7.1080	164.6916	605.4856		7.2799	154.1507	552.7347		7.2470	152.8861	550.8278
	1500	14.2674	255.3085	680.4072		8.8325	187.4323	675.4597		8.7850	186.2406	674.5308

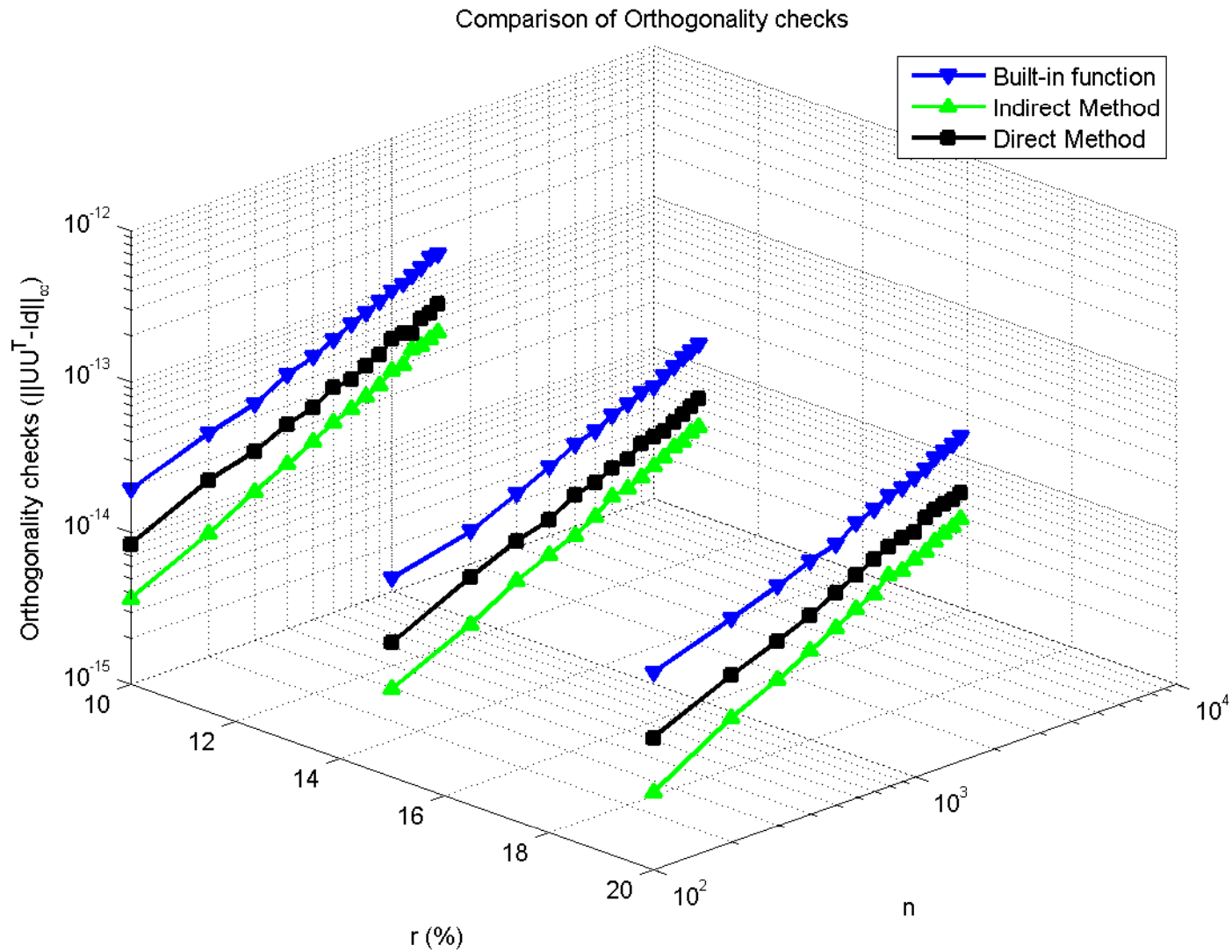
# Sparse matrices



# Sparse matrices



# Sparse matrices



# Sparse matrices

- Error in singular values

R (%)	n	Indirect Method	Direct Method	R (%)	Indirect Method	Direct Method	R (%)	Indirect Method	Direct Method
10	100	0.395e-12	0.0452e-12	15	0.030e-12	0.094e-12	20	0.080e-12	8.171e-13
	200	0.7633e-12	0.1811e-12		0.742e-12	0.22e-12		1.01e-12	2.415e-13
	700	4.708e-12	1.03e-12		2.59e-12	1.286e-12		1.156e-12	1.5134e-12
	800	1.4762e-11	1.76e-12		2.001e-12	1.485e-12		19.78e-12	2.0428e-12
	1400	6.724e-12	3.797e-12		6.305e-11	3.606e-12		6.398e-12	4.7251e-12
	1500	1.2641e-11	2.913e-12		3.143e-11	5.226e-12		6.488e-12	6.6293e-12



Thank you