Table 4: Time costs on different UCR datasets

		K-Shape	Medoid-Shape	in-database K-Shape	in-database Medoid-Shape	FrOKShape	wFCM	PAM + DTW	MUSLA	Time2Feat
Sensor	Air (Chlorine)	121.58	7.61	0.71	0.56	119.62	51.31	Timeout	Timeout	143.33
	Freezer	66.10	7.62	0.77	0.45	141.03	123.94	6997.19	Timeout	122.41
	Plane	3.23	4.11	0.15	0.26	6.54	4.13	92.73	429.94	12.95
Simulated	BME	10.64	0.32	0.052	0.040	1.59	3.00	13.44	208.10	14.28
	CBF	6.26	1.43	0.064	0.059	34.06	16.37	485.57	4217.43	22.59
Spectrum	Coffee	1.58	0.14	0.25	0.079	1.36	0.27	3.29	260.08	11.65
	Meat	9.27	0.92	1.68	0.48	4.11	1.29	59.12	3476.05	19.86
Image	Diatom	11.87	3.90	0.82	0.33	85.14	28.39	365.11	1130.84	17.30
	Phalanx	3.76	0.77	0.015	0.017	5.04	1.28	45.71	408.43	15.02
Device	ECG	212.94	30.08	1.07	1.68	343.30	72.07	Timeout	23473.11	163.96
	ElectricDevices	465.51	48.97	0.56	5.62	3326.17	899.70	Timeout	Timeout	310.92
	Computers	75.32	3.74	5.75	0.41	646.38	19.50	1004.54	Timeout	72.09
Motion	Worms	677.83	12.17	32.28	2.56	603.63	542.83	2623.55	30725.54	141.02
	Haptics	919.36	35.45	58.56	2.70	557.25	645.08	9737.84	Timeout	159.35
Power	ItalyPower	0.52	0.17	0.013	0.073	1.82	1.19	10.90	51.04	31.73
	PowerCons	2.09	0.44	0.037	0.018	149.82	6.26	35.88	1117.01	17.11
Traffic	Melbourne	36.44	18.60	0.033	0.39	189.91	145.95	1986.62	1121.06	97.43
	ChinaTown	0.27	0.091	0.077	0.036	0.39	0.22	1.41	7.44	14.61
Others	InsectEPG	227.46	4.80	4.44	0.37	21.90	68.90	590.08	8992.81	43.00
	Fungi	128.62	1.01	56.79	16.69	281.86	79.85	905.21	1017.90	11.35

Table 5: Rand Index on different UCR datasets

		K-Shape	Medoid-Shape	in-database K-Shape	in-database Medoid-Shape	FrOKShape	wFCM	PAM + DTW	MUSLA	Time2Feat
Sensor	Air (Chlorine)	0.5248	0.5330	0.5082	0.5187	0.5276	0.5314	–	–	0.4975
	Freezer	0.6387	0.6255	0.5960	0.6205	0.6400	0.5994	0.6255	–	0.5272
	Plane	0.9568	0.9755	0.9479	0.9710	0.9173	0.9159	0.9973	0.9438	0.8679
Simulated	BME	0.6131	0.6684	0.6016	0.6202	0.6677	0.7185	0.7404	0.5659	0.7675
	CBF	0.8754	0.7630	0.8199	0.7281	0.6478	0.5296	0.9403	0.8252	0.8709
Spectrum	Coffee	0.8247	0.8396	0.8058	0.8052	0.6837	0.6296	0.8968	0.6111	0.5071
	Meat	0.7294	0.7449	0.7251	0.7267	0.7378	0.7238	0.7153	0.5435	0.7368
Image	Diatom	0.9013	0.9272	0.8562	0.9086	0.9125	0.8363	0.7751	0.5371	0.7731
	Phalanx	0.7252	0.7478	0.7089	0.7132	0.6872	0.7484	0.7351	0.5794	0.6079
Device	ECG	0.7600	0.8182	0.7468	0.7719	0.7607	0.7377	–	0.4962	0.7093
	ElectricDevices	0.7182	0.6866	0.6778	0.6839	0.7145	0.4301	–	–	0.7862
	Computers	0.5329	0.5350	0.5196	0.5241	0.5145	0.5002	0.5339	–	0.5010
Motion	Worms	0.6431	0.6462	0.6354	0.6347	0.6506	0.6051	0.6635	0.7368	0.6419
	Haptics	0.6838	0.6754	0.6597	0.6680	0.6737	0.5243	0.6909	–	0.5470
Power	ItalyPower	0.6735	0.6898	0.6351	0.6688	0.5029	0.4995	0.4997	0.5084	0.5018
	PowerCons	0.5113	0.5619	0.5075	0.5040	0.5358	0.5303	0.6725	0.5131	0.7765
Traffic	Melbourne	0.8703	0.8705	0.7950	0.8328	0.8726	0.8754	0.8682	0.8957	0.8119
	ChinaTown	0.8079	0.7658	0.8032	0.7383	0.6631	0.6493	0.6316	0.5122	0.9307
Others	InsectEPG	0.5568	0.6840	0.5249	0.6055	0.8701	0.6340	1.0000	0.9458	0.5739
	Fungi	0.8764	0.9937	0.8737	0.9869	0.3081	0.7121	0.9961	0.9438	0.9302

A ADDITIONAL EVALUATION

A.1 Scalability in Cluster Numbers

Figure 14 shows the time costs under different cluster numbers k. When k increases, K-Shape and in-database K-Shape take more time, since K-Shape may take more iterations and in-database K-Shape may aggregate more clusters. Medoid-Shape and in-database Medoid-Shape also cost more time, and their time costs increase slightly faster than that of K-Shape and in-database K-Shape. This is because the time complexity of Medoid-Shape and in-database Medoid-Shape is proportional to $O(k^2)$, as analyzed in Sections 4.3 and 5.3. In practice, we usually set a small cluster number k in practice, so the time costs of Medoid-Shape and its in-database adaptation are still acceptable. Remarkably, our in-database proposals consistently show higher efficiency than out-of-database methods under all cluster numbers, thanks to the utilization of pre-computed metadata.

A.2 Effectiveness Evaluation

We conduct evaluation on effectiveness in Figure 15 with varying data sizes. We utilize Compactness [21] for two unlabeled private datasets as effectiveness metrics, which measures the average intra-cluster shape-based distances for all clusters, i.e., Compactness = $\frac{1}{n}\sum_{i=1}^{n}\min_{C_j}\mathrm{SBD}(X_i, C_j)$. For two labeled public datasets, we use Rand Index [34], defined by $R = \frac{TP+TN}{TP+TN+FP+FN}$, where TP, TN, FP and FN denote true positive, true negative, false positive and false negative classification series, respectively. Lower Compactness or higher Rand Index implies a better clustering result. As illustrated in Figure 15, all the methods achieve relatively close effectiveness with less than 0.05 discrepancy on Rand Index, whereas our in-database proposals cost significantly less time.

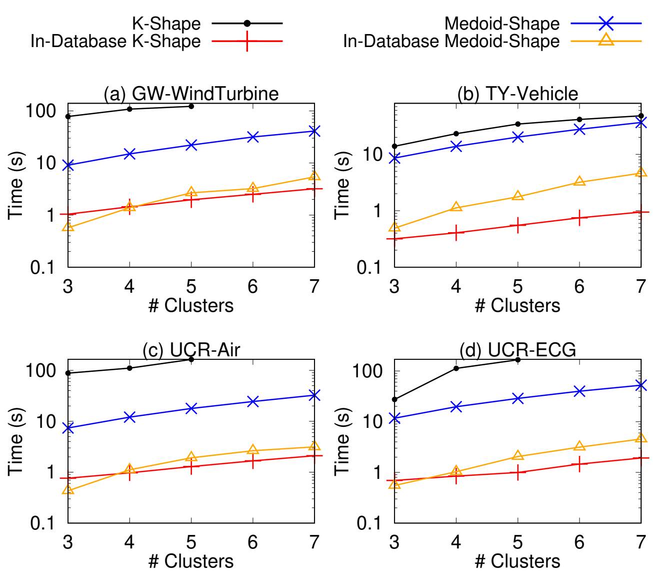

Figure 14: Time costs under different number of clusters

A.3 Varying Page Sizes

Figure 16 shows the time costs under different database page sizes. Page size serves as a configured parameter for databases, which determines the maximum number of points per page. Given fixed overall data sizes, page number N will decreases as page size increases. Thereby, referring to the complexity analysis in Sections 3.3 and 5.3, the time costs of the in-database proposals decrease with the increase of page sizes, due to less pages to aggregate. While the time costs of two out-of-database methods almost keep constant, since they load data out of databases and cluster from scratch, i.e., not affected by database configuration.

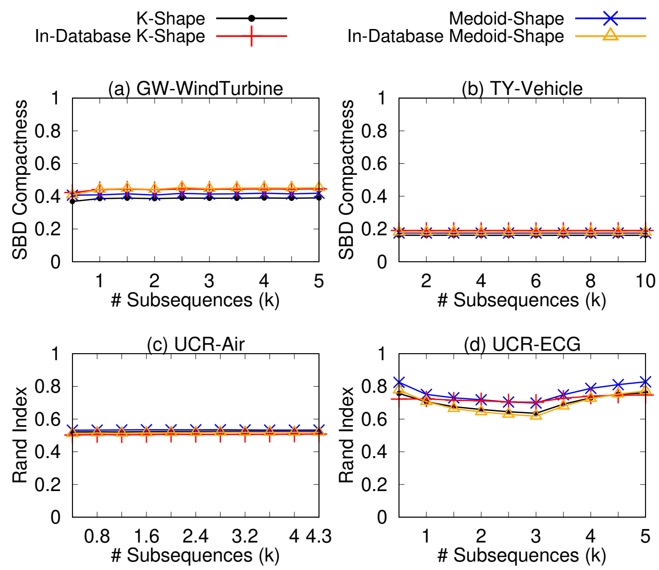

Figure 15: Effectiveness under different data sizes

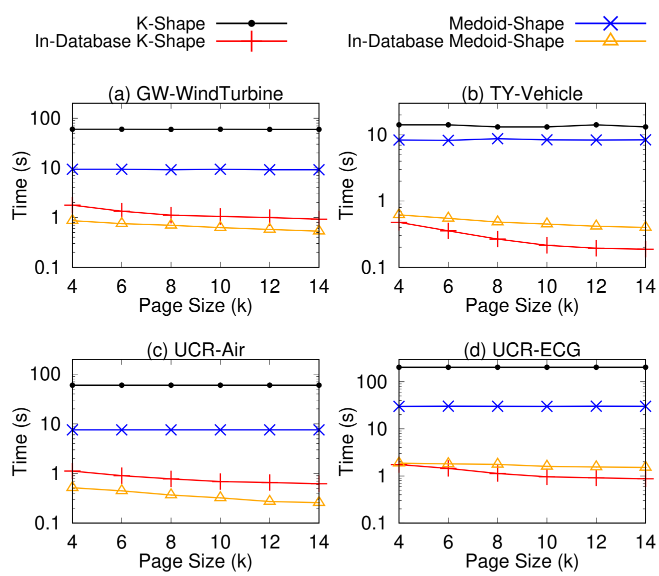

Figure 16: Time costs under different page sizes