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An empirical study on combining diverse static analysis tools for web security vulnerabilities based on development scenarios

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Supplementary Material

Due to space limitations, in the paper the results tables (Table 8 for the WordPress Plugins Dataset (WPD) and Table 9 for the Synthetic Dataset (SD)) only show the TOP 5 (of 31) solutions of combining the results of five Automated Static Analysis Tools (ASATs) for each scenario.

In this document we provide several tables, one for each scenario, with all solutions of combining the results of the five ASATs. Tables 1, 2, 3 and 4 list the results organized by scenario, class of vulnerability and together SQLi and XSS vulnerabilities for the WPD. The tables 6, 7, 8 show similar data for the SD.

This work extends a preliminary version presented at the 13th European Dependable Computing Conference (EDCC 2017).

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Additionally, we include two tables with all solutions of combining the results of the five ASATs regardless the scenarios. Table 5 list the results for the WPD and Table 9 list the results for the SD. The tables are

This document can be consulted online at `https://github.com/pjcnunes/Computing2018/EDCC\_CJ-DC-TP2017\_2nd\_SupplementaryMaterial.pdf`

Appendices

A Best Solutions for the WordPress plugins dataset: SQLi, XSS and SQLi + XSS

Table 1 Best Solutions for the WordPress plugins: SQLi. XSS and SQLi + XSS: Highest-quality

SQLi							XSS							SQLi + XSS						
Tools	TP	FP	Pg	MM	TM	P/R	Tools	TP	FP	Pg	MM	TM	P/R	Tools	TP	FP	Pg	MM	TM	P/R
Highest-quality				Rec.	Prec.						Rec.	Prec.						Rec.	Prec.	
ac	65	5	9	.867	.929	-	ab	165	43	11	.982	.793	-	abc	230	50	-	.947	.821	-
ace	65	5	9	.867	.929	-	abe	165	43	11	.982	.793	-	abcd	230	50	-	.947	.821	-
abce	65	5	9	.867	.929	-	abc	165	45	11	.982	.786	-	abcde	230	50	-	.947	.821	-
acde	65	5	9	.867	.929	-	abd	165	45	11	.982	.786	-	abce	230	50	-	.947	.821	-
abc	65	5	9	.867	.929	-	abce	165	45	11	.982	.786	-	acde	205	31	-	.844	.869	-
acd	65	5	9	.867	.929	-	abde	165	45	11	.982	.786	-	acd	204	29	-	.840	.876	-
abcd	65	5	9	.867	.929	-	abcde	165	45	11	.982	.786	-	ab	194	48	-	.798	.802	-
abcde	65	5	9	.867	.929	-	abcd	165	45	11	.982	.786	-	abe	194	48	-	.798	.802	-
ce	49	4	7	.653	.925	-	ade	140	26	11	.833	.843	-	abd	194	50	-	.798	.795	-
c	49	4	7	.653	.925	-	acde	140	26	11	.833	.843	-	abde	194	50	-	.798	.795	-
bc	49	4	7	.653	.925	-	ad	139	24	10	.827	.853	-	ace	184	27	-	.757	.872	-
cd	49	4	7	.653	.925	-	acd	139	24	10	.827	.853	-	bcde	180	41	-	.741	.814	-
bce	49	4	7	.653	.925	-	bcde	131	37	11	.780	.780	-	bce	179	38	-	.737	.825	-
cde	49	4	7	.653	.925	-	bce	130	34	11	.774	.793	-	bcd	173	41	-	.712	.808	-
bcde	49	4	7	.653	.925	-	bde	128	35	11	.762	.785	-	ac	172	25	-	.708	.873	-
bcd	49	4	7	.653	.925	-	be	126	30	11	.750	.808	-	ade	169	31	-	.695	.845	-
a	29	5	5	.387	.853	-	bcd	124	37	11	.738	.770	-	ad	168	29	-	.691	.853	-
ae	29	5	5	.387	.853	-	bd	121	35	11	.720	.776	-	bc	166	37	-	.683	.818	-
ab	29	5	5	.387	.853	-	ace	119	22	11	.708	.844	-	ae	143	25	-	.588	.851	-
ad	29	5	5	.387	.853	-	bc	117	33	10	.696	.780	-	cde	133	22	-	.547	.858	-
abe	29	5	5	.387	.853	-	ae	114	20	11	.679	.851	-	a	131	23	-	.539	.851	-
ade	29	5	5	.387	.853	-	b	113	29	10	.673	.796	-	bde	128	35	-	.527	.785	-
abde	29	5	5	.387	.853	-	ac	107	20	9	.637	.843	-	be	126	30	-	.519	.808	-
abd	29	5	5	.387	.853	-	a	102	18	8	.607	.850	-	cd	124	20	-	.510	.861	-
e	0	0	0	.000	-	-	cde	84	18	8	.500	.824	-	bd	121	35	-	.498	.776	-
be	0	0	0	.000	-	-	de	78	16	8	.464	.830	-	b	113	29	-	.465	.796	-
d	0	0	0	.000	-	-	cd	75	16	7	.446	.824	-	ce	106	13	-	.436	.891	-
de	0	0	0	.000	-	-	d	69	14	7	.411	.831	-	de	78	16	-	.321	.830	-
b	0	0	0	.000	-	-	ce	57	9	8	.339	.864	-	c	72	10	-	.296	.878	-
bde	0	0	0	.000	-	-	e	44	5	7	.262	.898	-	d	69	14	-	.284	.831	-
bd	0	0	0	.000	-	-	c	23	6	3	.137	.793	-	e	44	5	-	.181	.898	-

MM - Main Metric. TM - Tiebreaker Metric. Rec. - Recall. Prec. - Precision. Pg - # of plugins
Infor. - Informedness. F-Meas. - F-Measure. Marked. - Markedness.
Tools: a - phpSAFE. b - RIPS. c - WAP. d Pixy. e - WeVerca.

Table 2 Best Solutions for the WordPress plugins: SQLi. XSS and SQLi + XSS: High-quality

SQLi							XSS							SQLi + XSS						
Tools	TP	FP	Pg	MM	TM	P/R	Tools	TP	FP	Pg	MM	TM	P/R	Tools	TP	FP	Pg	MM	TM	P/R
High-quality				Infor.	Rec.	Prec.					Infor.	Rec.	Prec.					Infor.	Rec.	Prec.
acde	318	59	36	.866	.919	.844	abce	1841	224	51	.961	1.000	.892	abcde	2159	284	-	.946	.987	.884
abce	318	60	36	.865	.919	.841	abcde	1841	224	51	.961	1.000	.892	abce	2159	284	-	.946	.987	.884
abcde	318	60	36	.865	.919	.841	abe	1838	223	51	.960	.998	.892	abde	2124	283	-	.930	.971	.882
ace	316	59	36	.860	.913	.843	abde	1838	223	51	.960	.998	.892	abe	2124	283	-	.930	.971	.882
acd	311	58	35	.847	.899	.843	abc	1770	224	51	.922	.961	.888	abc	2081	284	-	.910	.951	.880
abc	311	60	35	.845	.899	.838	abcd	1770	224	51	.922	.961	.888	abcd	2081	284	-	.910	.951	.880
abcd	311	60	35	.845	.899	.838	abd	1767	223	51	.921	.959	.888	abd	2046	283	-	.894	.935	.878
ac	306	58	35	.832	.884	.841	ab	1766	223	51	.920	.959	.888	ab	2045	283	-	.894	.935	.878
ade	286	59	31	.774	.827	.829	acde	1431	183	50	.745	.777	.887	acde	1749	242	-	.764	.799	.878
abe	286	60	31	.773	.827	.827	ade	1424	180	49	.742	.773	.888	ade	1710	239	-	.747	.782	.877
abde	286	60	31	.773	.827	.827	acd	1346	182	50	.699	.731	.881	acd	1657	240	-	.723	.757	.873
ae	284	59	31	.768	.821	.828	ad	1339	179	49	.696	.727	.882	ace	1603	157	-	.710	.733	.911
ad	279	58	30	.754	.806	.828	ace	1287	98	50	.682	.699	.929	ad	1618	237	-	.705	.739	.872
ab	279	60	30	.753	.806	.823	ae	1276	95	49	.676	.693	.931	ae	1560	154	-	.691	.713	.910
abd	279	60	30	.753	.806	.823	bcde	1231	199	48	.634	.668	.861	ac	1489	153	-	.658	.681	.907
a	274	58	30	.740	.792	.825	bde	1225	198	48	.631	.665	.861	a	1438	148	-	.636	.657	.907
bcde	94	6	20	.266	.272	.940	ac	1183	95	49	.626	.642	.926	bcde	1325	205	-	.576	.606	.866
bce	93	6	20	.263	.269	.939	bce	1214	195	47	.626	.659	.862	bce	1307	201	-	.568	.597	.867
bcd	87	6	19	.246	.251	.935	be	1207	194	47	.622	.655	.862	bde	1277	200	-	.555	.584	.865
bc	85	6	18	.240	.246	.934	a	1164	90	46	.616	.632	.928	be	1258	196	-	.547	.575	.865
cde	65	5	18	.183	.188	.929	bcd	1056	199	47	.539	.573	.841	bcd	1143	205	-	.493	.522	.848
ce	61	5	17	.172	.176	.924	bd	1050	198	47	.536	.570	.841	bc	1106	201	-	.477	.505	.846
cd	58	4	17	.164	.168	.935	bc	1021	195	46	.521	.554	.840	bd	1095	200	-	.472	.500	.846
bde	52	2	10	.148	.150	.963	b	1013	194	46	.517	.550	.839	b	1056	196	-	.454	.483	.843
be	51	2	10	.146	.147	.962	cde	664	155	35	.334	.361	.811	cde	729	160	-	.310	.333	.820
bd	45	2	9	.128	.130	.957	de	645	151	33	.324	.350	.810	de	668	152	-	.283	.305	.815
c	44	4	12	.124	.127	.917	ce	477	59	30	.249	.259	.890	ce	538	64	-	.237	.246	.894
b	43	2	8	.122	.124	.956	cd	472	153	32	.230	.256	.755	cd	530	157	-	.220	.242	.771
de	23	1	8	.066	.067	.958	e	436	50	25	.228	.237	.897	e	454	51	-	.200	.207	.899
e	18	1	6	.051	.052	.947	d	453	148	28	.221	.246	.754	d	469	148	-	.193	.214	.760
d	16	0	7	.046	.046	1.000	c	219	55	18	.110	.119	-	c	263	59	-	.112	.120	.817

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Tools: a - phpSAFE. b - RIPS. c - WAP. d Pixy. e - WeVerca.

B Best Solutions for the synthetic dataset: SQLi / XSS

Table 3 Best Solutions for the WordPress plugins: SQLi. XSS and SQLi + XSS: Medium-quality

SQLi							XSS							SQLi + XSS						
Tools	TP	FP	Pg	MM	TM	P/R	Tools	TP	FP	Pg	MM	TM	P/R	Tools	TP	FP	Pg	MM	TM	P/R
Medium-quality				F-Meas.	Rec.	Prec.					F-Meas.	Rec.	Prec.					F-Meas.	Rec.	Prec.
abce	251	163	21	.737	.940	.606	abce	2386	652	46	.879	.999	.785	abcde	2637	815	-	.863	.993	.764
abcde	251	163	21	.737	.940	.606	abcde	2386	652	46	.879	.999	.785	abce	2637	815	-	.863	.993	.764
abc	250	163	21	.735	.936	.605	abc	2383	652	46	.879	.998	.785	abc	2633	815	-	.863	.991	.764
abcd	250	163	21	.735	.936	.605	abcd	2383	652	46	.879	.998	.785	abcd	2633	815	-	.863	.991	.764
abde	237	163	19	.711	.888	.593	abde	2359	652	46	.874	.987	.783	abde	2596	815	-	.856	.977	.761
abd	236	163	19	.709	.884	.591	abe	2345	652	46	.871	.982	.782	abe	2580	815	-	.853	.971	.760
abe	235	163	19	.707	.880	.590	abd	2328	652	46	.867	.975	.781	abd	2564	815	-	.850	.965	.759
ab	233	163	19	.703	.873	.588	ab	2314	652	46	.864	.969	.780	ab	2547	815	-	.846	.959	.758
acd	168	63	20	.675	.629	.727	bcde	2006	494	44	.821	.840	.802	bcde	2183	607	-	.802	.822	.782
ac	159	50	20	.668	.596	.761	bce	1989	492	44	.817	.833	.802	bce	2166	605	-	.798	.816	.782
acde	169	85	20	.649	.633	.665	bde	1971	494	44	.812	.825	.800	bde	2128	607	-	.789	.801	.778
bce	177	113	12	.636	.663	.610	be	1938	491	44	.805	.811	.798	be	2093	604	-	.782	.788	.776
bcde	177	113	12	.636	.663	.610	bcd	1914	494	44	.798	.801	.795	bcd	2090	607	-	.781	.787	.775
bc	176	113	12	.633	.659	.609	bc	1891	491	43	.793	.792	.794	bc	2067	604	-	.776	.778	.774
bcd	176	113	12	.633	.659	.609	bd	1851	494	44	.782	.775	.789	bd	2007	607	-	.762	.756	.768
ace	160	84	20	.626	.599	.656	b	1812	490	43	.773	.759	.787	b	1965	603	-	.752	.740	.765
ad	145	63	18	.611	.543	.697	acde	1630	317	43	.752	.682	.837	acde	1799	402	-	.741	.677	.817
ade	146	85	18	.586	.547	.632	ade	1574	317	43	.736	.659	.832	ade	1720	402	-	.720	.648	.811
bde	157	113	6	.585	.588	.581	acd	1533	309	43	.725	.642	.832	acd	1701	372	-	.719	.640	.821
bd	156	113	6	.582	.584	.580	ace	1431	276	43	.699	.599	.838	ace	1591	360	-	.691	.599	.815
be	155	113	6	.579	.581	.578	ad	1435	309	43	.694	.601	.823	ad	1580	372	-	.686	.595	.809
b	153	113	6	.574	.573	.575	ae	1338	276	43	.669	.560	.829	ae	1452	360	-	.650	.547	.801
ae	114	84	17	.490	.427	.576	ac	1147	267	43	.603	.480	.811	ac	1306	317	-	.610	.492	.805
cd	89	13	11	.482	.333	.873	cde	1030	67	26	.591	.431	.939	cde	1120	102	-	.578	.422	.917
a	99	50	15	.476	.371	.664	de	962	65	25	.563	.403	.937	de	1017	100	-	.539	.383	.910
cde	90	35	11	.459	.337	.720	a	970	267	41	.535	.406	.784	a	1069	317	-	.529	.402	.771
c	72	0	11	.425	.270	1.000	cd	828	59	24	.506	.347	.933	cd	917	72	-	.503	.345	.927
ce	79	34	11	.416	.296	.699	ce	786	24	23	.491	.329	.970	ce	865	58	-	.483	.326	.937
d	54	13	4	.323	.202	.806	d	717	56	23	.454	.300	.928	d	771	69	-	.441	.290	.918
de	55	35	4	.308	.206	.611	e	621	21	19	.410	.260	.967	e	642	55	-	.383	.242	.921
e	21	34	3	.130	.079	.382	c	344	13	18	.251	.144	.964	c	416	13	-	.270	.157	.970

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Infor. - Informedness. F-Meas. - F-Measure. Marked. - Markedness.
Tools: a - phpSAFE. b - RIPS. c - WAP. d Pixy. e - WeVerca.

Table 4 Best Solutions for the WordPress plugins: SQLi. XSS and SQLi + XSS: Low-quality

SQLi							XSS							SQLi + XSS						
Tools	TP	FP	Pg	MM	TM	P/R	Tools	TP	FP	Pg	MM	TM	P/R	Tools	TP	FP	Pg	MM	TM	P/R
Low-quality				Marked.	Prec.	Rec.					Marked.	Prec.	Rec.					Marked.	Prec.	Rec.
bc	6	0	2	.963	1.000	.120	c	62	3	6	.835	.954	.114	c	67	3	-	.857	.957	.202
bce	6	0	2	.963	1.000	.120	abce	543	117	12	.822	.823	.996	cde	124	10	-	.835	.925	.340
bcde	6	0	2	.963	1.000	.120	abcde	543	117	12	.822	.823	.996	ce	111	9	-	.832	.925	.310
bcd	6	0	2	.963	1.000	.120	abc	542	117	12	.822	.823	.994	cd	87	8	-	.819	.916	.252
c	5	0	2	.962	1.000	.100	abcd	542	117	12	.822	.823	.994	de	92	9	-	.815	.911	.264
ce	5	0	2	.962	1.000	.100	abde	534	116	12	.818	.822	.980	e	73	8	-	.802	.901	.216
cde	5	0	2	.962	1.000	.100	abe	533	116	12	.818	.821	.978	abcde	584	149	-	.794	.797	.880
cd	5	0	2	.962	1.000	.100	abd	533	116	12	.818	.821	.978	abce	584	149	-	.794	.797	.880
be	1	0	1	.959	1.000	.020	ab	532	116	12	.817	.821	.976	abc	583	149	-	.794	.796	.879
b	1	0	1	.959	1.000	.020	cde	119	10	9	.816	.923	.218	abcd	583	149	-	.794	.796	.879
bd	1	0	1	.959	1.000	.020	acde	299	41	12	.815	.879	.549	abde	571	148	-	.789	.794	.869
bde	1	0	1	.959	1.000	.020	ac	267	34	11	.815	.887	.490	abe	570	148	-	.788	.794	.868
abce	41	32	8	.554	.562	.820	ace	292	40	12	.813	.880	.536	abd	570	148	-	.788	.794	.868
abc	41	32	8	.554	.562	.820	ce	106	9	8	.813	.922	.194	ab	569	148	-	.788	.794	.867
abcd	41	32	8	.554	.562	.820	ade	283	40	12	.808	.876	.519	bcde	427	92	-	.788	.823	.767
abcde	41	32	8	.554	.562	.820	acd	276	39	12	.806	.876	.506	bce	423	92	-	.786	.821	.762
ace	40	32	8	.547	.556	.800	ae	273	39	12	.804	.875	.501	bcd	412	92	-	.780	.817	.750
ac	40	32	8	.547	.556	.800	a	244	33	10	.803	.881	.448	d	51	7	-	.776	.879	.156
acd	40	32	8	.547	.556	.800	de	92	9	9	.799	.911	.169	bde	402	91	-	.775	.815	.739
acde	40	32	8	.547	.556	.800	ad	260	38	12	.798	.873	.477	bc	404	92	-	.775	.815	.741
abe	37	32	8	.525	.536	.740	cd	82	8	9	.797	.911	.150	be	397	91	-	.773	.814	.733
ab	37	32	8	.525	.536	.740	bcde	421	92	11	.787	.821	.772	acde	339	73	-	.771	.823	.673
abd	37	32	8	.525	.536	.740	e	73	8	7	.785	.901	.134	ace	332	72	-	.768	.822	.665
abde	37	32	8	.525	.536	.740	bce	417	92	11	.784	.819	.765	bd	387	91	-	.767	.810	.721
ae	36	32	7	.517	.529	.720	bcd	406	92	11	.777	.815	.745	ac	307	66	-	.765	.823	.634
a	36	32	7	.517	.529	.720	bde	401	91	11	.776	.815	.736	b	378	91	-	.761	.806	.711
ad	36	32	7	.517	.529	.720	be	396	91	11	.772	.813	.727	acd	316	71	-	.760	.817	.644
ade	36	32	7	.517	.529	.720	bc	398	92	10	.772	.812	.730	ade	319	72	-	.760	.816	.647
e	0	0	0	-2.000	-	.000	bd	386	91	11	.766	.809	.708	ae	309	71	-	.755	.813	.634
d	0	0	0	-2.000	-	.000	b	377	91	10	.760	.806	.692	ad	296	70	-	.748	.809	.616
de	0	0	0	-2.000	-	.000	d	51	7	9	.758	.879	.094	a	280	65	-	.748	.812	.596

MM - Main Metric. TM - Tiebreaker Metric. Rec. - Recall. Prec. - Precision. Pg - # of plugins
Infor. - Informedness. F-Meas. - F-Measure. Marked. - Markedness.
Tools: a - phpSAFE. b - RIPS. c - WAP. d Pixy. e - WeVerca.

Table 5 Best Solutions for the WordPress plugins regardless scenarios: SQLi. XSS and SQLi + XSS

SQLi						XSS						SQLi + XSS				
Tools	TP	FP	Pg	MM	TM	Tools	TP	FP	Pg	MM	TM	Tools	TP	FP	MM	TM
				Rec.	Prec.					Rec.	Prec.				Rec.	Prec.
abce	675	260	74	.915	.722	abce	4935	1038	120	.998	.826	abde	5610	1298	.987	.812
abcde	675	260	74	.915	.722	abcde	4935	1038	120	.998	.826	abcde	5610	1298	.987	.812
abc	667	260	73	.904	.720	abde	4896	1036	120	.990	.825	ade	5527	1298	.973	.810
abcd	667	260	73	.904	.720	abe	4881	1034	120	.987	.825	acde	5527	1298	.973	.810
acde	592	181	73	.802	.766	abc	4860	1038	120	.983	.824	bde	5485	1296	.965	.809
abde	589	260	63	.798	.694	abcd	4860	1038	120	.983	.824	bcde	5468	1294	.962	.809
abe	587	260	63	.795	.693	abd	4793	1036	120	.970	.822	de	5374	1296	.946	.806
acd	584	158	72	.791	.787	ab	4777	1034	120	.966	.822	cde	5355	1294	.942	.805
ace	581	180	73	.787	.764	bcde	3789	822	114	.766	.822	abcd	4115	945	.724	.813
abd	581	260	62	.787	.691	bce	3750	813	113	.759	.822	abd	4092	748	.720	.845
ab	578	260	62	.783	.690	bde	3725	818	114	.753	.820	abe	4075	936	.717	.813
ac	570	145	72	.772	.797	be	3667	806	113	.742	.820	abce	3935	933	.693	.808
ade	497	181	61	.673	.733	acde	3500	567	116	.708	.861	bcd	3918	744	.690	.840
ad	489	158	60	.663	.756	bcd	3500	822	113	.708	.810	ae	3878	712	.683	.845
ae	463	180	60	.627	.720	bc	3427	811	109	.693	.809	ace	3874	921	.682	.808
a	438	145	57	.594	.751	ade	3421	563	115	.692	.859	bd	3818	945	.672	.802
bcde	326	123	41	.442	.726	bd	3408	818	113	.689	.806	be	3743	934	.659	.800
bce	325	123	41	.440	.725	b	3315	804	109	.671	.805	bce	3710	616	.653	.858
bcd	318	123	40	.431	.721	acd	3294	554	115	.666	.856	ce	3662	708	.644	.838
bc	316	123	39	.428	.720	ad	3173	550	114	.642	.852	e	3610	933	.635	.795
bde	210	115	17	.285	.646	ace	3129	436	116	.633	.878	acd	3512	919	.618	.793
cde	209	44	38	.283	.826	ae	3001	430	115	.607	.875	ad	3464	610	.610	.850
be	207	115	17	.281	.643	ac	2704	416	112	.547	.867	cd	3274	561	.576	.854
bd	202	115	16	.274	.637	a	2480	408	105	.502	.859	d	2918	553	.514	.841
cd	201	21	37	.272	.905	cde	1897	250	78	.384	.884	abc	2106	294	.371	.878
b	197	115	15	.267	.631	de	1777	241	75	.359	.881	bc	1855	277	.326	.870
ce	194	43	37	.263	.819	cd	1457	236	72	.295	.861	ab	1658	257	.292	.866
c	170	8	32	.230	.955	ce	1426	101	69	.288	.934	b	1620	144	.285	.918
de	78	36	12	.106	.684	d	1290	225	67	.261	.852	ac	1360	238	.239	.851
d	70	13	11	.095	.843	e	1174	84	58	.238	.933	a	1213	119	.213	.911
e	39	35	9	.053	.527	c	648	77	45	.131	.894	c	818	85	.144	.906

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Tools: a - phpSAFE. b - RIPS. c - WAP. d Pixy. e - WeVerca.

Table 6 Best Solutions for the synthetic dataset: SQLi. XSS and SQLi + XSS: Highest-quality

SQLi						XSS						SQLi + XSS					
Tools	TP	FP	MM	TM	P/R	Tools	TP	FP	MM	TM	P/R	Tools	TP	FP	MM	TM	P/R
Highest-quality			Rec.	Prec.					Rec.	Prec.					Rec.	Prec.	
bde	355	2072	.805	.146	-	abde	3290	4192	.817	.440		abde	3645	6264	- .816	.368	-
abde	355	2072	.805	.146	-	abcde	3290	4232	.817	.437		abcde	3645	6364	- .816	.364	-
bcde	355	2132	.805	.143	-	ade	3286	4142	.816	.442		ade	3628	5971	- .812	.378	-
abcde	355	2132	.805	.143	-	acde	3286	4182	.816	.440		acde	3628	6071	- .812	.374	-
de	342	1607	.776	.176	-	bde	3226	4176	.801	.436		bde	3581	6248	- .801	.364	-
cde	342	1817	.776	.158	-	bcde	3226	4216	.801	.434		bcde	3581	6348	- .801	.361	-
ade	342	1829	.776	.158	-	de	3210	3950	.797	.448		de	3552	5557	- .795	.390	-
acde	342	1889	.776	.153	-	cde	3210	4111	.797	.439		cde	3552	5928	- .795	.375	-
be	262	1635	.594	.138	-	abcd	2525	2908	.627	.465		abcd	2744	4366	- .614	.386	-
abe	262	1635	.594	.138	-	abd	2483	2670	.616	.482		abd	2702	4020	- .605	.402	-
bce	262	1695	.594	.134	-	bcd	2461	2892	.611	.460		abe	2689	5093	- .602	.346	-
abce	262	1695	.594	.134	-	abe	2427	3458	.603	.412		abce	2689	5195	- .602	.341	-
ce	249	1372	.565	.154	-	abce	2427	3500	.603	.410		bcd	2680	4350	- .600	.381	-
ae	249	1390	.565	.152	-	bd	2419	2654	.601	.477		ae	2666	4798	- .597	.357	-
ace	249	1450	.565	.147	-	ae	2417	3408	.600	.415		ace	2666	4900	- .597	.352	-
e	234	1086	.531	.177	-	ace	2417	3450	.600	.412		bd	2638	4004	- .590	.397	-
bd	219	1350	.497	.140	-	be	2363	3442	.587	.407		be	2625	5077	- .587	.341	-
abd	219	1350	.497	.140	-	bce	2363	3484	.587	.404		bce	2625	5179	- .587	.336	-
bcd	219	1458	.497	.131	-	e	2336	3209	.580	.421		ce	2585	4750	- .578	.352	-
abcd	219	1458	.497	.131	-	ce	2336	3378	.580	.409		e	2570	4295	- .575	.374	-
ad	168	939	.381	.152	-	acd	2272	2549	.564	.471		acd	2440	3596	- .546	.404	-
acd	168	1047	.381	.138	-	ad	2230	2311	.554	.491		ad	2398	3250	- .537	.425	-
d	156	609	.354	.204	-	cd	2030	2231	.504	.476		cd	2186	3146	- .489	.410	-
cd	156	915	.354	.146	-	d	1958	1783	.486	.523		d	2114	2392	- .473	.469	-
b	126	885	.286	.125	-	abc	1214	1750	.301	.410		abc	1340	2743	- .300	.328	-
ab	126	885	.286	.125	-	bc	1150	1734	.286	.399		bc	1276	2727	- .286	.319	-
bc	126	993	.286	.113	-	ab	1112	1452	.276	.434		ab	1238	2337	- .277	.346	-
abc	126	993	.286	.113	-	b	1048	1436	.260	.422		b	1174	2321	- .263	.336	-
a	75	468	.170	.138	-	ac	758	1162	.188	.395		ac	833	1738	- .186	.324	-
ac	75	576	.170	.115	-	a	656	864	.163	.432		a	731	1332	- .164	.354	-
c	63	430	.143	.128	-	c	408	712	.101	.364		c	471	1142	- .105	.292	-

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Tools: a - phpSAFE. b - RIPS. c - WAP. d Pixy. e - WeVerca.

Table 7 Best Solutions for the synthetic dataset: SQLi. XSS and SQLi + XSS: High-quality

SQLi						XSS						SQLi + XSS					
Tools	TP	FP	MM	TM	P/R	Tools	TP	FP	MM	TM	P/R	Tools	TP	FP	MM	TM	P/R
High-quality			Infor.	Rec.	Prec.				Infor.	Rec.	Prec.				Infor.	Rec.	Prec.
d	150	222	.590	.769	.403	d	121	107	.182	.513	.531	d	271	329	.418	.629	.452
de	190	498	.572	.974	.276	cd	121	107	.182	.513	.531	de	378	766	.387	.877	.330
bd	183	504	.532	.939	.266	ad	121	107	.182	.513	.531	bd	371	772	.367	.861	.325
cde	190	597	.493	.974	.241	acd	121	107	.182	.513	.531	bcd	371	826	.332	.861	.310
bcd	183	558	.488	.939	.247	c	0	0	.000	.000	-	cd	271	464	.332	.629	.369
cd	150	357	.481	.769	.296	a	0	0	.000	.000	-	abd	371	838	.325	.861	.307
ad	183	570	.478	.939	.243	ac	0	0	.000	.000	-	cde	378	865	.324	.877	.304
abd	183	570	.478	.939	.243	b	188	268	-.031	.797	.412	abcd	371	892	.290	.861	.294
acd	183	624	.435	.939	.227	ab	188	268	-.031	.797	.412	ad	304	677	.272	.705	.310
abcd	183	624	.435	.939	.227	bc	188	268	-.031	.797	.412	e	283	620	.260	.657	.313
bde	195	712	.425	1.000	.215	bd	188	268	-.031	.797	.412	acd	304	731	.238	.705	.294
bcde	195	742	.401	1.000	.208	de	188	268	-.031	.797	.412	bde	383	1018	.237	.889	.273
ade	195	778	.372	1.000	.200	cde	188	268	-.031	.797	.412	ade	383	1046	.219	.889	.268
abde	195	778	.372	1.000	.200	ade	188	268	-.031	.797	.412	bcde	383	1048	.218	.889	.268
e	128	376	.353	.656	.254	abd	188	268	-.031	.797	.412	b	269	640	.215	.624	.296
acde	195	808	.348	1.000	.194	bcd	188	268	-.031	.797	.412	ce	295	742	.210	.684	.284
abcde	195	808	.348	1.000	.194	abc	188	268	-.031	.797	.412	acde	383	1076	.200	.889	.263
ce	140	498	.316	.718	.219	abcd	188	268	-.031	.797	.412	abde	383	1084	.195	.889	.261
be	149	632	.254	.764	.191	acde	188	268	-.031	.797	.412	be	337	938	.182	.782	.264
bce	149	662	.230	.764	.184	e	155	244	-.096	.657	.388	bc	269	694	.180	.624	.279
ae	149	698	.201	.764	.176	ce	155	244	-.096	.657	.388	abcde	383	1114	.176	.889	.256
abe	149	698	.201	.764	.176	ae	155	244	-.096	.657	.388	ab	269	706	.172	.624	.276
ace	149	728	.177	.764	.170	ace	155	244	-.096	.657	.388	bce	337	968	.163	.782	.258
abce	149	728	.177	.764	.170	be	188	306	-.148	.797	.381	abe	337	1004	.140	.782	.251
b	81	372	.115	.415	.179	abe	188	306	-.148	.797	.381	abc	269	760	.138	.624	.261
bc	81	426	.072	.415	.160	bce	188	306	-.148	.797	.381	abce	337	1034	.120	.782	.246
a	81	438	.062	.415	.156	bde	188	306	-.148	.797	.381	ae	304	942	.103	.705	.244
ab	81	438	.062	.415	.156	abde	188	306	-.148	.797	.381	ace	304	972	.083	.705	.238
c	36	188	.033	.185	.161	bcde	188	306	-.148	.797	.381	c	36	188	-.037	.084	.161
ac	81	492	.018	.415	.141	abce	188	306	-.148	.797	.381	a	81	438	-.092	.188	.156
abc	81	492	.018	.415	.141	abcde	188	306	-.148	.797	-	ac	81	492	-.127	.188	.141

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Tools: a - phpSAFE. b - RIPS. c - WAP. d Pixy. e - WeVerca.

Table 8 Best Solutions for the synthetic dataset: SQLi. XSS and SQLi + XSS: Medium-quality

SQLi						XSS						SQLi + XSS					
Tools	TP	FP	MM	TM	P/R	Tools	TP	FP	MM	TM	P/R	Tools	TP	FP	MM	TM	P/R
Medium-quality			F-Meas.	Rec.	Prec.				F-Meas.	Rec.	Prec.				F-Meas.	Rec.	Prec.
e	132	882	.205	.478	.130	d	81	90	.626	.921	.474	ce	176	910	.243	.484	.162
ce	132	882	.205	.478	.130	ad	81	90	.626	.921	.474	e	176	910	.243	.484	.162
ae	132	948	.195	.478	.122	bd	81	90	.626	.921	.474	ace	176	976	.232	.484	.153
ace	132	948	.195	.478	.122	cd	81	90	.626	.921	.474	ae	176	976	.232	.484	.153
de	265	2588	.169	.960	.093	de	81	90	.626	.921	.474	cde	346	2678	.204	.951	.114
cde	265	2588	.169	.960	.093	cde	81	90	.626	.921	.474	de	346	2678	.204	.951	.114
be	167	1553	.167	.605	.097	bde	81	90	.626	.921	.474	acde	346	2744	.200	.951	.112
bce	167	1553	.167	.605	.097	ade	81	90	.626	.921	.474	ade	346	2744	.200	.951	.112
ade	265	2654	.166	.960	.091	abd	81	90	.626	.921	.474	d	306	2400	.199	.841	.113
acde	265	2654	.166	.960	.091	acd	81	90	.626	.921	.474	cd	306	2400	.199	.841	.113
abe	167	1619	.162	.605	.094	bcd	81	90	.626	.921	.474	bcd	345	2811	.196	.948	.109
abce	167	1619	.162	.605	.094	abcd	81	90	.626	.921	.474	bd	345	2811	.196	.948	.109
bd	264	2721	.162	.957	.088	abde	81	90	.626	.921	.474	bce	211	1581	.196	.580	.118
bcd	264	2721	.162	.957	.088	bcde	81	90	.626	.921	.474	be	211	1581	.196	.580	.118
bde	274	2837	.162	.993	.088	acde	81	90	.626	.921	.474	ad	306	2466	.195	.841	.110
bcde	274	2837	.162	.993	.088	abcde	81	90	.626	.921	.474	acd	306	2466	.195	.841	.110
d	225	2310	.160	.815	.089	e	44	28	.550	.500	.611	bde	355	2927	.195	.975	.108
cd	225	2310	.160	.815	.089	ce	44	28	.550	.500	.611	bcde	355	2927	.195	.975	.108
abde	274	2903	.159	.993	.086	be	44	28	.550	.500	.611	abcd	345	2877	.192	.948	.107
abcde	274	2903	.159	.993	.086	ae	44	28	.550	.500	.611	abd	345	2877	.192	.948	.107
abd	264	2787	.159	.957	.087	abe	44	28	.550	.500	.611	abde	355	2993	.191	.975	.106
abcd	264	2787	.159	.957	.087	bce	44	28	.550	.500	.611	abcde	355	2993	.191	.975	.106
ad	225	2376	.156	.815	.087	ace	44	28	.550	.500	.611	abce	211	1647	.190	.580	.114
acd	225	2376	.156	.815	.087	abce	44	28	.550	.500	.611	abe	211	1647	.190	.580	.114
b	105	1155	.137	.380	.083	a	0	0	-	.000	-	b	105	1155	.129	.288	.083
bc	105	1155	.137	.380	.083	b	0	0	-	.000	-	bc	105	1155	.129	.288	.083
ab	105	1221	.131	.380	.079	c	0	0	-	.000	-	ab	105	1221	.124	.288	.079
abc	105	1221	.131	.380	.079	ab	0	0	-	.000	-	abc	105	1221	.124	.288	.079
c	0	0	-	-	-	ac	0	0	-	.000	-	ac	0	66	-	.000	.000
a	0	66	-	.000	.000	bc	0	0	-	.000	-	a	0	66	-	.000	.000
ac	0	66	-	.000	.000	abc	0	0	-	.000	-	c	0	0	-	-	-

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Infor. - Informedness. F-Meas. - F-Measure. Marked. - Markedness.
Tools: a - phpSAFE. b - RIPS. c - WAP. d Pixy. e - WeVerca.

Table 9 Best Solutions for the synthetic dataset regardless scenarios: SQLi. XSS and SQLi + XSS

SQLi						XSS						SQLi + XSS				
Tools	TP	FP	Pg	MM	TM	Tools	TP	FP	Pg	MM	TM	Tools	TP	FP	MM	TM
				Rec.	Prec.					Rec.	Prec.				Rec.	Prec.
bde	824	5621		.253	.128	abde	3559	4588		.017	.437	d	812	1836	.026	.154
bcde	824	5711		.243	.126	abcde	3559	4628		.010	.435	de	1612	4264	.009	.306
abde	824	5753		.238	.125	ade	3555	4500		.031	.441	bd	1714	4724	-.003	.326
abcde	824	5843		.227	.124	acde	3555	4540		.024	.439	bcd	3460	8135	.091	.657
ade	802	5261		.270	.132	bde	3495	4572		.005	.433	cd	4383	10471	.104	.833
acde	802	5351		.260	.130	bcde	3495	4612		-.002	.431	abd	3237	7876	.067	.615
de	797	4693		.331	.145	de	3479	4308		.047	.447	cde	3418	7735	.111	.649
cde	797	5002		.295	.137	cde	3479	4469		.019	.438	abcd	4383	10341	.113	.833
bd	666	4575		.201	.127	abcd	2794	3266		.072	.461	ad	3237	7744	.076	.615
abd	666	4707		.185	.124	abd	2752	3028		.104	.476	e	914	2296	.014	.174
bcd	666	4737		.182	.123	bcd	2730	3250		.060	.457	acd	3050	6793	.107	.579
abcd	666	4869		.167	.120	bd	2688	3012		.092	.472	bde	4357	9891	.139	.828
be	578	3820		.192	.131	abe	2659	3792		-.051	.412	ade	3146	6848	.121	.598
bce	578	3910		.181	.129	abce	2659	3834		-.058	.410	bcde	3008	6393	.126	.571
abe	578	3952		.176	.128	ae	2616	3680		-.041	.416	b	4357	9761	.148	.828
abce	578	4042		.166	.125	ace	2616	3722		-.049	.413	ce	3146	6716	.130	.598
ad	576	3885		.182	.129	be	2595	3776		-.063	.407	acde	1548	4116	.008	.294
acd	576	4047		.163	.125	bce	2595	3818		-.070	.405	abde	1650	4576	-.005	.313
d	531	3141		.219	.145	e	2535	3481		-.025	.421	be	3396	7987	.089	.645
cd	531	3582		.168	.129	ce	2535	3650		-.055	.410	bc	4319	10323	.102	.820
ae	530	3036		.230	.149	acd	2474	2746		.089	.474	abcde	3173	7728	.065	.603
ace	530	3126		.219	.145	ad	2432	2508		.121	.492	ab	3354	7587	.109	.637
ce	521	2752		.253	.159	cd	2232	2428		.089	.479	bce	4319	10193	.111	.820
e	494	2344		.270	.174	d	2160	1980		.151	.522	abe	3173	7596	.074	.603
b	312	2412		.063	.115	abc	1402	2018		-.030	.410	abc	507	1330	.004	.096
ab	312	2544		.048	.109	bc	1338	2002		-.042	.401	abce	2763	6010	.107	.525
bc	312	2574		.044	.108	ab	1300	1720		-.002	.431	ae	4276	9471	.153	.812
abc	312	2706		.029	.103	b	1236	1704		-.013	.420	ace	3056	6402	.135	.581
a	156	972		.059	.138	ac	758	1162		-.029	.395	c	2691	5121	.155	.511
ac	156	1134		.040	.121	a	656	864		.000	.432	a	4276	9001	.186	.812
c	99	618		.037	.138	c	408	712		.094	.364	ac	3029	5825	.170	.575

MM - Main Metric. TM - Tiebreaker Metric. Rec. - Recall. Prec. - Precision.
Infor. - Informedness. F-Meas. - F-Measure. Marked. - Markedness.
Tools: a - phpSAFE. b - RIPS. c - WAP. d Pixy. e - WeVerca.