

Table 3. The Time Cost (s) of Datalog Tools in Alias Analysis

benchmark	#Bddbddb	#Bddbddb_Q	#Soufflé	#Soufflé_Q
antlr	32.8144	141.8307	35.0751	297.0240
bloat	35.0884	143.7255	43.0332	325.6576
chart	98.6985	OOM	166.4251	1495.6658
eclipse	31.5554	143.4400	37.1262	305.575
fop	86.5511	OOM	127.5806	1030.0977
hsqldb	27.0256	129.6572	33.4026	289.6273
jython	36.5633	158.2006	48.7007	338.2145
luindex	28.1286	139.2618	33.7284	293.5388
lusearch	25.9214	127.3481	35.6444	300.2493
pmd	33.2137	139.5986	39.2113	312.2487
xalan	24.8578	122.685	31.0505	285.5684

Table 4. The Time Cost (s) of Datalog Tools in Data Dependence Analysis

benchmark	#Bddbddb	#Bddbddb_Q	#Soufflé	#Soufflé_Q
btree	0.8719	14.4030	0.2324	0.8354
check	1.7834	29.8846	1.9043	5.8171
compiler	1.4158	25.2306	1.1606	3.6035
compress	1.5622	24.9803	1.2353	3.8162
crypto	2.2462	34.9051	2.7487	8.2912
derby	2.0821	35.8188	2.4180	7.4305
helloworld	1.3285	22.4236	1.0894	3.3830
mpegaudio	3.4403	47.8261	6.0963	18.4269
mushroom	0.5947	10.2571	0.0687	0.3319
parser	0.8089	14.2149	0.1879	0.7040
sample	0.5738	10.9836	0.0714	0.3362
scimark	1.5378	29.1997	1.3720	4.1613
startup	1.9672	29.2309	2.0013	6.0261
sunflow	1.3185	22.1699	0.9987	3.0887
xml	15.4744	147.6023	45.7704	136.9710

A THE PERFORMANCE OF DATALOG TOOLS

Datalog tools are also widely used in static analysis, where they take analysis *rules* and a set of initial *facts* as input, and derive new *facts* based on these *rules*, ultimately computing the closure of all relations. In this section, we evaluate the performance of the corresponding Datalog tools on the two benchmarks. We selected two tools, Soufflé [23] and Bddbddb [66], and the analysis rules are shown as follows:

- (1) $Eq(x, y) \text{ :- } Eq(y, x)$
- (2) $Eq(x, z) \text{ :- } Eq(x, y), Eq(y, z)$
- (3) $Fun(x, f, z) \text{ :- } Fun(x, f, y), Eq(y, z)$
- (4) $Eq(x, y) \text{ :- } Fun(x, f, z), Fun(y, f, z)$

We evaluated Bddbddb and Soufflé on alias analysis and data dependency analysis. The experimental results are shown in Table 3 and Table 4, where #Bddbddb and #Soufflé represent the time taken by Bddbddb and Soufflé to compute the relation closure. Additionally, #Bddbddb_Q and #Soufflé_Q represent the total time for Bddbddb and Soufflé to compute the relation closure and execute queries, respectively. In the table, OOM (Out Of Memory) indicates that the memory limit has been exceeded. Due to the slower query speed of Bddbddb and Soufflé, we limited the queries to 1000 pairs of nodes.

Compared to the Dyck reachability-based method and the EUF SMT-based method, Datalog tools perform significantly worse across both benchmarks. For example, in alias analysis, Bddbddb and Soufflé take more than 20 seconds to compute the relation closure, whereas the Dyck reachability-based and EUF SMT-based methods typically complete the task in under 1 second, with some tools finishing in less than 0.1 seconds. In terms of query time, both the Dyck reachability-based method and the EUF SMT-based method complete a thousand queries within 0.06 seconds across all benchmarks, while Datalog tools take over a hundred seconds, even requiring around 0.2 seconds for smaller programs like mushroom. Furthermore, as the program size increases, the time cost of Datalog tools grows rapidly.

The Dyck reachability-based method and the EUF SMT-based method leverage the Union-Find data structure for handling equivalence relations. Experimental results show that this approach offers significant advantages over BDD-based methods when dealing with equivalence relations.