BioQueue: a novel pipeline framework to accelerate bioinformatics analysis

Supplementary Information

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Supplementary Note 1. The strategy to estimate the usage of memory. According to its implementation, BioQueue classifies the memory usage of a software into one of two categories: input insensitive and input sensitive. For input insensitive software, it will not store or just store a part of input data into memory, like HISAT2, to keep a balance between speed and memory usage. The memory usage of a software can be considered as a constant in some extent, so it can be estimated by calculating the mean usage. For input sensitive software, which prefers to store all input data into memory to achieve a high speed, the memory usage can be calculated by linear regression using the size of input data as explanatory variable.

Prior to estimating the memory usage of a software, BioQueue calculates the size of input data. During software execution, BioQueue monitors both physical and virtual memories used by the software and saves the maximum usage separately. When generating a model, BioQueue attempts to fit a linear regression model first; if the correlation coefficient satisfies the threshold, BioQueue will predict the memory usage by using this model. Otherwise, BioQueue will predict memory usage by calculating the mean size of training data.

When BioQueue dispatches jobs alone, it will consider both physical and virtual memory constraints. However, when BioQueue runs on clusters, though BioQueue will provide predictions for both physical and virtual memory usage, the final implementation will depend on the DRMs and operating system. For example, TorquePBS allows BioQueue to provide guidance on allocating both physical and virtual memories; however, for HTCondor 8.0+ on Linux distros, it only accepts the expected maximum physical memory needed by a processed job.

33   **Supplementary Note 2. Cluster plug-ins for BioQueue.** The support for clusters
34   depends on corresponding plug-ins. Each python file in the folder
35   "worker>>cluster_models" will be considered as a plug-in. BioQueue can directly
36   employ these plug-ins and users do not need to modify any code of BioQueue.
37   However, limited by the clusters accessible to us, BioQueue now just provides build-in
38   plug-ins for TorquePBS (already tested under production environment) and HTCondor
39   (only tested in virtual machines). Therefore, we expect our users who have the
40   privilege to access other types of DRMs can get involved in developing more cluster
41   plugins. We have provided a detailed guidance of developing new plug-ins for
42   BioQueue that is accessible at the documentation.
43
44
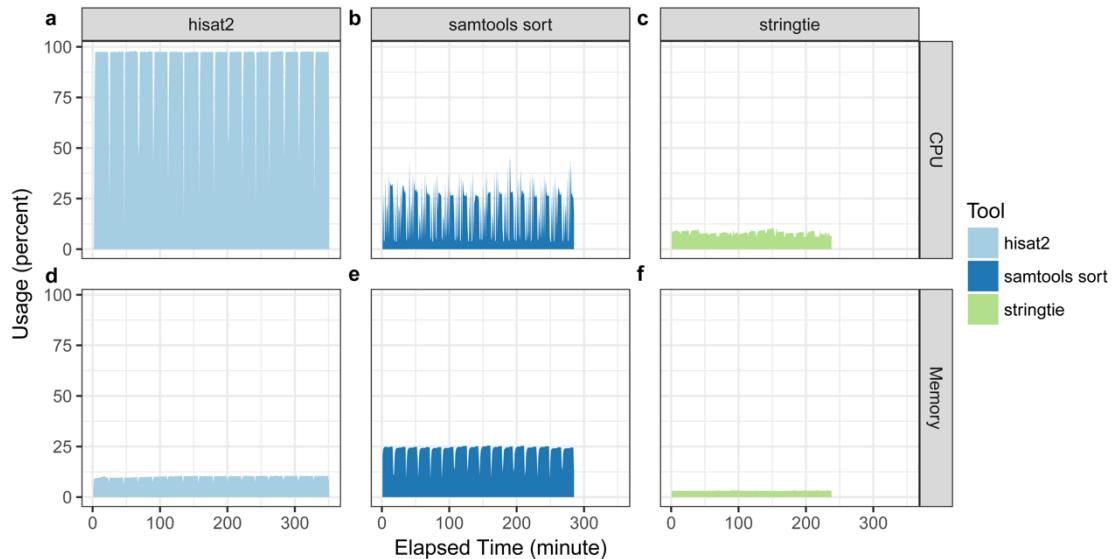
Supplementary Fig. 1. The CPU and memory usage of three popular tools in bioinformatics. Each tool is specified to launch 16 parallel threads on a server with 16 cores/64 GB of RAM. When mapping reads, hisat2 can fully use the CPU resources (a), but samtools **(b)** and stringtie **(c)** just use less than 50% of the CPU cores allotted to them due to the implementation of the software and hardware limits (such as I/O bottlenecks). In this case, the memory remains abundant **(d-f)**. However, for some memory-intensive tools (such as STAR), memory can be the bottleneck.
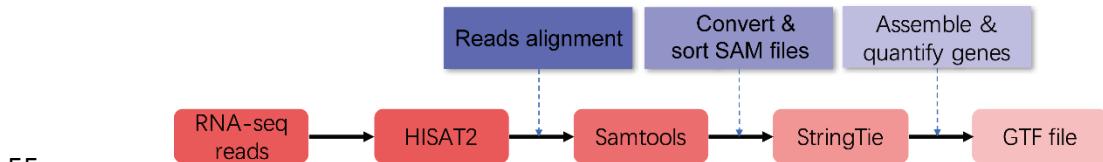
Supplementary Fig. 2. Benchmark test of the protocol. We used an actual biological data set, a previously published RNA-seq archive (E-MTAB-513) from the EBI ArrayExpress (http://www.ebi.ac.uk/arrayexpress), to run our test protocol, derived from the first three steps of a widely-used protocol (Pertea *et al*., 2016). We performed a benchmark test on a server with 16 cores/64 GB of RAM following this protocol. Software enrolled in the benchmark are listed in Supplementary Table 1.
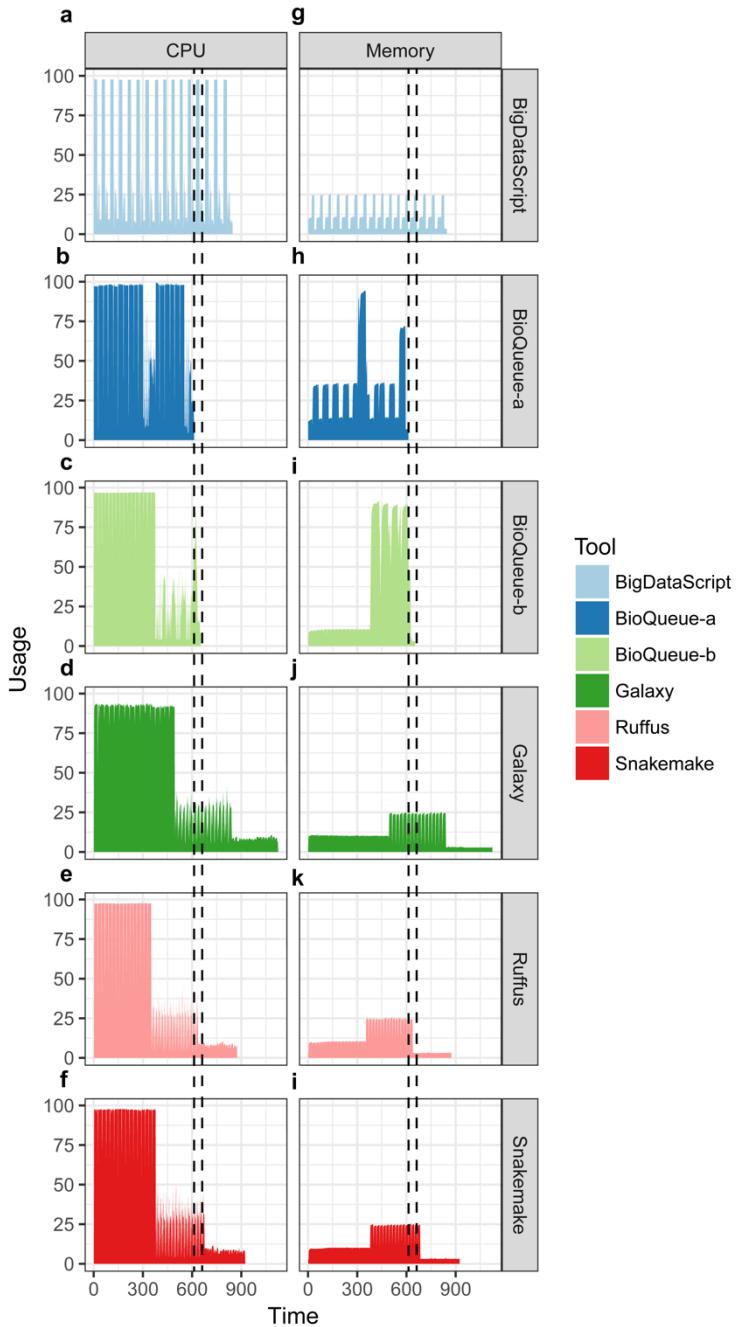
Supplementary Fig. 3. CPU and memory usage in the benchmark test. (a) to **(f)** The CPU cores used by these tools. **(g)** to **(i)** The memory used by these tools. In **(b)**, **(c)**, **(h)** and **(i)**, the graphs show that BioQueue accelerates the whole process by making a more sufficient use of the computing resources than others. "BioQueue-a" denotes running BioQueue with a prediction model that is automatically imported from BioQueue Open Platform (http://bioqueue.nefu.edu.cn), while "BioQueue-b" denotes running BioQueue without a pre-existing prediction model. Under both circumstances, BioQueue can boost the processes.
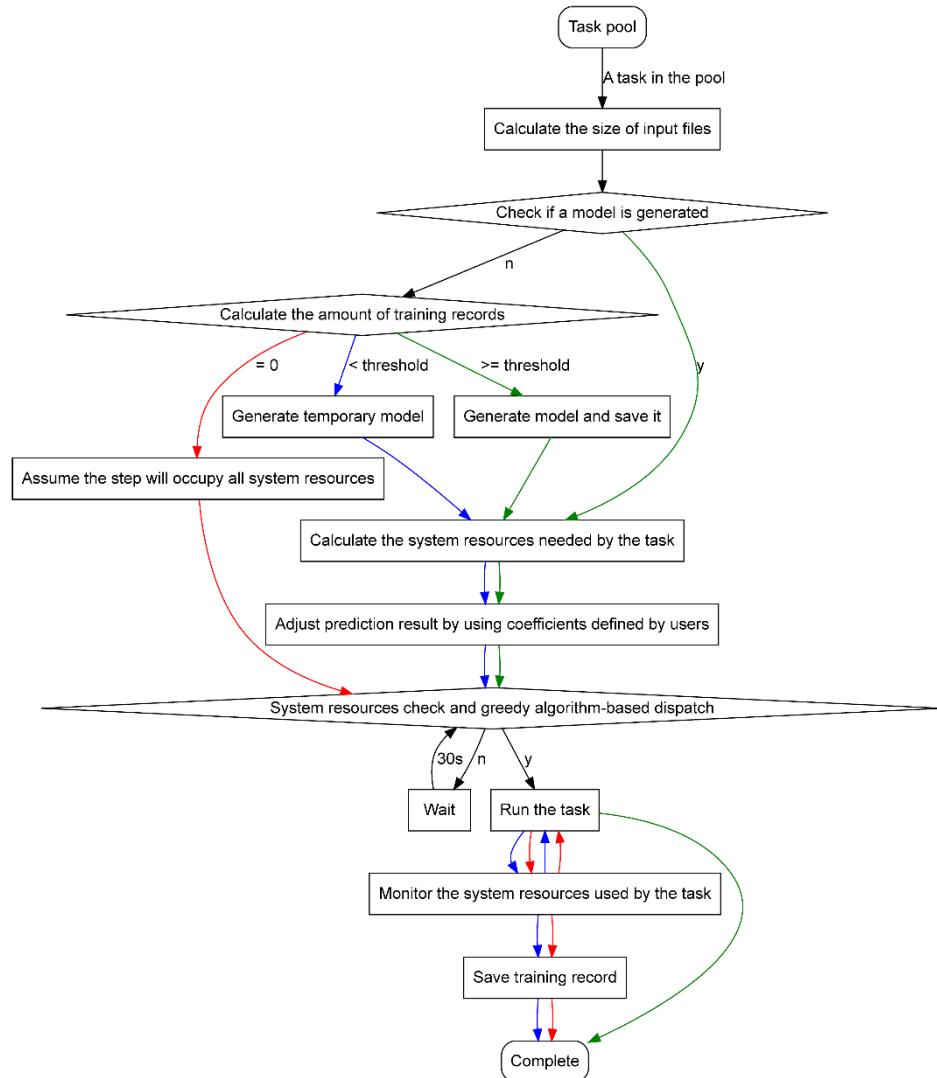
Supplementary Fig. 4. The training-monitoring-estimation logic of BioQueue running in a local or cloud environment. There are three circumstances for BioQueue: **(a)** when BioQueue runs a step without any previous experience (red lines), it assumes that the step will occupy all computing resources and starts a monitor process of detecting the system resources used by the task; **(b)** when BioQueue runs a step with limited experience insufficient to generate an optimal model (blue lines), it will also start the monitor process; **(c)** when BioQueue runs with a generated model (green lines), it will not start the monitor process. "threshold" in the graph means the minimum amount of training records to generate an optimal model.

Task pool

A task in the pool

Calculate the size of input files

Check if a model is generated

n

Calculate the amount of training records

= 0   < threshold   >= threshold   y

Generate temporary model   Generate model and save it

No guidance on allocating resources

Calculate the system resources needed by the task

Adjust prediction result by using coefficients defined by users

Submit the task via DRMs

y

Run the task

Monitor the system resources used by the task

Save training record

Complete

Supplementary Fig. 5. The training-monitoring-estimation logic of BioQueue running in a cluster. Similar to the strategy depicted in Supplementary Fig. 4, there are the same three circumstances for BioQueue. However, when running in a cluster, BioQueue uses predicted resources to guide DRMs to allocate computing resources rather than dispatch jobs directly.

Supplementary Table 1. Versions of software employed in the benchmark test of Supplementary Fig. 2.

Software	Version
hisat2	2.0.5
samtools	1.3.1
stringtie	1.3.3
BioQueue	1.0.0
BigDataScript	0.999
Galaxy	17.01
Ruffus	2.6.3
Snakemake	3.11.2

100 **Supplementary Table 2. Browser Compatibility of BioQueue workbench.** We carefully
101 tested BioQueue's workbench on all combinations (n=827) of operating systems and
102 browsers that we could access. The test proves that BioQueue is compatible to all
103 major browsers.
104

Operating System	Browser	Result
	Internet Explorer 8.0.6001.18702	✓
	Chrome 15.0.874.121	✓
	Chrome 16.0.912.77	✓
	Chrome 17.0.963.66	✓
	Chrome 18.0.1025.152	✓
	Chrome 19.0.1084.56	✓
	Chrome 20.0.1132.57	✓
	Chrome 21.0.1180.89	✓
	Chrome 22.0.1229.96	✓
	Chrome 23.0.1271.64	✓
	Chrome 24.0.1312.57	✓
	Chrome 25.0.1364.160	✓
	Chrome 26.0.1410.43	✓
	Chrome 27.0.1453.110	✓
	Chrome 28.0.1500.72	✓
Microsoft Windows XP	Chrome 29.0.1547.62	✓
n=117	Chrome 30.0.1599.101	✓
	Chrome 31.0.1650.57	✓
	Chrome 32.0.1700.76	✓
	Chrome 33.0.1750.117	✓
	Chrome 34.0.1847.116	✓
	Chrome 35.0.1916.114	✓
	Chrome 36.0.1985.125	✓
	Chrome 37.0.2062.102	✓
	Chrome 38.0.2125.101	✓
	Chrome 39.0.2171.65	✓
	Chrome 40.0.2214.94	✓
	Chrome 41.0.2272.89	✓
	Chrome 42.0.2311.135	✓
	Chrome 43.0.2357.65	✓
	Chrome 44.0.2403.89	✓
	Chrome 45.0.2454.85	✓
	Chrome 46.0.2490.71	✓

Chrome 47.0.2526.73	✓
Chrome 48.0.2564.97	✓
Chrome 49.0.2623.75	✓
Firefox 3.6.17	✓
Firefox 4.0.1	✓
Firefox 5.0.1	✓
Firefox 6.0	✓
Firefox 7.0	✓
Firefox 8.0.1	✓
Firefox 9.0.1	✓
Firefox 10.0	✓
Firefox 11.0	✓
Firefox 12.0	✓
Firefox 13.0	✓
Firefox 14.0.1	✓
Firefox 15.0	✓
Firefox 16.0.2	✓
Firefox 17.0.1	✓
Firefox 18.0.2	✓
Firefox 19.0.2	✓
Firefox 20.0.1	✓
Firefox 21.0	✓
Firefox 22.0	✓
Firefox 23.0.1	✓
Firefox 24.0	✓
Firefox 25.0	✓
Firefox 26.0	✓
Firefox 27.0	✓
Firefox 28.0	✓
Firefox 29.0	✓
Firefox 30.0	✓
Firefox 31.0	✓
Firefox 32.0	✓
Firefox 33.1.1	✓
Firefox 34.0.5	✓
Firefox 35.0	✓
Firefox 36.0	✓
Firefox 37.0.1	✓
Firefox 38.0	✓

Firefox 40.0	✓
Firefox 41.0	✓
Firefox 42.0	✓
Firefox 43.0	✓
Firefox 44.0	✓
Firefox 45.0	✓
Firefox 46.0	✓
Firefox 47.0.1	✓
Firefox 48.0	✓
Firefox 49.0	✓
Firefox 50.0	✓
Firefox 51.0	✓
Firefox 52.0	✓
Opera 10.6	✓
Opera 11.11	✓
Opera 11.51	✓
Opera 11.62	✓
Opera 12.10	✓
Opera 12.14	✓
Opera 12.15	✓
Opera 12.16	✓
Opera 15.0.1147.153	✓
Opera 18.0.1284.68	✓
Opera 19.0.1326.63	✓
Opera 20.0.1387.64	✓
Opera 21.0.1432.57	✓
Opera 22.0.1471.50	✓
Opera 23.0.1522.60	✓
Opera 24.0.1558.53	✓
Opera 25.0.1614.50	✓
Opera 26.0.1656.32	✓
Opera 27.0.1689.54	✓
Opera 28.0.1750.48	✓
Opera 29.0.1795.47	✓
Opera 30.0.1835.59	✓
Opera 31.0.1889.99	✓
Opera 32.0.1948.25	✓
Opera 33.0.1990.43	✓
Opera 34.0.2036.25	✓

	Opera 35.0.2066.37	✓
	Opera 36.0.2130.32	✓
	Yandex 14.12.2125.9579	✓
	Safari 4.0.5 (531.22.7)	✓
	Safari 5.0.5 (7533.21.1)	✓
	Safari 5.1.7 (7534.57.2)	✓
Microsoft Windows 7 n=145	Internet Explorer 8.0.7601.17514	✓
	Internet Explorer 9.0.8112.16421	✓
	Internet Explorer 10.0.9200.16521	✓
	Internet Explorer 11.0.9600.16428IS	✓
	Chrome 15.0.874.121	✓
	Chrome 16.0.912.77	✓
	Chrome 17.0.963.66	✓
	Chrome 18.0.1025.152	✓
	Chrome 19.0.1084.56	✓
	Chrome 20.0.1132.57	✓
	Chrome 21.0.1180.89	✓
	Chrome 22.0.1229.96	✓
	Chrome 23.0.1271.64	✓
	Chrome 24.0.1312.57	✓
	Chrome 25.0.1364.160	✓
	Chrome 26.0.1410.43	✓
	Chrome 27.0.1453.110	✓
	Chrome 28.0.1500.72	✓
	Chrome 29.0.1547.62	✓
	Chrome 30.0.1599.101	✓
	Chrome 31.0.1650.57	✓
	Chrome 32.0.1700.76	✓
	Chrome 33.0.1750.117	✓
	Chrome 34.0.1847.116	✓
	Chrome 35.0.1916.114	✓
	Chrome 36.0.1985.125	✓
	Chrome 37.0.2062.102	✓
	Chrome 38.0.2125.101	✓
	Chrome 39.0.2171.65	✓
	Chrome 40.0.2214.94	✓
	Chrome 41.0.2272.89	✓
	Chrome 42.0.2311.135	✓
	Chrome 43.0.2357.65	✓

Chrome 44.0.2403.89	✓
Chrome 45.0.2454.85	✓
Chrome 46.0.2490.71	✓
Chrome 47.0.2526.73	✓
Chrome 48.0.2564.97	✓
Chrome 49.0.2623.75	✓
Chrome 50.0.2661.75	✓
Chrome 51.0.2704.79	✓
Chrome 52.0.2743.82	✓
Chrome 53.0.2785.101	✓
Chrome 54.0.2840.59	✓
Chrome 55.0.2883.75	✓
Chrome 56.0.2924.87	✓
Chrome 57.0.2987.110	✓
Chrome 58.0.3029.81	✓
Chrome 59.0.3071.15	✓
Firefox 3.6.17	✓
Firefox 4.0.1	✓
Firefox 5.0.1	✓
Firefox 6.0	✓
Firefox 7.0	✓
Firefox 8.0.1	✓
Firefox 9.0.1	✓
Firefox 10.0	✓
Firefox 11.0	✓
Firefox 12.0	✓
Firefox 13.0	✓
Firefox 14.0.1	✓
Firefox 15.0	✓
Firefox 16.0.2	✓
Firefox 17.0.1	✓
Firefox 18.0.2	✓
Firefox 19.0.2	✓
Firefox 20.0.1	✓
Firefox 21.0	✓
Firefox 22.0	✓
Firefox 23.0.1	✓
Firefox 24.0	✓
Firefox 25.0	✓

Firefox 26.0	✓
Firefox 27.0	✓
Firefox 28.0	✓
Firefox 29.0	✓
Firefox 30.0	✓
Firefox 31.0	✓
Firefox 32.0	✓
Firefox 33.1.1	✓
Firefox 34.0.5	✓
Firefox 35.0	✓
Firefox 36.0	✓
Firefox 37.0.1	✓
Firefox 38.0	✓
Firefox 40.0	✓
Firefox 41.0	✓
Firefox 42.0	✓
Firefox 43.0	✓
Firefox 44.0	✓
Firefox 45.0	✓
Firefox 46.0	✓
Firefox 47.0.1	✓
Firefox 48.0	✓
Firefox 49.0	✓
Firefox 50.0	✓
Firefox 51.0	✓
Firefox 52.0	✓
Firefox 53.0	✓
Firefox 54.0b1	✓
Opera 10.6	✓
Opera 11.11	✓
Opera 11.51	✓
Opera 11.62	✓
Opera 12.10	✓
Opera 12.14	✓
Opera 12.15	✓
Opera 12.16	✓
Opera 15.0.1147.153	✓
Opera 16.0.1196.73	✓
Opera 17.0.1241.53	✓

Opera 18.0.1284.68	✓
Opera 19.0.1326.63	✓
Opera 20.0.1387.64	✓
Opera 21.0.1432.57	✓
Opera 22.0.1471.50	✓
Opera 23.0.1522.60	✓
Opera 24.0.1558.53	✓
Opera 25.0.1614.50	✓
Opera 26.0.1656.32	✓
Opera 27.0.1689.54	✓
Opera 28.0.1750.48	✓
Opera 29.0.1795.47	✓
Opera 30.0.1835.59	✓
Opera 31.0.1889.99	✓
Opera 32.0.1948.25	✓
Opera 33.0.1990.43	✓
Opera 34.0.2036.25	✓
Opera 35.0.2066.37	✓
Opera 36.0.2130.32	✓
Opera 37.0.2178.32	✓
Opera 38.0.2220.29	✓
Opera 39.0.2256.43	✓
Opera 40.0.2308.54	✓
Opera 41.0.2353.46	✓
Opera 42.0.2393.85	✓
Opera 43.0.2442.806	✓
Opera 44.0.2510.1449	✓
Opera 44.0.2510.857	✓
Opera 45.0.2552.635	✓
Opera 46.0.2573.0	✓
Yandex 14.12.2125.9579	✓
Safari 4.0.5 (531.22.7)	✓
Safari 5.0.5 (7533.21.1)	✓
Safari 5.1.7 (7534.57.2)	✓

Microsoft Windows 8 n=116	Internet Explorer 10.0.9200.17228	✓
	Internet Explorer 10.0.9200.17229 (Metro)	✓
	Chrome 22.0.1229.96	✓
	Chrome 23.0.1271.64	✓
	Chrome 24.0.1312.57	✓

Chrome 25.0.1364.160	✓
Chrome 26.0.1410.43	✓
Chrome 27.0.1453.110	✓
Chrome 28.0.1500.72	✓
Chrome 29.0.1547.62	✓
Chrome 30.0.1599.101	✓
Chrome 31.0.1650.57	✓
Chrome 32.0.1700.76	✓
Chrome 33.0.1750.117	✓
Chrome 34.0.1847.116	✓
Chrome 35.0.1916.114	✓
Chrome 36.0.1985.125	✓
Chrome 37.0.2062.102	✓
Chrome 38.0.2125.101	✓
Chrome 39.0.2171.65	✓
Chrome 40.0.2214.94	✓
Chrome 41.0.2272.89	✓
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Chrome 43.0.2357.65	✓
Chrome 44.0.2403.89	✓
Chrome 45.0.2454.85	✓
Chrome 46.0.2490.71	✓
Chrome 47.0.2526.73	✓
Chrome 48.0.2564.97	✓
Chrome 49.0.2623.75	✓
Chrome 50.0.2661.75	✓
Chrome 51.0.2704.79	✓
Chrome 52.0.2743.82	✓
Chrome 53.0.2785.101	✓
Chrome 54.0.2840.59	✓
Chrome 55.0.2883.75	✓
Chrome 56.0.2924.87	✓
Chrome 57.0.2987.110	✓
Chrome 58.0.3029.81	✓
Chrome 59.0.3071.15	✓
Firefox 16.0.2	✓
Firefox 17.0.1	✓
Firefox 18.0.2	✓
Firefox 19.0.2	✓

Firefox 20.0.1	✓
Firefox 21.0	✓
Firefox 22.0	✓
Firefox 23.0.1	✓
Firefox 24.0	✓
Firefox 25.0	✓
Firefox 26.0	✓
Firefox 27.0	✓
Firefox 28.0	✓
Firefox 29.0	✓
Firefox 30.0	✓
Firefox 31.0	✓
Firefox 32.0	✓
Firefox 33.1.1	✓
Firefox 34.0.5	✓
Firefox 35.0	✓
Firefox 36.0	✓
Firefox 37.0.1	✓
Firefox 38.0	✓
Firefox 40.0	✓
Firefox 41.0	✓
Firefox 42.0	✓
Firefox 43.0	✓
Firefox 44.0	✓
Firefox 45.0	✓
Firefox 46.0	✓
Firefox 47.0.1	✓
Firefox 48.0	✓
Firefox 49.0	✓
Firefox 50.0	✓
Firefox 51.0	✓
Firefox 52.0	✓
Firefox 53.0	✓
Firefox 54.0b1	✓
Opera 12.10	✓
Opera 12.14	✓
Opera 12.15	✓
Opera 12.16	✓
Opera 15.0.1147.153	✓

	Opera 16.0.1196.73	✓
	Opera 17.0.1241.53	✓
	Opera 18.0.1284.68	✓
	Opera 19.0.1326.63	✓
	Opera 20.0.1387.64	✓
	Opera 21.0.1432.57	✓
	Opera 22.0.1471.50	✓
	Opera 23.0.1522.60	✓
	Opera 24.0.1558.53	✓
	Opera 25.0.1614.50	✓
	Opera 26.0.1656.32	✓
	Opera 27.0.1689.54	✓
	Opera 28.0.1750.48	✓
	Opera 29.0.1795.47	✓
	Opera 30.0.1835.59	✓
	Opera 31.0.1889.99	✓
	Opera 32.0.1948.25	✓
	Opera 33.0.1990.43	✓
	Opera 34.0.2036.25	✓
	Opera 35.0.2066.37	✓
	Opera 36.0.2130.32	✓
	Opera 37.0.2178.32	✓
	Opera 38.0.2220.29	✓
	Opera 39.0.2256.43	✓
	Opera 40.0.2308.54	✓
	Opera 41.0.2353.46	✓
	Opera 42.0.2393.85	✓
	Opera 43.0.2442.806	✓
	Opera 44.0.2510.857	✓
	Opera 45.0.2552.635	✓
	Opera 46.0.2573.0	✓
	Yandex 14.12.2125.9579	✓
	Safari 5.1.7 (7534.57.2)	✓
	Internet Explorer 11.0.9600.16663	✓
	Internet Explorer 11.0.9600.16663 (Metro)	✓
Microsoft Windows 8.1 n=116	Chrome 22.0.1229.96	✓
	Chrome 23.0.1271.64	✓
	Chrome 24.0.1312.57	✓
	Chrome 25.0.1364.160	✓

Chrome 26.0.1410.43	✓
Chrome 27.0.1453.110	✓
Chrome 28.0.1500.72	✓
Chrome 29.0.1547.62	✓
Chrome 30.0.1599.101	✓
Chrome 31.0.1650.57	✓
Chrome 32.0.1700.76	✓
Chrome 33.0.1750.117	✓
Chrome 34.0.1847.116	✓
Chrome 35.0.1916.114	✓
Chrome 36.0.1985.125	✓
Chrome 37.0.2062.102	✓
Chrome 38.0.2125.101	✓
Chrome 39.0.2171.65	✓
Chrome 40.0.2214.94	✓
Chrome 41.0.2272.89	✓
Chrome 42.0.2311.135	✓
Chrome 43.0.2357.65	✓
Chrome 44.0.2403.89	✓
Chrome 45.0.2454.85	✓
Chrome 46.0.2490.71	✓
Chrome 47.0.2526.73	✓
Chrome 48.0.2564.97	✓
Chrome 49.0.2623.75	✓
Chrome 50.0.2661.75	✓
Chrome 51.0.2704.79	✓
Chrome 52.0.2743.82	✓
Chrome 53.0.2785.101	✓
Chrome 54.0.2840.59	✓
Chrome 55.0.2883.75	✓
Chrome 56.0.2924.87	✓
Chrome 57.0.2987.110	✓
Chrome 58.0.3029.81	✓
Chrome 59.0.3071.15	✓
Firefox 16.0.2	✓
Firefox 17.0.1	✓
Firefox 18.0.2	✓
Firefox 19.0.2	✓
Firefox 20.0.1	✓

Firefox 21.0	✓
Firefox 22.0	✓
Firefox 23.0.1	✓
Firefox 24.0	✓
Firefox 25.0	✓
Firefox 26.0	✓
Firefox 27.0	✓
Firefox 28.0	✓
Firefox 29.0	✓
Firefox 30.0	✓
Firefox 31.0	✓
Firefox 32.0	✓
Firefox 33.1.1	✓
Firefox 34.0.5	✓
Firefox 35.0	✓
Firefox 36.0	✓
Firefox 37.0.1	✓
Firefox 38.0	✓
Firefox 40.0	✓
Firefox 41.0	✓
Firefox 42.0	✓
Firefox 43.0	✓
Firefox 44.0	✓
Firefox 45.0	✓
Firefox 46.0	✓
Firefox 47.0.1	✓
Firefox 48.0	✓
Firefox 49.0	✓
Firefox 50.0	✓
Firefox 51.0	✓
Firefox 52.0	✓
Firefox 53.0	✓
Firefox 54.0b1	✓
Opera 12.10	✓
Opera 12.14	✓
Opera 12.15	✓
Opera 12.16	✓
Opera 15.0.1147.153	✓
Opera 16.0.1196.73	✓

	Opera 17.0.1241.53	✓
	Opera 18.0.1284.68	✓
	Opera 19.0.1326.63	✓
	Opera 20.0.1387.64	✓
	Opera 21.0.1432.57	✓
	Opera 22.0.1471.50	✓
	Opera 23.0.1522.60	✓
	Opera 24.0.1558.53	✓
	Opera 25.0.1614.50	✓
	Opera 26.0.1656.32	✓
	Opera 27.0.1689.54	✓
	Opera 28.0.1750.48	✓
	Opera 29.0.1795.47	✓
	Opera 30.0.1835.59	✓
	Opera 31.0.1889.99	✓
	Opera 32.0.1948.25	✓
	Opera 33.0.1990.43	✓
	Opera 34.0.2036.25	✓
	Opera 35.0.2066.37	✓
	Opera 36.0.2130.32	✓
	Opera 37.0.2178.32	✓
	Opera 38.0.2220.29	✓
	Opera 39.0.2256.43	✓
	Opera 40.0.2308.54	✓
	Opera 41.0.2353.46	✓
	Opera 42.0.2393.85	✓
	Opera 43.0.2442.806	✓
	Opera 44.0.2510.857	✓
	Opera 45.0.2552.635	✓
	Opera 46.0.2573.0	✓
	Yandex 14.12.2125.9579	✓
	Safari 5.1.7 (7534.57.2)	✓
Microsoft Windows 10 n=74	Microsoft Edge 15 (40.15063.0.0)	✓
	Microsoft Edge 14 (38.14393.0.0)	✓
	Internet Explorer 11.0.15063.0	✓
	Chrome 37.0.2062.102	✓
	Chrome 38.0.2125.101	✓
	Chrome 39.0.2171.65	✓
	Chrome 40.0.2214.94	✓

Chrome 41.0.2272.89	✓
Chrome 42.0.2311.135	✓
Chrome 43.0.2357.65	✓
Chrome 44.0.2403.89	✓
Chrome 45.0.2454.85	✓
Chrome 46.0.2490.71	✓
Chrome 47.0.2526.73	✓
Chrome 48.0.2564.97	✓
Chrome 49.0.2623.75	✓
Chrome 50.0.2661.75	✓
Chrome 51.0.2704.79	✓
Chrome 52.0.2743.82	✓
Chrome 53.0.2785.113	✓
Chrome 54.0.2840.59	✓
Chrome 55.0.2883.75	✓
Chrome 56.0.2924.87	✓
Chrome 57.0.2987.110	✓
Chrome 58.0.3029.81	✓
Chrome 59.0.3071.16	✓
Firefox 32.0	✓
Firefox 33.1.1	✓
Firefox 34.0.5	✓
Firefox 35.0	✓
Firefox 36.0	✓
Firefox 37.0.1	✓
Firefox 38.0	✓
Firefox 40.0	✓
Firefox 41.0	✓
Firefox 42.0	✓
Firefox 43.0	✓
Firefox 44.0	✓
Firefox 45.0	✓
Firefox 46.0	✓
Firefox 47.0.1	✓
Firefox 48.0	✓
Firefox 49.0	✓
Firefox 50.0	✓
Firefox 51.0	✓
Firefox 52.0	✓

Firefox 53.0	✓
Firefox 54.0b1	✓
Opera 23.0.1522.60	✓
Opera 24.0.1558.53	✓
Opera 25.0.1614.50	✓
Opera 26.0.1656.32	✓
Opera 27.0.1689.54	✓
Opera 28.0.1750.48	✓
Opera 29.0.1795.47	✓
Opera 30.0.1835.59	✓
Opera 31.0.1889.99	✓
Opera 32.0.1948.25	✓
Opera 33.0.1990.43	✓
Opera 34.0.2036.25	✓
Opera 35.0.2066.37	✓
Opera 36.0.2130.32	✓
Opera 37.0.2178.32	✓
Opera 38.0.2220.29	✓
Opera 39.0.2256.43	✓
Opera 40.0.2308.54	✓
Opera 41.0.2353.46	✓
Opera 42.0.2393.85	✓
Opera 43.0.2442.806	✓
Opera 44.0.2510.857	✓
Opera 45.0.2552.635	✓
Opera 46.0.2573.0	✓
Yandex 14.12.2125.9579	✓
Safari 5.1.7 (7534.57.2)	✓

	Safari 4.0.5 (6531.22.7, 6531.22)	✓
	Safari 5.0.5 (6533.21.1, 6533.21)	✓
	Safari 5.1.9 (6534.59.8)	✓
	Firefox 4.0.1	✓
	Firefox 39.0.3	✓
OS X Snow Leopard n=42	Firefox 40.0	✓
	Firefox 41.0	✓
	Firefox 42.0	✓
	Firefox 43.0	✓
	Firefox 44.0	✓
	Firefox 45.0	✓

	Firefox 46.0	✓
	Firefox 47.0.1	✓
	Firefox 48.0	✓
	Chrome 16.0.912.75	✓
	Chrome 40.0.2214.93	✓
	Chrome 41.0.2272.76	✓
	Chrome 42.0.2311.135	✓
	Chrome 43.0.2357.65	✓
	Chrome 44.0.2403.89	✓
	Chrome 45.0.2454.85	✓
	Chrome 46.0.2490.71	✓
	Chrome 47.0.2526.73	✓
	Chrome 48.0.2564.97	✓
	Chrome 49.0.2623.75	✓
	Opera 11.11.2109	✓
	Opera 11.62.1347	✓
	Opera 12.00.1467	✓
	Opera 12.12.1707	✓
	Opera 12.14.1738	✓
	Opera 12.15.1748	✓
	Opera 15.0.1147.153	✓
	Opera 16.0.1196.73	✓
	Opera 17.0.1241.53	✓
	Opera 18.0.1284.68	✓
	Opera 19.0.1326.59	✓
	Opera 20.0.1387.64	✓
	Opera 21.0.1432.57	✓
	Opera 22.0.1471.50	✓
	Opera 23.0.1522.60	✓
	Opera 24.0.1558.53	✓
	Opera 25.0.1614.50	✓
	Safari 5.1.5 (6534.55.3)	✓
	Safari 6.0.5 (7536.30.1)	✓
	Firefox 3.6.28	✓
OS X Lion	Firefox 4.0.1	✓
n=37	Firefox 34.0.5	✓
	Firefox 35.0	✓
	Firefox 36.0	✓
	Firefox 37.0.1	✓

	Firefox 38.0	✓
	Firefox 40.0	✓
	Firefox 41.0	✓
	Firefox 42.0	✓
	Firefox 43.0	✓
	Firefox 43.0	✓
	Firefox 44.0	✓
	Chrome 16.0.912.75	✓
	Chrome 40.0.2214.93	✓
	Chrome 41.0.2272.76	✓
	Chrome 42.0.2311.135	✓
	Chrome 43.0.2357.65	✓
	Chrome 44.0.2403.89	✓
	Chrome 45.0.2454.85	✓
	Chrome 46.0.2490.71	✓
	Chrome 47.0.2526.73	✓
	Chrome 48.0.2564.97	✓
	Chrome 49.0.2623.75	✓
	Opera 11.11.2109	✓
	Opera 28.0.1750.48	✓
	Opera 29.0.1795.47	✓
	Opera 30.0.1835.59	✓
	Opera 31.0.1889.99	✓
	Opera 32.0.1948.25	✓
	Opera 33.0.1990.43	✓
	Opera 34.0.2036.25	✓
	Opera 35.0.2066.37	✓
	Opera 36.0.2130.32	✓
	Opera 37.0.2178.32	✓
OS X Mountain Lion n=36	Safari 6.2.8 (8537.85.17.9.1)	✓
	Firefox 3.6.28	✓
	Firefox 39.0.3	✓
	Firefox 40.0	✓
	Firefox 41.0	✓
	Firefox 42.0	✓
	Firefox 43.0	✓
	Firefox 44.0	✓
	Firefox 45.0	✓
	Firefox 46.0	✓

Firefox 47.0.1	✓
Firefox 48.0	✓
Chrome 16.0.912.75	✓
Chrome 39.0.2171.65	✓
Chrome 40.0.2214.93	✓
Chrome 41.0.2272.76	✓
Chrome 42.0.2311.135	✓
Chrome 43.0.2357.65	✓
Chrome 44.0.2403.89	✓
Chrome 45.0.2454.85	✓
Chrome 46.0.2490.71	✓
Chrome 47.0.2526.73	✓
Chrome 48.0.2564.97	✓
Chrome 49.0.2623.75	✓
Opera 11.11.2109	✓
Opera 28.0.1750.48	✓
Opera 29.0.1795.47	✓
Opera 30.0.1835.59	✓
Opera 31.0.1889.99	✓
Opera 32.0.1948.25	✓
Opera 33.0.1990.43	✓
Opera 34.0.2036.25	✓
Opera 35.0.2066.37	✓
Opera 36.0.2130.32	✓
Opera 37.0.2178.32	✓
Yandex 14.12.2125.9577	✓
OS X Mavericks n=35	Safari 7.1.8 (9537.85.17.9.1)	✓
	Firefox 4.0.1	✓
	Firefox 45.0	✓
	Firefox 46.0	✓
	Firefox 47.0.1	✓
	Firefox 48.0	✓
	Firefox 49.0	✓
	Firefox 50.0	✓
	Firefox 51.0	✓
	Firefox 52.0	✓
	Firefox 53.0	✓
	Firefox 54.0b1	✓
	Chrome 16.0.912.75	✓

	Chrome 50.0.2661.75	✓
	Chrome 51.0.2704.79	✓
	Chrome 52.0.2743.82	✓
	Chrome 53.0.2785.89	✓
	Chrome 54.0.2840.59	✓
	Chrome 55.0.2883.75	✓
	Chrome 56.0.2924.76	✓
	Chrome 57.0.2987.98	✓
	Chrome 58.0.3029.81	✓
	Chrome 59.0.3071.15	✓
	Opera 11.11.2109	✓
	Opera 37.0.2178.32	✓
	Opera 38.0.2220.29	✓
	Opera 39.0.2256.43	✓
	Opera 40.0.2308.54	✓
	Opera 41.0.2353.46	✓
	Opera 42.0.2393.85	✓
	Opera 43.0.2442.806	✓
	Opera 44.0.2510.857	✓
	Opera 45.0.2552.635	✓
	Opera 46.0.2573.0	✓
	Yandex 14.12.2125.9577	✓
OS X Yosemite n=35	Safari 8.0.8 (10600.8.9)	✓
	Firefox 3.6.28	✓
	Firefox 45.0	✓
	Firefox 46.0	✓
	Firefox 47.0.1	✓
	Firefox 48.0	✓
	Firefox 49.0	✓
	Firefox 50.0	✓
	Firefox 51.0	✓
	Firefox 52.0	✓
	Firefox 53.0	✓
	Firefox 54.0b1	✓
	Chrome 16.0.912.75	✓
	Chrome 50.0.2661.75	✓
	Chrome 51.0.2704.79	✓
	Chrome 52.0.2743.82	✓
	Chrome 53.0.2785.89	✓

	Chrome 54.0.2840.59	✓
	Chrome 55.0.2883.75	✓
	Chrome 56.0.2924.76	✓
	Chrome 57.0.2987.98	✓
	Chrome 58.0.3029.81	✓
	Chrome 59.0.3071.15	✓
	Opera 12.12.1707	✓
	Opera 37.0.2178.32	✓
	Opera 38.0.2220.29	✓
	Opera 39.0.2256.43	✓
	Opera 40.0.2308.54	✓
	Opera 41.0.2353.46	✓
	Opera 42.0.2393.85	✓
	Opera 43.0.2442.806	✓
	Opera 44.0.2510.857	✓
	Opera 45.0.2552.635	✓
	Opera 46.0.2573.0	✓
	Yandex 14.12.2125.9577	✓
OS X EI Capitan n=36	Safari 9.1.3 (11601.7.8)	✓
	Safari Technology Preview 9.1.1	✓
	Firefox 4.0.1	✓
	Firefox 45.0	✓
	Firefox 46.0	✓
	Firefox 47.0.1	✓
	Firefox 48.0	✓
	Firefox 49.0	✓
	Firefox 50.0	✓
	Firefox 51.0	✓
	Firefox 52.0	✓
	Firefox 53.0	✓
	Firefox 54.0b1	✓
	Chrome 16.0.912.75	✓
	Chrome 50.0.2661.75	✓
	Chrome 51.0.2704.79	✓
	Chrome 52.0.2743.82	✓
	Chrome 53.0.2785.89	✓
	Chrome 54.0.2840.59	✓
	Chrome 55.0.2883.75	✓
	Chrome 56.0.2924.76	✓

	Chrome 57.0.2987.98	✓
	Chrome 58.0.3029.81	✓
	Chrome 59.0.3071.15	✓
	Opera 12.12.1707	✓
	Opera 37.0.2178.32	✓
	Opera 38.0.2220.29	✓
	Opera 39.0.2256.43	✓
	Opera 40.0.2308.54	✓
	Opera 41.0.2353.46	✓
	Opera 42.0.2393.85	✓
	Opera 43.0.2442.806	✓
	Opera 44.0.2510.857	✓
	Opera 45.0.2552.635	✓
	Opera 46.0.2573.0	✓
	Yandex 14.12.2125.9577	✓
	Safari 10.1 (12603.1.30.0.34)	✓
	Firefox 11.0	✓
	Firefox 45.0	✓
	Firefox 46.0	✓
	Firefox 47.0.1	✓
	Firefox 48.0	✓
	Firefox 49.0	✓
	Firefox 50.0	✓
	Firefox 51.0	✓
	Firefox 52.0	✓
	Firefox 53.0	✓
OS X Sierra	Firefox 54.0b1	✓
n=35	Chrome 27.0.1453.116	✓
	Chrome 50.0.2661.75	✓
	Chrome 51.0.2704.79	✓
	Chrome 52.0.2743.82	✓
	Chrome 53.0.2785.89	✓
	Chrome 54.0.2840.59	✓
	Chrome 55.0.2883.75	✓
	Chrome 56.0.2924.76	✓
	Chrome 57.0.2987.98	✓
	Chrome 58.0.3029.81	✓
	Chrome 59.0.3071.15	✓
	Opera 12.12.1707	✓

	Opera 37.0.2178.32	✓
	Opera 38.0.2220.29	✓
	Opera 39.0.2256.43	✓
	Opera 40.0.2308.54	✓
	Opera 41.0.2353.46	✓
	Opera 42.0.2393.85	✓
	Opera 43.0.2442.806	✓
	Opera 44.0.2510.857	✓
	Opera 45.0.2552.635	✓
	Opera 46.0.2573.0	✓
	Yandex 14.12.2125.9577	✓
Ubuntu 14.04.5 n=3	Chrome 58.0.3029.81	✓
	Firefox 47.0	✓
	Browser 0.23	✓

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