Advanced Systems Lab (Fall'16) – Third Milestone

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Grading

Section	Points
1	
2	
3	
4	
5	
Total	

Contents

1 System as One Unit

1.1 Data

The experimental data used in this section comes from the updated trace experiment, found in results/trace_rep3 (short names `trace_ms*`, `trace_mw` and `trace_req` in Milestone 1). For details, see Milestone 2, Appendix A.

The first 2 minutes and last 2 minutes were dropped as warm-up and cool-down time similarly to previous milestones.

1.2 Model

In this section I create an M/M/1 model of the system. This means the following definitions and assumptions:

- The queues are defined as having infinite buffer capacity.
- The population size is infinite.
- The service discipline is FCFS.
- Interarrival times and the service times are exponentially distributed.
- We treat the SUT as a single server and as a black box.
- Arrivals are individual, so we have a birth-death process.

Parameter estimation Using the available experimental data, it is not possible to directly calculate the mean arrival rate λ and mean service rate μ so we need to estimate them somehow. I estimated both using throughput of the system: I take λ to be the *mean* throughput over 1-second windows, and μ to be the the *maximum* throughput in any 1-second window, calculated from middleware logs. I chose a 1-second window because a too small window is highly susceptible to noise whereas a too large window size drowns out useful information.

Problems The assumptions above obviously do not hold for our actual system. Especially strong is the assumption of a single server; since we actually have multiple servers, this model is likely to predict the behaviour of the system very poorly. A second problem arises from my very indirect method of estimating parameters for the model (and an arbitrary choice of time window) which introduces inaccuracies.

1.3 Comparison of model and experiments

Explain the characteristics and behavior of the model built, and compare it with the experimental data (collected both outside and inside the middleware). Map the similarities and differences to aspects of the design or the experiments.

Table 1 shows a comparison of the predictions of the M/M/1 model with actual results from the trace experiment.

TODO: this whole subsection

TODO: mention that IRTL doesn't hold for the model

TODO: mention that number of jobs is calculated using Little's law

	metric	predicted	actual
1	response_time_mean	0.38	14.55
2	response_time_std	0.38	17.62
3	response_time_quantile50	0.27	12.00
4	response_time_quantile95	1.15	30.00
5	waiting_time_mean	0.31	13.22
6	waiting_time_std	0.38	17.06
7	utilisation	0.20	
8	num_jobs_in_system_mean	3.95	149.79
9	num_jobs_in_system_std	4.42	
10	num_jobs_in_queue_mean	3.15	136.11
11	num_jobs_in_queue_std	4.26	
12	num_jobs_served_in_busy_period_mean	4.95	
13	num_jobs_served_in_busy_period_std	13.19	
14	busy_period_duration_mean	0.38	
15	busy_period_duration_std	0.76	

Table 1: Comparison of experimental results ('actual') and predictions of the M/M/1 model ('predicted') for different metrics. Where the 'actual' column is empty, experimental data was not detailed enough to calculate the desired metric. All time units are milliseconds.

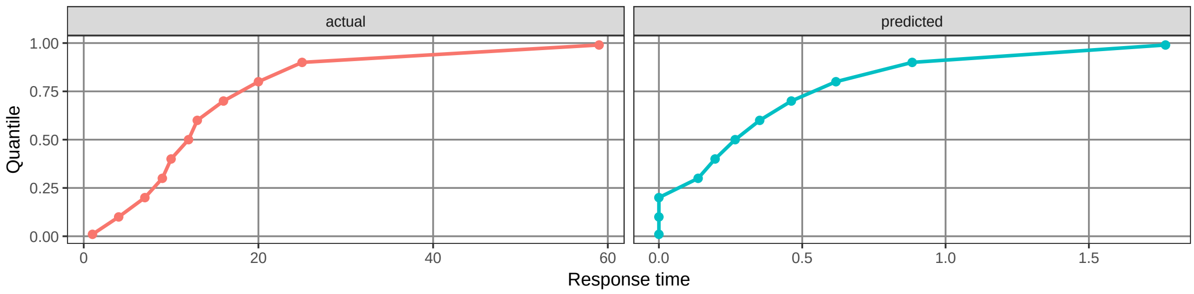


Figure 1: Quantiles of the response time distribution: experimental results and predictions of the M/M/1 model. Note the extreme difference in the response time scale.

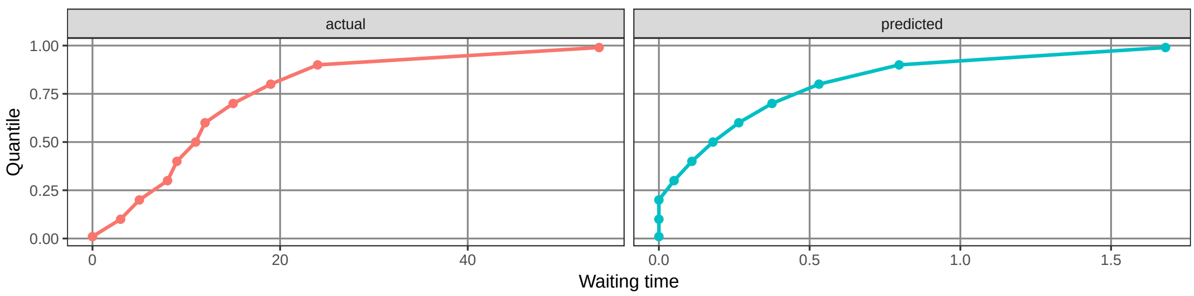


Figure 2: Quantiles of the waiting time distribution: experimental results and predictions of the M/M/1 model. Note the extreme difference in the queue time scale.

2 Analysis of System Based on Scalability Data

2.1 Data

The experimental data used in this section comes from Milestone 2 Section 1 and can be found in `results/throughput`.

2.2 Model

The assumptions and definitions of the M/M/m model are the same as for the M/M/1 model laid out in Section 1.2 with the following modifications:

- We treat the SUT as a collection of m servers.
- All jobs waiting for service are held in one queue.
- If any server is idle, an arriving job is serviced immediately.
- If all servers are busy, an arriving job is added to the queue.

Parameters TODO: describe how I found the parameters

Problems TODO:

1. I actually have m queues (one for each server), not a single queue; each request is assigned to a server when LoadBalancer receives it.
2. I map requests to servers uniformly. M/M/m assumes that each server takes a request when it finishes with the previous one, but that is not true in my case – I take earlier

2.3 Comparison of model and experiments

TODO:

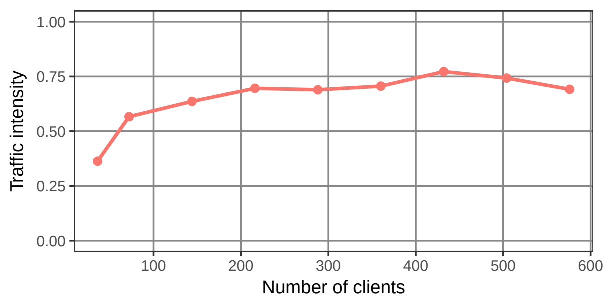


Figure 3: TODO:

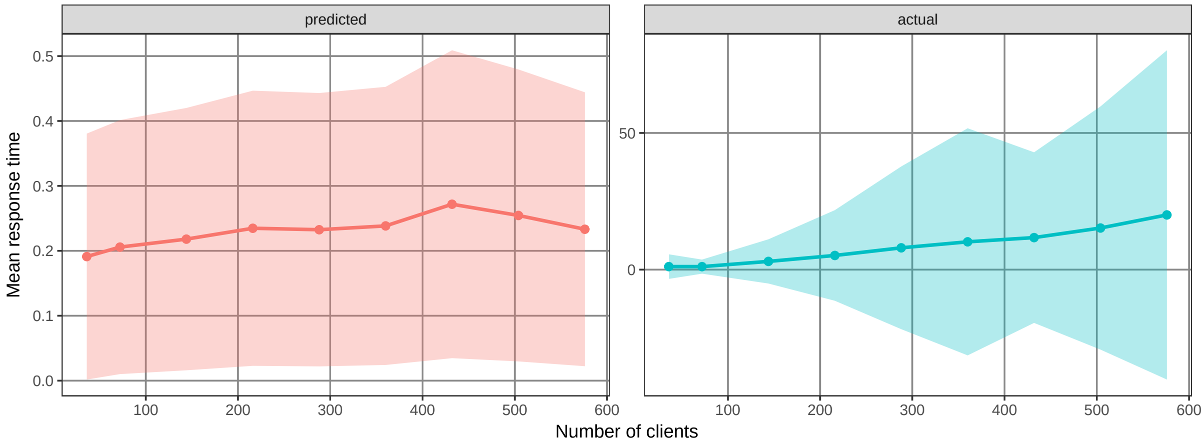


Figure 4: TODO: note difference in scale

	variable	clients	predicted	actual
1	response_time_mean	36	0.19	1.11
2	response_time_mean	72	0.21	1.10
3	response_time_mean	144	0.22	3.01
4	response_time_mean	216	0.23	5.19
5	response_time_mean	288	0.23	7.98
6	response_time_mean	360	0.24	10.18
7	response_time_mean	432	0.27	11.72
8	response_time_mean	504	0.25	15.23
9	response_time_mean	576	0.23	20.02
10	response_time_std	36	0.19	4.51
11	response_time_std	72	0.20	2.58
12	response_time_std	144	0.20	8.09
13	response_time_std	216	0.21	16.58
14	response_time_std	288	0.21	29.77
15	response_time_std	360	0.21	41.55
16	response_time_std	432	0.24	31.21
17	response_time_std	504	0.22	44.49
18	response_time_std	576	0.21	60.23

Table 2: Comparison of experimental results and predictions of the M/M/m model.

3 System as Network of Queues

3.1 Guidelines

Length: 1-3 pages

Based on the outcome of the different modeling efforts from the previous sections, build a comprehensive network of queues model for the whole system. Compare it with experimental data and use the methods discussed in the lecture and the book to provide an in-depth analysis of the behavior. This includes the identification and analysis of bottlenecks in your system. Make sure to follow the model-related guidelines described in the Notes!

4 Factorial Experiment

4.1 Guidelines

"the performance is expected to improve as the memory size is increased or the number of disk drives is increased. In such cases we can begin by experimenting at the minimum and the maximum level of the factor."

4.2 Experiment design

TODO: what am I predicting? mean response time. maybe should just take SET requests?

TODO: factors: replication and num servers

TODO: what did I keep fixed (threads, write perc, etc – see ms2 experiment description tables)

TODO: how many repetitions? $2^k r$, $r =$?

TODO: justify levels start with the min and max because this way you get an initial idea of whether it makes sense to do more detailed experiments on this factor

4.3 Data

TODO: ms2 exp3, repetitions, total number of runs that i used

4.4 Results

	variable	variation
1	error	0.672
2	xa_servers	0.024
3	xb_replication	0.000
4	xc_writes	0.276
5	x_ab	0.049
6	x_bc	0.012
7	x_ac	0.005
8	x_abc	0.002

Table 3: TODO: caption

multiplicative model is not necessary because: a) range of values covered is small, residuals are small compared to actual values and the spread of residuals is independent of whether actual values are small or large TODO: check if this is true

additive model =¿ mean error 1665; multiplicative =¿ mean error 1667

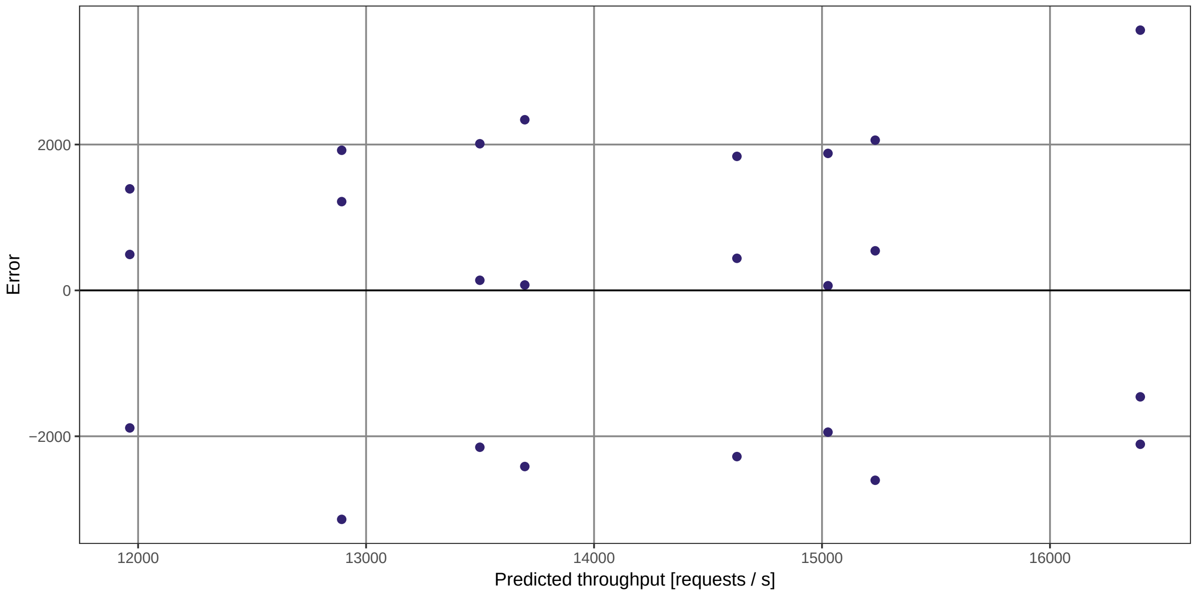


Figure 5: TODO: note scale

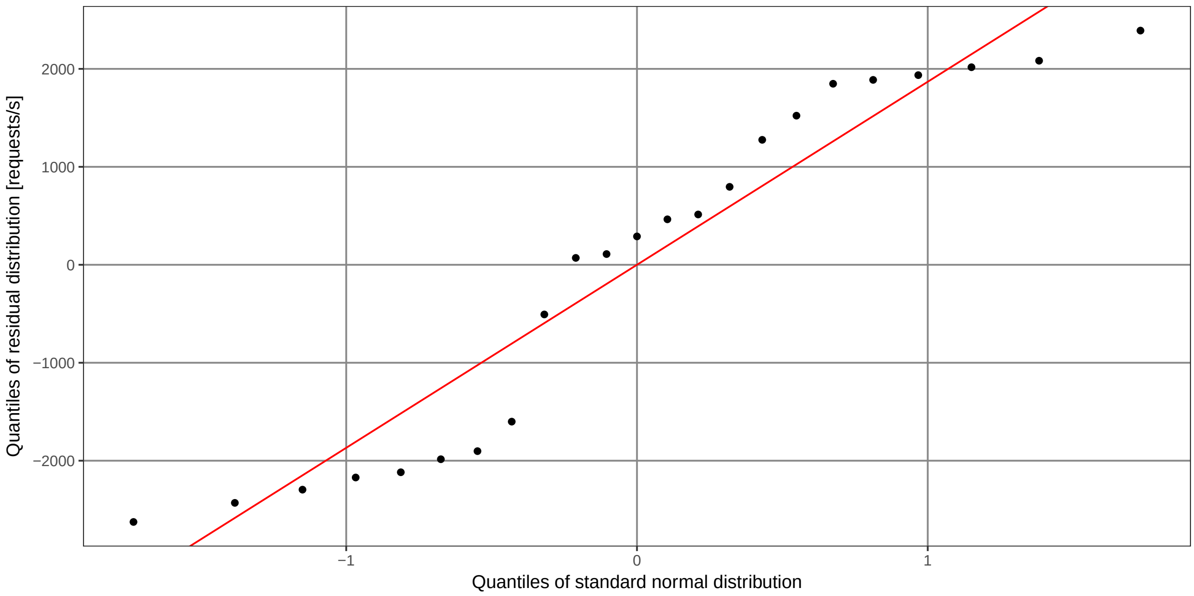


Figure 6: TODO: what is red line

5 Interactive Law Verification

5.1 Data

The experimental data used in this section comes from Milestone 2, Section 2 (Effect of Replication) and can be found in `results/replication` (short name `replication-S*-R*-r*` in Milestone 2). This includes a total of 27 experiments in 9 different configurations.

The first 2 minutes and last 2 minutes were **not** dropped because the Interactive Response Time Law (IRTL) should hold also in warm-up and cool-down periods. Repetitions at the same configuration were considered as separate experiments.

5.2 Model

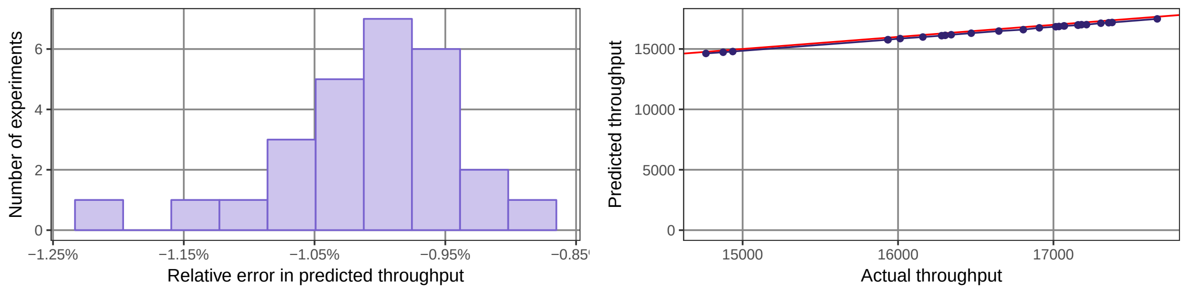
We are assuming a closed system, i.e. clients wait for a response from the server before sending another request. Under this assumption, the IRTL should hold:

$$R = \frac{N}{X} - Z$$

where R is mean response time, Z is waiting time in the client, N is the number of clients and X is throughput.

5.3 Results

Using IRTL, we can verify the validity of experiments by calculating the predicted throughput $X_{predicted}$ (given the number of clients C and mean response time R) and comparing it with actual throughput X_{actual}. This is precisely what I did for all experiments of Milestone 2, Section 2. $C = 180$ in all experiments, and both R and X_{actual} are aggregated results reported by the three memaslap instances generating load in that experiment.



(a) Histogram of the relative error of throughput predicted using IRTL, counting the number of experiments in a given error range. Note the horizontal scale does not include 0.

(b) Throughput predicted using IRTL (dark points), as a function of actual throughput calculated from experimental data. The red line shows hypothetical perfect predictions (the $x = y$ line). Note the horizontal scale does not include 0.

Figure 7: Evaluation of the validity of Milestone 2 Section 2 experiments

If we assume the wait time Z to be 0, we get a mean relative prediction error of -1.01%, defined as $\frac{X_{predicted} - X_{actual}}{X_{actual}}$. The distribution of these errors is shown in Figure 7a; the distribution looks reasonably symmetric. Figure 7b plots $X_{predicted}$ against X_{actual} and shows again that the predicted throughput is very close to actual throughput, but consistently smaller in all regions of the graph.

If we assume a nonzero Z and estimate it from the experiments, we get a mean estimated wait time of -0.111ms. Clearly this is impossible: wait time must be non-negative.

To explain these results, we need to answer the question: why is the actual throughput lower than the actual throughput? It could be that memaslap starts the clock for a new request before stopping the clock for the previous request – which would violate the closed system assumption – but this is very unlikely as it would be a major design flaw in memaslap.

A more plausible hypothesis is that the effective value of N is slightly lower than the concurrency I set using the relevant command line flags – because the number of cores in the memaslap machine is much lower than the concurrency I'm using.

Regardless of the exact reason of the deviation, the IRTL holds to a reasonably high accuracy. Perfect accuracy is impossible even without the middleware: in the baseline experiments (Milestone 1 Section 2), relative prediction error is 0.2%-0.5% in a selection of values of N that I checked.

TODO: if time think about what could be causing the -1%, but not a priority

Appendix A: Template appendix