

Simulation Experiment Results

Victor Tsang (z5209633)

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Load in the results

```
library(knitr)
library(tidyverse)
library(latex2exp)

load("../data/synthetic-data.RData")
attach(synthetic.data.config)

estimates = readRDS("../data/sim_exp-estimate_extinction_results.RDS")
```

```
# Point estimates
performance.point_estimates = estimates %>%
  filter(!is.na(point)) %>%
  group_by(error_factor, method) %>%
  summarise(MSE_000 = mean((point - theta.true)^2)/1000,
            bias = mean(point)-theta.true,
            variance_000 = var(point)/1000,
            avg_runtime = mean(point_runtime))
```

```
## 'summarise()' has grouped output by 'error_factor'. You can override using the
## '.groups' argument.
```

```
kable(performance.point_estimates)
```

error_factor	method	MSE_000	bias	variance_000	avg_runtime
0	BA-MLE	264.2727	35.26247	264.0856	0.0000241
0	GRIWM	1143.9442	-910.24400	316.6667	2.2955959
0	GRIWM-corrected	1676.6301	-1160.42400	331.3718	14.2799933
0	MINMI	286.3593	175.10167	256.7256	0.0000101
0	MLE	498.4446	509.77378	239.5334	0.0000130
0	SI-UGM	290.4109	186.47845	256.6634	4.4242394
0	STRAUSS	265.4449	36.50031	265.1733	0.0000146
1	BA-MLE	284.0751	-60.31354	281.5636	0.0000450
1	GRIWM	1482.8898	-1076.41600	325.5205	2.3225908
1	GRIWM-corrected	2108.6852	-1330.35200	340.2096	14.3278799
1	MINMI	287.6329	85.15322	281.5078	0.0005012
1	MLE	429.7157	418.74901	255.3865	0.0000191

error_factor	method	MSE_000	bias	variance_000	avg_runtime
1	SI-UGM	285.9112	97.26159	277.5616	2.0293313
1	STRAUSS	286.9027	-64.59601	283.8655	0.0000387
2	BA-MLE	635.8984	-317.77076	537.0684	0.0000158
2	GRIWM	2751.9844	-1476.72400	573.5649	2.3258716
2	GRIWM-corrected	3622.3498	-1739.66000	598.3262	14.2027869
2	MINMI	560.5955	-61.69559	559.0253	0.0005218
2	MLE	515.3085	173.55166	487.1369	0.0000134
2	SI-UGM	542.4839	-19.65905	544.2745	1.7308850
2	STRAUSS	645.4422	-328.56985	539.6426	0.0000142
4	BA-MLE	1788.2467	-820.60440	1119.3325	0.0000153
4	GRIWM	6706.9604	-2381.60800	1039.0600	2.3208188
4	GRIWM-corrected	8182.1955	-2662.92800	1095.3915	14.2912016
4	MINMI	1285.9511	-185.59998	1256.5299	0.0004930
4	MLE	1104.4375	-305.33752	1015.2676	0.0000137
4	SI-UGM	1215.1789	-29.28444	1219.1981	1.3886812
4	STRAUSS	1875.1304	-865.57457	1130.4328	0.0000144

```
# Confidence Intervals
performance.conf_int_estimates = estimates %>%
  filter(!is.na(conf_int_runtime)) %>%
  mutate(width = upper - lower,
         contains_theta = ifelse(theta.true > lower & theta.true < upper, 1, 0)) %>%
  group_by(error_factor, method) %>%
  summarise(coverage = mean(contains_theta),
            avg_width = mean(width),
            avg_runtime = mean(conf_int_runtime))
```

'summarise()' has grouped output by 'error_factor'. You can override using the
'.groups' argument.

```
kable(performance.point_estimates)
```

error_factor	method	MSE_000	bias	variance_000	avg_runtime
0	BA-MLE	264.2727	35.26247	264.0856	0.0000241
0	GRIWM	1143.9442	-910.24400	316.6667	2.2955959
0	GRIWM-corrected	1676.6301	-1160.42400	331.3718	14.2799933
0	MINMI	286.3593	175.10167	256.7256	0.0000101
0	MLE	498.4446	509.77378	239.5334	0.0000130
0	SI-UGM	290.4109	186.47845	256.6634	4.4242394
0	STRAUSS	265.4449	36.50031	265.1733	0.0000146
1	BA-MLE	284.0751	-60.31354	281.5636	0.0000450
1	GRIWM	1482.8898	-1076.41600	325.5205	2.3225908
1	GRIWM-corrected	2108.6852	-1330.35200	340.2096	14.3278799
1	MINMI	287.6329	85.15322	281.5078	0.0005012
1	MLE	429.7157	418.74901	255.3865	0.0000191
1	SI-UGM	285.9112	97.26159	277.5616	2.0293313
1	STRAUSS	286.9027	-64.59601	283.8655	0.0000387
2	BA-MLE	635.8984	-317.77076	537.0684	0.0000158
2	GRIWM	2751.9844	-1476.72400	573.5649	2.3258716

error_factor	method	MSE_000	bias	variance_000	avg_runtime
2	GRIWM-corrected	3622.3498	-1739.66000	598.3262	14.2027869
2	MINMI	560.5955	-61.69559	559.0253	0.0005218
2	MLE	515.3085	173.55166	487.1369	0.0000134
2	SI-UGM	542.4839	-19.65905	544.2745	1.7308850
2	STRAUSS	645.4422	-328.56985	539.6426	0.0000142
4	BA-MLE	1788.2467	-820.60440	1119.3325	0.0000153
4	GRIWM	6706.9604	-2381.60800	1039.0600	2.3208188
4	GRIWM-corrected	8182.1955	-2662.92800	1095.3915	14.2912016
4	MINMI	1285.9511	-185.59998	1256.5299	0.0004930
4	MLE	1104.4375	-305.33752	1015.2676	0.0000137
4	SI-UGM	1215.1789	-29.28444	1219.1981	1.3886812
4	STRAUSS	1875.1304	-865.57457	1130.4328	0.0000144

Point Estimates

```
library(kableExtra)
```

```
## Warning: package 'kableExtra' was built under R version 4.2.2
```

```
##
```

```
## Attaching package: 'kableExtra'
```

```
## The following object is masked from 'package:dplyr':
```

```
##
```

```
## group_rows
```

```
for (err in error_factors) {
  print(kable(performance.point_estimates %>%
    filter(error_factor == err) %>%
    mutate(across(!c(method, avg_runtime), round)) %>%
    mutate(avg_runtime=round(avg_runtime, digits=5)) %>%
    arrange(MSE_000)))
}
```

error_factor	method	MSE_000	bias	variance_000	avg_runtime
0	BA-MLE	264	35	264	0.00002
0	STRAUSS	265	37	265	0.00001
0	MINMI	286	175	257	0.00001
0	SI-UGM	290	186	257	4.42424
0	MLE	498	510	240	0.00001
0	GRIWM	1144	-910	317	2.29560
0	GRIWM-corrected	1677	-1160	331	14.27999

error_factor	method	MSE_000	bias	variance_000	avg_runtime
1	BA-MLE	284	-60	282	0.00004
1	SI-UGM	286	97	278	2.02933
1	STRAUSS	287	-65	284	0.00004
1	MINMI	288	85	282	0.00050
1	MLE	430	419	255	0.00002
1	GRIWM	1483	-1076	326	2.32259
1	GRIWM-corrected	2109	-1330	340	14.32788

error_factor	method	MSE_000	bias	variance_000	avg_runtime
2	MLE	515	174	487	0.00001
2	SI-UGM	542	-20	544	1.73088
2	MINMI	561	-62	559	0.00052
2	BA-MLE	636	-318	537	0.00002
2	STRAUSS	645	-329	540	0.00001
2	GRIWM	2752	-1477	574	2.32587
2	GRIWM-corrected	3622	-1740	598	14.20279

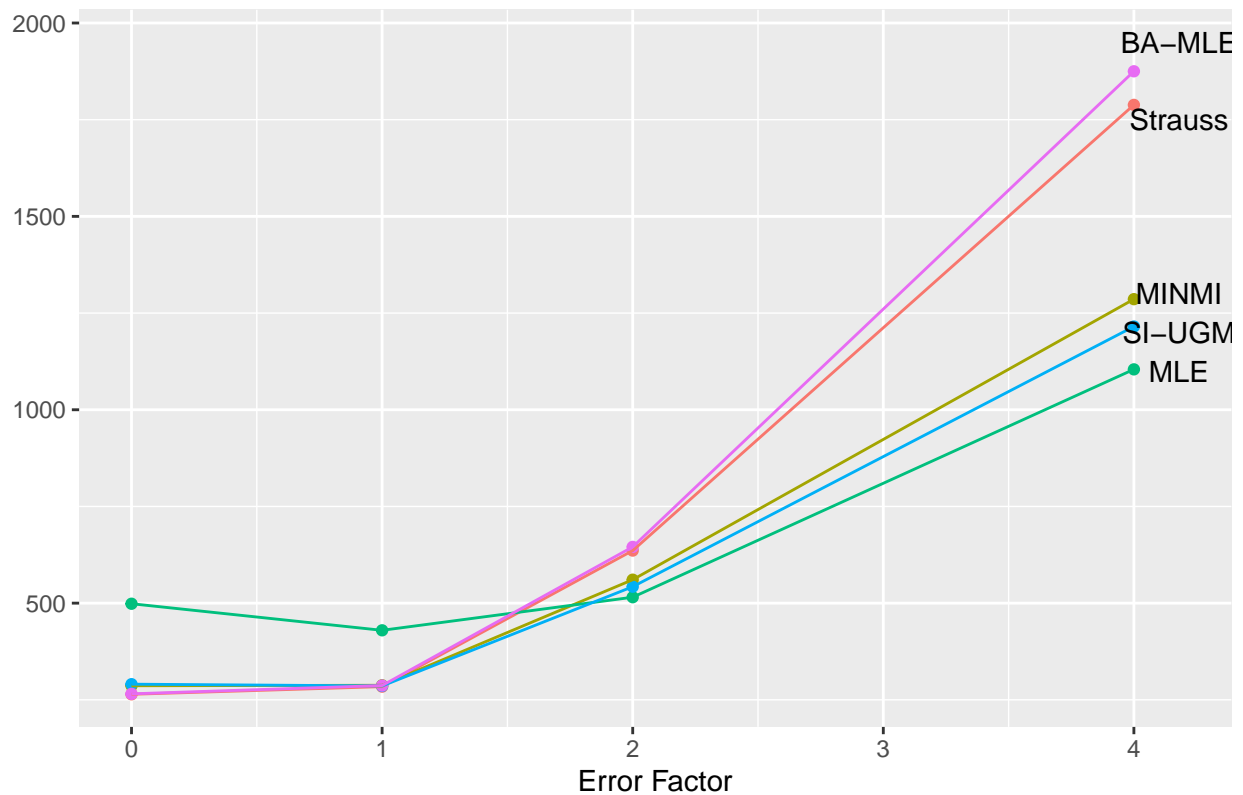
error_factor	method	MSE_000	bias	variance_000	avg_runtime
4	MLE	1104	-305	1015	0.00001
4	SI-UGM	1215	-29	1219	1.38868
4	MINMI	1286	-186	1257	0.00049
4	BA-MLE	1788	-821	1119	0.00002
4	STRAUSS	1875	-866	1130	0.00001
4	GRIWM	6707	-2382	1039	2.32082
4	GRIWM-corrected	8182	-2663	1095	14.29120

```
performance.point_estimates %>%
  filter(error_factor == 1) %>%
  mutate(across(!c(method, avg_runtime), round)) %>%
  mutate(avg_runtime=round(avg_runtime, digits=5)) %>%
  arrange(MSE_000) %>%
  ungroup() %>%
  select(-error_factor) %>%
  kable(booktabs=T, col.names = c("Method", "MSE\n(000's years)", "Bias (years)", "Variance\n(000's years)", "Average Runtime (seconds)"))
```

Method	MSE (000's years)	Bias (years)	Variance (000's years)	Average Runtime (seconds)
BA-MLE	284	-60	282	0.00004
SI-UGM	286	97	278	2.02933
STRAUSS	287	-65	284	0.00004
MINMI	288	85	282	0.00050
MLE	430	419	255	0.00002
GRIWM	1483	-1076	326	2.32259
GRIWM-corrected	2109	-1330	340	14.32788

```
performance.point_estimates %>%
  filter(!(method %in% c("GRIWM", "GRIWM-corrected"))) %>%
  ggplot(aes(x=error_factor, y=MSE_000, colour=method)) +
  geom_point() +
  geom_line() +
  guides(colour="none") +
  annotate("text", x=4.18, y=c(1950, 1750, 1300, 1200, 1100), label=c("BA-MLE", "Strauss", "MINMI", "SI-UGM", "MLE"),
  labs(x="Error Factor", y=NULL, title="MSE ('000 years) of each Method"))
```

MSE ('000 years) of each Method



Confidence Intervals

```
options(scipen=9)
for (metric in c("coverage", "avg_width", "avg_runtime")) {
  print(kable(
    performance.conf_int_estimates %>%
      select(c(method, error_factor, one_of(metric))) %>%
      pivot_wider(id_cols = method,
                  names_from=error_factor,
                  values_from=one_of(metric),
                  names_prefix=paste(metric, "| error = sigma*")) %>%
      arrange(!sym(paste(metric, "| error = sigma*0")))
  ))
}
```

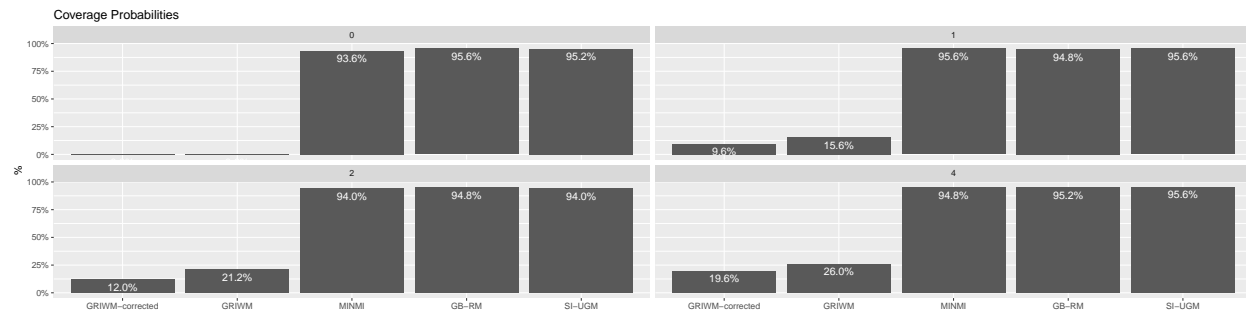
method	coverage error = sigma*0	coverage error = sigma*1	coverage error = sigma*2	coverage error = sigma*3
GRIWM	0.000	0.156	0.212	0.212
GRIWM-corrected	0.000	0.096	0.120	0.120
MINMI	0.936	0.956	0.940	0.940
SI-UGM	0.952	0.956	0.940	0.940
GB-RM	0.956	0.948	0.948	0.948

method	avg_width	error = sigma*0	avg_width	error = sigma*1	avg_width	error = sigma*2	avg
GRIWM		0.000		1161.740		2191.180	
GRIWM-corrected		0.000		1190.240		2242.436	
MINMI		1910.220		2331.017		2948.932	
SI-UGM		1949.626		2350.378		2972.823	
GB-RM		2040.898		2361.442		3003.598	

method	avg_runtime	error = sigma*0	avg_runtime	error = sigma*1	avg_runtime	error = sigma*2
MINMI		0.0000671		0.0014753		0.0018413
GB-RM		0.0202166		0.0235130		0.0230765
GRIWM		2.2955959		2.3225908		2.3258716
SI-UGM		4.4242394		2.0293313		1.7308850
GRIWM-corrected		14.2799933		14.3278799		14.2027869

```
performance.conf_int_estimates %>%
```

```
ggplot(aes(x=reorder(method, coverage, descending=TRUE), y=coverage)) +
  geom_col() +
  geom_text(aes(label=scales::percent(coverage)), position = position_dodge(.9), vjust = 1.5, colour="white") +
  labs(x=NULL, y="%", title="Coverage Probabilities") +
  facet_wrap(error_factor ~.) +
  scale_y_continuous(labels = scales::percent)
```



```
estimates %>%
  filter(!is.na(lower)) %>%
  select(method, lower, point, upper) %>%
  pivot_longer(cols=c(lower, point, upper)) %>%
  filter(!is.na(value)) %>%
  ggplot(aes(x=value, fill=name)) +
  geom_density(alpha=0.25) +
  geom_vline(aes(xintercept=theta.true)) +
  facet_wrap(method ~ .)
```

