Report of experiments

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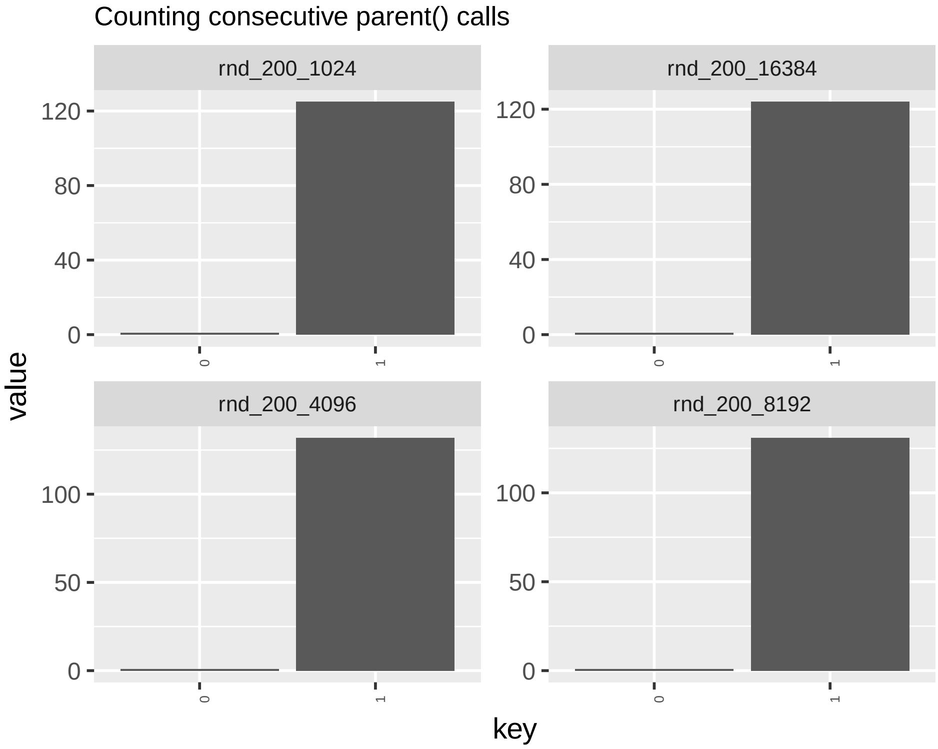
12/28/2016

Contents

1 Input properties

For various types ("mut_XMs_YMt_Z" means `s` and `t` are random identical strings of length X, and Y million respectively with mutations inserted every Z characters. "rnd_XMs_YMt" means `s` and `t` are random strings of length X, and Y million respectively) of inputs run the MS algorithm and count the number of consecutive `wl()` or `parent()` calls during the `runs` or `ms` construction phase.



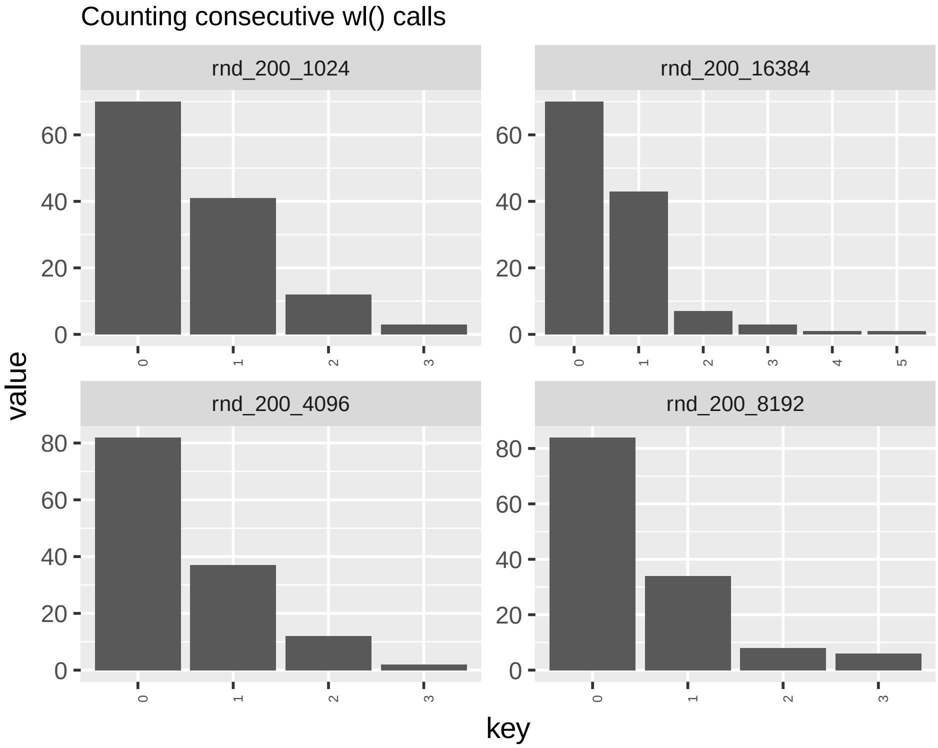


Table 1: Composition of the `runs` vector for various input types.

vector_value	rnd_200_1024	rnd_200_16384	rnd_200_4096	rnd_200_8192
0	126	125	133	132
1	74	75	67	68

2 Double vs. single rank

2.1 Code

The single rank and double rank implementations in sdsl: rank_support_v.hpp link

```
// RANK(idx)
const uint64_t* p = m_basic_block.data() + ((idx>>8)&0xFFFFFFFFFFFFFFFEULL);
return *p + ((*(p+1)>>(63 - 9*((idx&0x1FF)>>6)))&0x1FF) +
      (idx&0x3F ? trait_type::word_rank(m_v->data(), idx) : 0);

// DOUBLE RANK OD(i, j)
if((i>>8) == (j>>8)){
  const uint64_t* p = m_basic_block.data() + ((i>>8)&0xFFFFFFFFFFFFFFFEULL);
  res.first  = *p + ((*(p+1)>>(63 - 9*((i&0x1FF)>>6)))&0x1FF) +
            (i&0x3F ? trait_type::word_rank(m_v->data(), i) : 0);
  res.second = *p + ((*(p+1)>>(63 - 9*((j&0x1FF)>>6)))&0x1FF) +
            (j&0x3F ? trait_type::word_rank(m_v->data(), j) : 0);
} else {
  const uint64_t* p = m_basic_block.data() + ((i>>8)&0xFFFFFFFFFFFFFFFEULL);
  res.first  = *p + ((*(p+1)>>(63 - 9*((i&0x1FF)>>6)))&0x1FF) +
            (i&0x3F ? trait_type::word_rank(m_v->data(), i) : 0);
  p -= (((i>>8)&0xFFFFFFFFFFFFFFFEULL) - ((j>>8)&0xFFFFFFFFFFFFFFFEULL));
  res.second = *p + ((*(p+1)>>(63 - 9*((j&0x1FF)>>6)))&0x1FF) +
            (j&0x3F ? trait_type::word_rank(m_v->data(), j) : 0);
}
return res

// DOUBLE RANK FC(i, j)
const uint64_t* b = m_basic_block.data();
const uint64_t* pi = b + ((i>>8)&0xFFFFFFFFFFFFFFFEULL);
const uint64_t* pj = b + ((j>>8)&0xFFFFFFFFFFFFFFFEULL);

return (*pi + ((*(pi+1)>>(63 - 9*((i&0x1FF)>>6)))&0x1FF) +
              (i&0x3F ? trait_type::word_rank(m_v->data(), i) : 0),
      *pj + ((*(pj+1)>>(63 - 9*((j&0x1FF)>>6)))&0x1FF) +
              (j&0x3F ? trait_type::word_rank(m_v->data(), j) : 0));
```

2.2 Performance

Table 2: Time (in ms) of 500K calls to `wl()` based on `single_rank()` or `double_rank()` methods on 100MB random DNA input; Mean/sd over 20 repetitions.

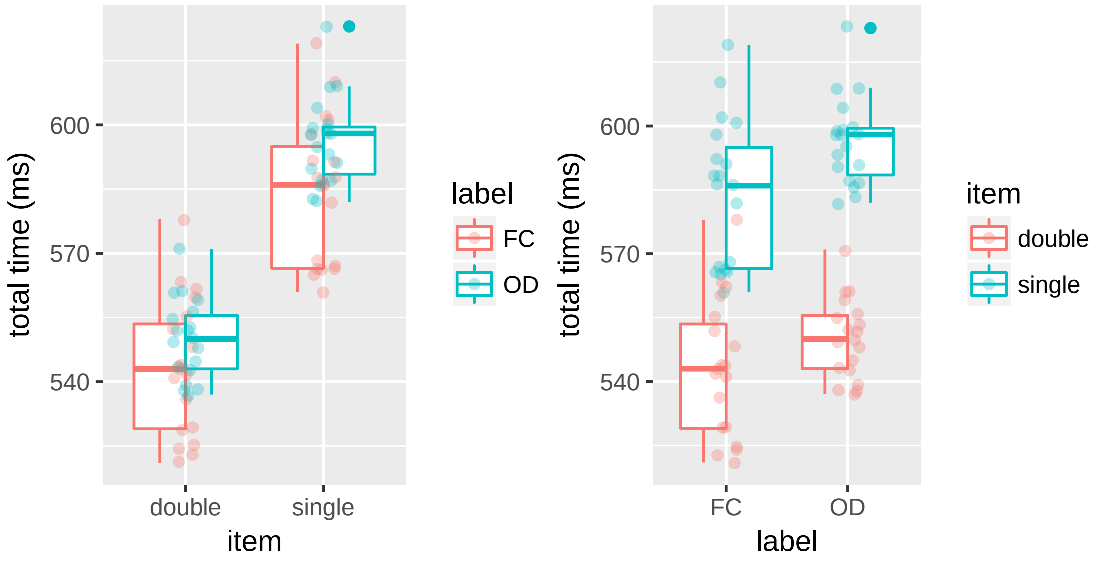
item	label	avg_time	sd_time
double	FC	543.11	15.88
double	OD	550.00	9.27
single	FC	584.32	17.11
single	OD	596.37	10.20

Table 3: Single vs. double rank. Absolute (double / single) and relative (100 * |double - single| / single) ratios of average times.

label	double	single	abs_ratio	rel_ratio
FC	543.11	584.32	0.93	7.05
OD	550.00	596.37	0.92	7.78

Table 4: FC vs. OD implementations. Absolute (FC / OD) and relative (100 * |FC - OD| / OD) ratios of average times

item	FC	OD	abs_ratio	rel_ratio
double	543.11	550.00	0.99	1.25
single	584.32	596.37	0.98	2.02



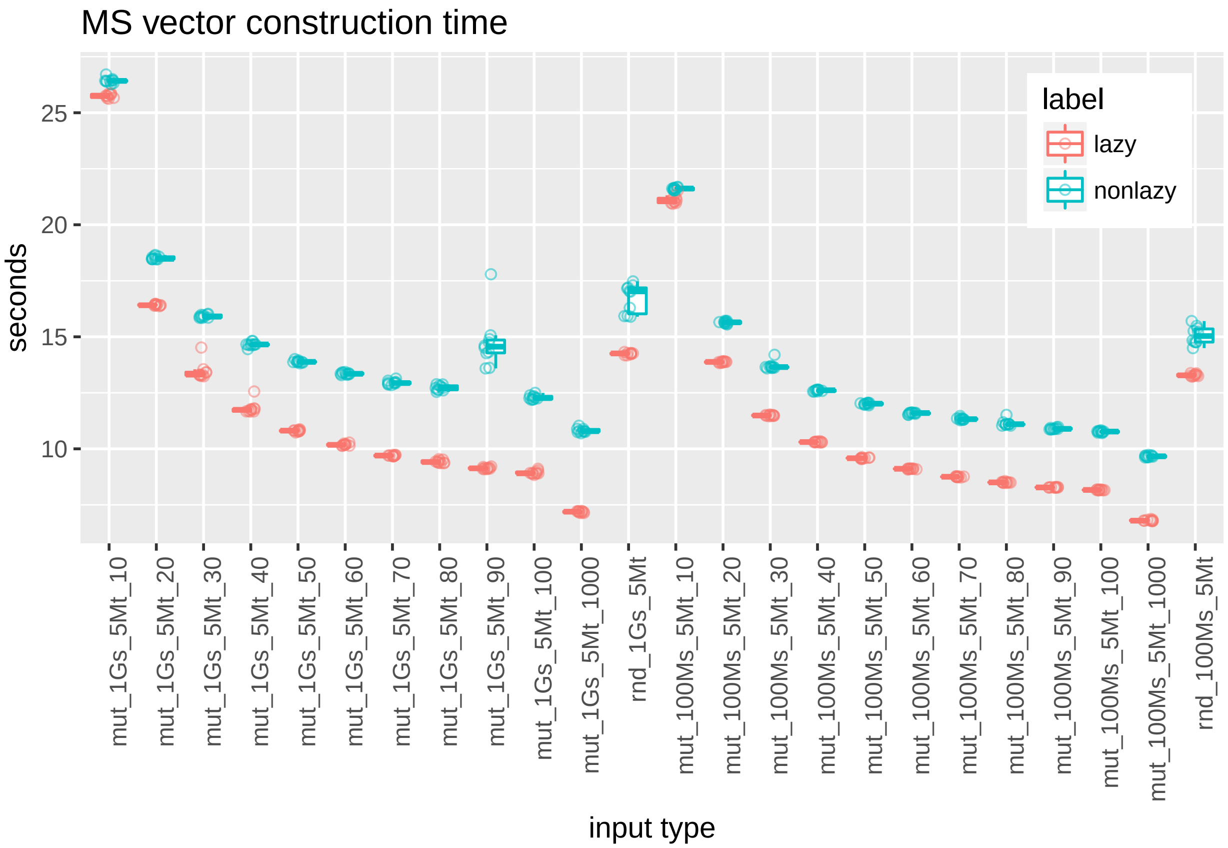
3 Lazy vs non-lazy

3.1 Code

The lazy and non-lazy versions differ in a couple of lines of code as follows

```
if(flags.lazy){
    for(; I.first <= I.second && h_star < ms_size; ){
        c = t[h_star];
        I = bstep_interval(st, I, c); //I.bstep(c);
        if(I.first <= I.second){
            v = st.lazy_wl(v, c);
            h_star++;
        }
    }
    if(h_star > h_star_prev) // // we must have called lazy_wl(). complete the node
        st.lazy_wl_followup(v);
} else { // non-lazy weiner links
    for(; I.first <= I.second && h_star < ms_size; ){
        c = t[h_star];
        I = bstep_interval(st, I, c); //I.bstep(c);
        if(I.first <= I.second){
            v = st.wl(v, c);
            h_star++;
        }
    }
}
```

3.2 Performance



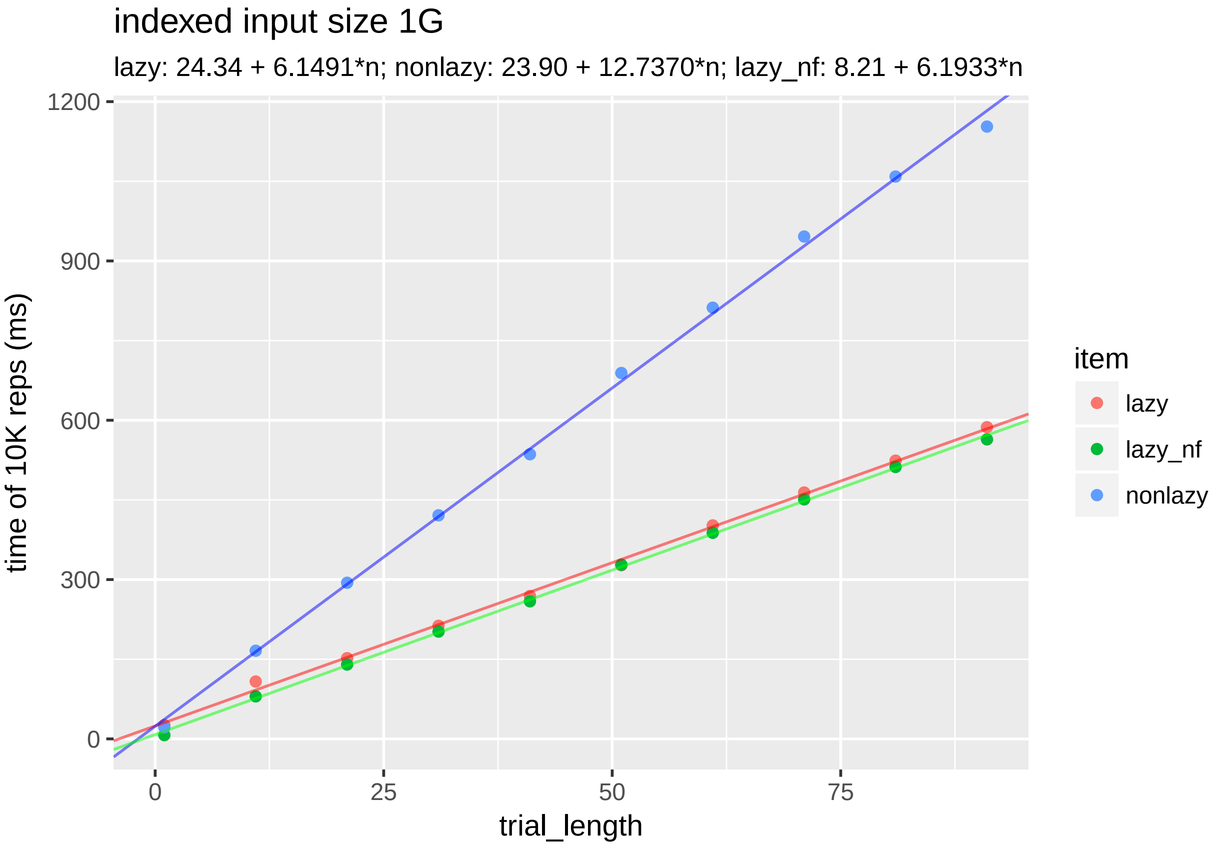
The right panel shows the time to construct the `runs` vector. This stage is the same for both versions and is shown as a control. On the left panel it can be seen that speedup correlates positively with both the size of the indexed string and the mutation period.

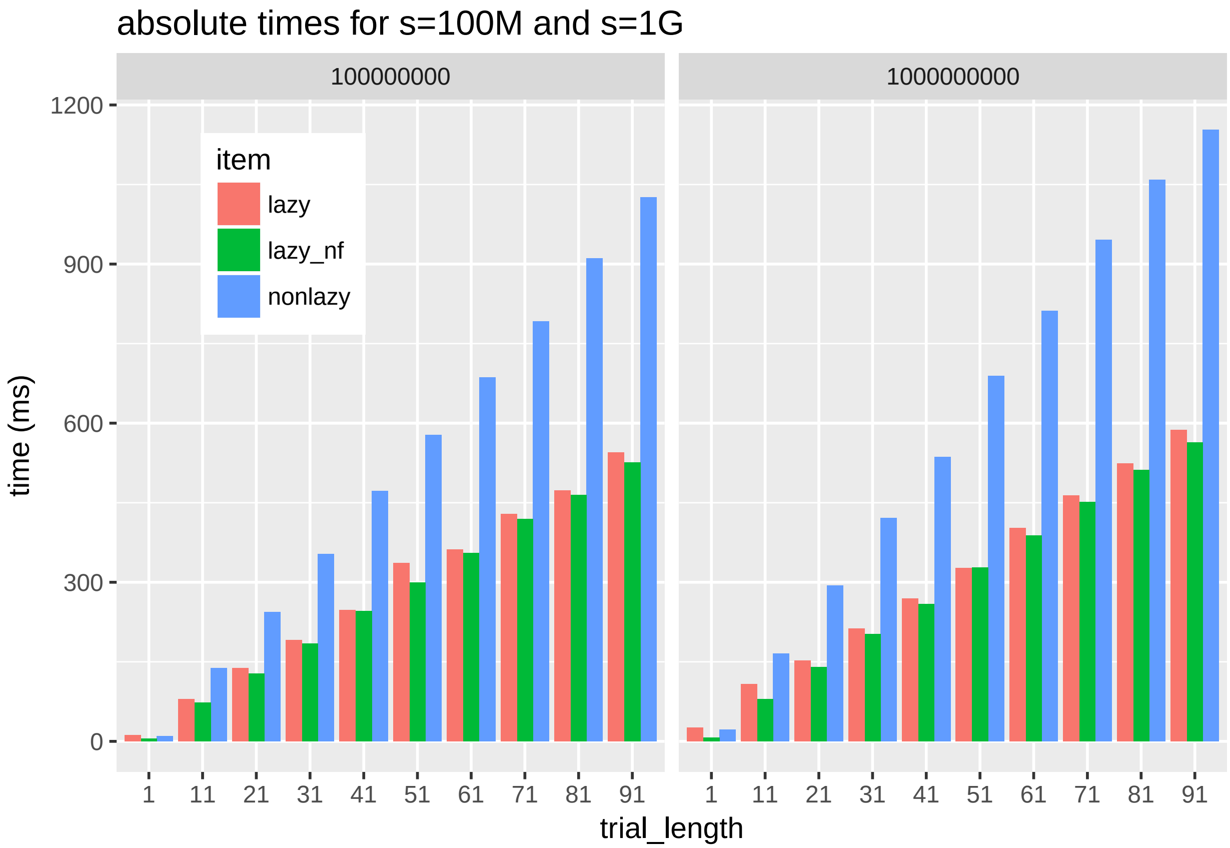
3.3 Sandbox timing

Measure the time of 10k repetitions of

- (lazy) n consecutive `lazy_wl()` calls followed by a `lazy_wl_followup()`
- (nonlazy) n consecutive `wl()` calls
- (lazy_nf) n consecutive `lazy_wl()` calls

```
// lazy
for(size_type i = 0; i < trial_length; i++)
    v = st.lazy_wl(v, s_rev[k--]);
if(h_star > h_star_prev) // // we must have called lazy_wl(). complete the node
    st.lazy_wl_followup(v);
...
// non-lazy
for(size_type i = 0; i < trial_length; i++)
    v = st.wl(v, s_rev[k--]);
...
// lazy_nf
for(size_type i = 0; i < trial_length; i++)
    v = st.lazy_wl(v, s_rev[k--]);
```





3.4 Check

In the experiments above we ran the program with the "lazy" or "non-lazy" flag and measured. The total time of each experiment can be written as $t_l = l_l + a$ and $t_n = l_n + a$ for the two versions respectively; only the ts being known. Furthermore, we have $\hat{l}_l$ and $\hat{l}_n$ estimations – computed by combining the time / wl call with the number of with the count of wl calls in each input (Section "Input Properties"). Hence we should expect

$$\delta t = t_l - t_n = l_l + a - l_n - a = l_l - l_n \approx \delta \hat{l} = \hat{l}_l - \hat{l}_n$$

b_path	t_l	t_n	l_l	l_n	delta_t	delta_l_hat
mut_100Ms_5Mt_10	21.12	21.61	8.56	6.16	-0.49	2.39
mut_100Ms_5Mt_100	8.16	10.77	3.36	4.33	-2.60	-0.97
mut_100Ms_5Mt_1000	6.80	9.67	2.84	4.15	-2.86	-1.31
mut_100Ms_5Mt_20	13.87	15.64	5.66	5.14	-1.77	0.52
mut_100Ms_5Mt_30	11.49	13.70	4.71	4.81	-2.21	-0.10
mut_100Ms_5Mt_40	10.31	12.60	4.22	4.64	-2.30	-0.41
mut_100Ms_5Mt_50	9.58	12.01	3.93	4.53	-2.43	-0.60
mut_100Ms_5Mt_60	9.11	11.58	3.74	4.47	-2.48	-0.72
mut_100Ms_5Mt_70	8.75	11.34	3.60	4.42	-2.59	-0.81
mut_100Ms_5Mt_80	8.51	11.13	3.50	4.38	-2.63	-0.88
mut_100Ms_5Mt_90	8.28	10.90	3.42	4.35	-2.62	-0.93
mut_1Gs_5Mt_10	25.75	26.43	7.57	6.65	-0.68	0.92
mut_1Gs_5Mt_100	8.94	12.29	3.49	4.90	-3.35	-1.41

b_path	t_l	t_n	l_l	l_n	delta_t	delta_l_hat
mut_1Gs_5Mt_1000	7.19	10.82	3.08	4.72	-3.63	-1.64
mut_1Gs_5Mt_20	16.42	18.52	5.30	5.68	-2.10	-0.37
mut_1Gs_5Mt_30	13.46	15.92	4.55	5.36	-2.46	-0.81
mut_1Gs_5Mt_40	11.81	14.66	4.17	5.20	-2.85	-1.02
mut_1Gs_5Mt_50	10.81	13.89	3.95	5.10	-3.08	-1.15
mut_1Gs_5Mt_60	10.19	13.36	3.80	5.03	-3.17	-1.24
mut_1Gs_5Mt_70	9.70	12.95	3.69	4.99	-3.26	-1.30
mut_1Gs_5Mt_80	9.43	12.72	3.61	4.95	-3.29	-1.35
mut_1Gs_5Mt_90	9.14	14.74	3.55	4.93	-5.60	-1.38
rnd_100Ms_5Mt	13.29	15.07	9.65	6.55	-1.78	3.10
rnd_1Gs_5Mt	14.25	16.72	8.20	6.92	-2.48	1.28

The numbers are not identical (process dependent factors might influence the running time of function calls), but they are correlated ($corr(\delta t, \delta \hat{l}) = 0.71$).

4 Double rank and fail

4.1 Code

```
// Given subtree_double_rank(v, i, j) -> (a.first, a.second) -- to simplify code

// DOUBLE RANK: int i, int j, char c
p = bit_path(c)
result_i, result_j = i, j;
node_type v = m_tree.root();
for (l = 0; l < path_len; ++l, p >>= 1) {
  a = subtree_double_rank(v, m_tree.bv_pos(v) + result_i, m_tree.bv_pos(v) + result_j);

  if(p&1){ // left child
      if(result_i > 0) result_i = a.first;
      if(result_j > 0) result_j = a.second;
  } else { // right child
      if(result_i > 0) result_i -= a.first;
      if(result_j > 0) result_j -= a.second;
  }
  v = m_tree.child(v, p&1); // goto child
}
return(result_i, result_j)

// DOUBLE RANK AND FAIL
p = bit_path(c)
result_i, result_j = i, j;
node_type v = m_tree.root();
for (l = 0; l < path_len; ++l, p >>= 1) {
  a = subtree_double_rank(v, m_tree.bv_pos(v) + result_i, m_tree.bv_pos(v) + result_j);

  if(p&1){ // left child
      if(result_i > 0) result_i = a.first;
      if(result_j > 0) result_j = a.second;
  } else { // right child
      if(result_i > 0) result_i -= a.first;
      if(result_j > 0) result_j -= a.second;
  }
  if(result_i == result_j) // Weiner Link call will fail
    return(0, 0)
  v = m_tree.child(v, p&1); // goto child
}
return(result_i, result_j)
```

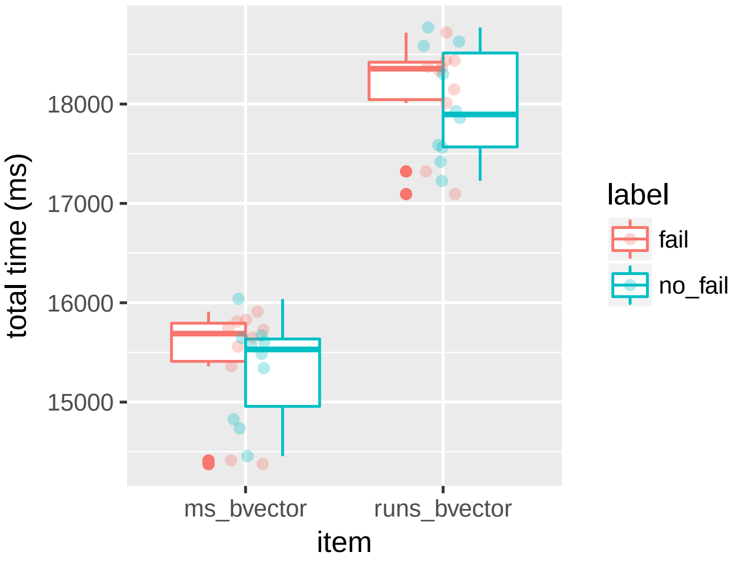
4.2 Performance

Table 6: Time (in ms) of 500K calls to `wl()` based on `single_rank()` or `double_rank()` methods on 100MB random DNA input; Mean/sd over 20 repetitions.

item	label	avg_time	sd_time
ms_bvector	fail	15438.3	571.52
ms_bvector	no_fail	15337.9	499.54
runs_bvector	fail	18125.9	520.69
runs_bvector	no_fail	17987.5	551.45

Table 7: Single vs. double rank. Absolute (double / single) and relative (100 * |double - single| / single) ratios of average times.

item	fail	no_fail	abs_ratio	rel_ratio
ms_bvector	15438.3	15337.9	1.01	0.65
runs_bvector	18125.9	17987.5	1.01	0.77



5 Parallelization

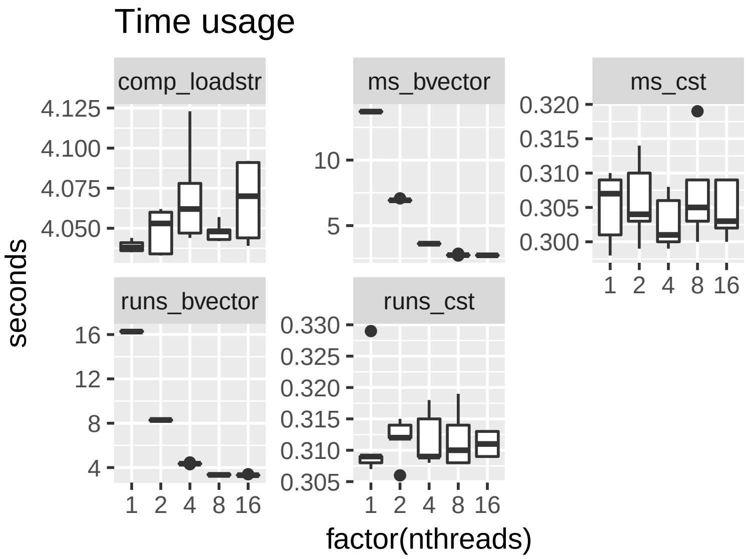
5.1 Code

See the pseudo-code in the repo (link)

5.2 Performance

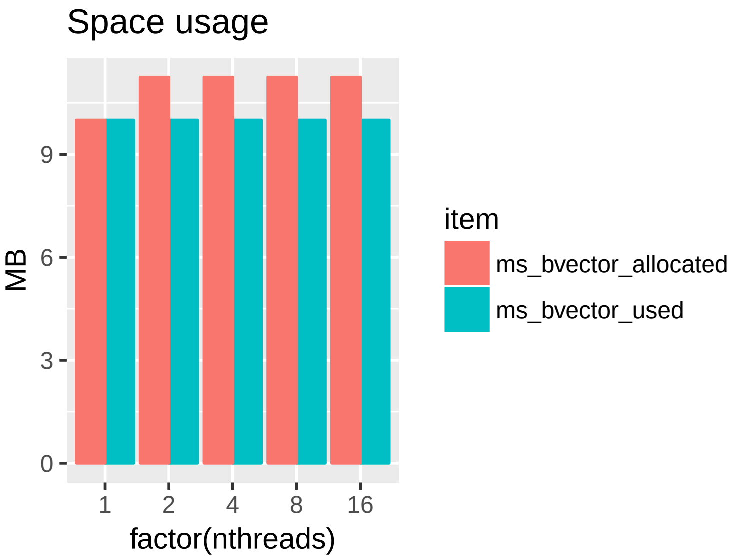
Run the MS construction program on the same input (random strings s of length 100M and t of length 5M) with varying parallelzation degree (nthreads = number of threads).

The time is reported over 5 runs for each fixed number of threads.



Space in MB for the same settings as above.

Each thread allocates its own ms vector with initial size $|t|/nthreads$ then it resizes by a factor of 1.5 each time it needs to. Resizing will always result in a vector smaller than $2|t|$ elements.


Space usage
MB
factor(nthreads)
item
ms_bvector_allocated
ms_bvector_used