CSCM: Combinatorial Sequence Coverage Measurement Tool

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CSCM (Combinatorial Sequence Coverage Measurement) is a tool developed in the Haskell programming language for measuring the *t*-way coverage of sequences. This is useful for software testing as well as comparing sequence covering array generation algorithms.

Install

1. Install Haskell from https://www.haskell.org/platform/
2. Download CSCM from: https://github.com/zachratliff22/CSCM-Tool.git
3. Use Cabal (this is usually installed when you use the Haskell installer), to install necessary packages:
   - **cabal update**
   - **cabal install parallel**
   - **cabal install split**

   These packages should be the only packages needed after the default install of Haskell, however, if other dependencies are not resolved you can install the missing package using the same format: **cabal install [package_name]**

4. Switch the the CSCM directory downloaded from Github
5. **ghc --make cscm.hs -threaded**

CSCM should now be compiled into an executable file. See the next section for usage details.

Usage

cscm [t-way] [test suite file] [event definition file] +RTS -N[num processes]

Example:

cscm 3 testsuite.txt events.txt +RTS -N4

The above command measures the 3-way coverage of the test suite file over the events specified in the events.txt file. Both files are comma delimited Unix-type text files. **Note, Windows text files usually include unwanted characters such as '\r', so these should be removed from the input files if you are running on the Windows Operating System.** There are a few sample files in the Github repository which will work on all operating systems.
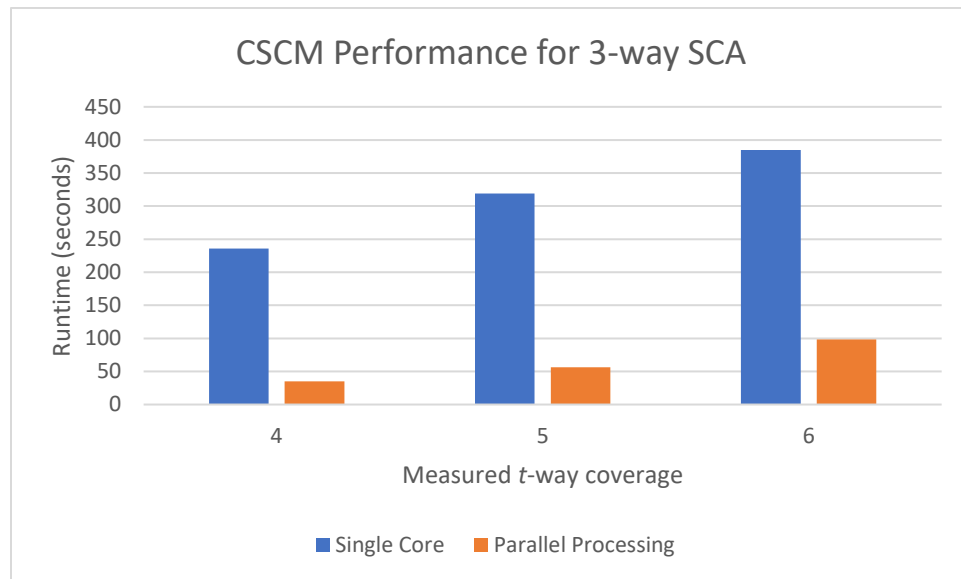
A few notes on the parameters:

- +RTS specifies to use Haskell's runtime system
- -N will specify the number of cores available on the system (Do not enter a higher number than is available on your system). Use -N1 to just run in a single process.
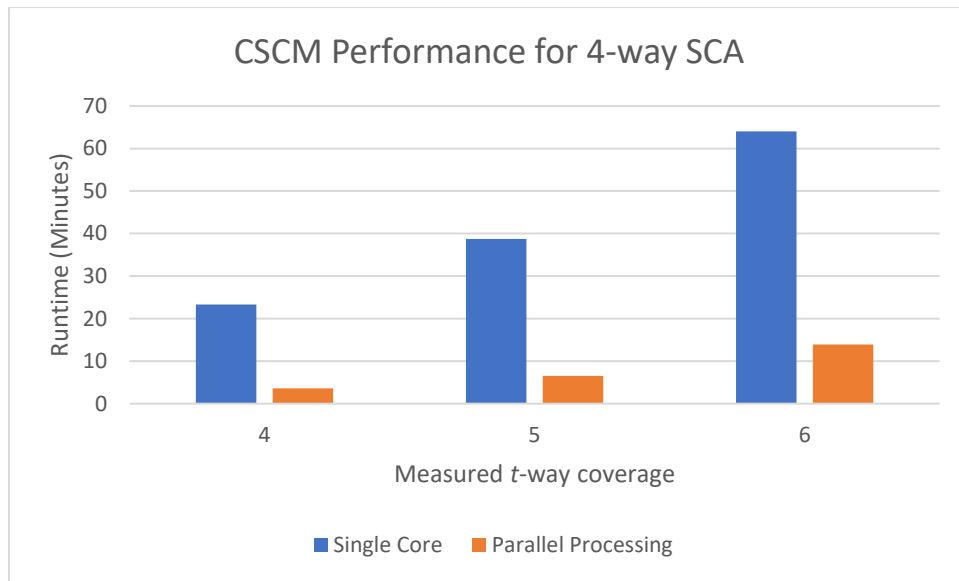
Performance

Below is a performance overview of the CSCM tool. Note that these performance metrics are for an HP Laptop with an Intel i7-8550U CPU (8 cores) and 16GB of RAM. The test files used are available in the Github repository, as well as at the end of this document. The program was executed with parallel processing parameter **-N7** (i.e. 7 OS threads / parallel processes were used).

In all the tests, 26 events were used (a-z), and the sequence covering arrays were generated via the NIST sequence covering array generator tool.

	3-way SCA		
t	Time (single core)	Time (parallel)	t-way coverage
4	235.92	35.168	70.44%
5	319.18	56.22	20.05%
6	384.98	98.637	3.57%

Note that the below graph and data is measured in minutes.

CSCM Performance for 4-way SCA

	4-way SCA		
t	**Time (single core)**	**Time (parallel)**	**t-way coverage**
4	23.325	3.633166667	100.00%
5	38.76666667	6.509166667	72.37%
6	64.00433333	13.895	18.40%

The *t*-way coverage metric just shows the resulting output from running the tool. As you can see, we can measure the (*t+k*)-way coverage of a *t*-way sequence covering array. The NIST sequence covering array generator tool provided fairly high (*t+1*)-way coverage in both cases, but provided low (*t+2*)-way coverage.

As you can see from the results above, the performance of CSCM is greatly increased when running in parallel, which is advised for systems with a larger number of events.

Appendix

NIST Sequence Covering Array Generator:

Event definition file

a,b,c,d,e,f,g,h,i,j,k,l,m,n,o,p,q,r,s,t,u,v,w,x,y,z

3-way sequence covering array file

```
a,b,c,d,e,f,g,h,i,j,k,l,m,n,o,p,q,r,s,t,u,v,w,x,y,z
z,y,x,w,v,u,t,s,r,q,p,o,n,m,l,k,j,i,h,g,f,e,d,c,b,a
r,n,k,t,d,s,f,l,g,y,z,b,h,o,v,c,x,a,w,i,u,m,e,p,q,j
j,q,p,e,m,u,i,w,a,x,c,v,o,h,b,z,y,g,l,f,s,d,t,k,n,r
w,o,u,h,f,c,p,n,y,i,j,s,g,k,r,b,t,e,q,m,a,z,d,x,l,v
v,l,x,d,z,a,m,q,e,t,b,r,k,g,s,j,i,y,n,p,c,f,h,u,o,w
m,b,i,f,x,t,s,n,l,z,a,u,w,j,d,p,k,o,c,v,q,y,r,h,e,g
g,e,h,r,y,q,v,c,o,k,p,d,j,w,u,a,z,l,n,s,t,x,f,i,b,m
o,a,k,g,n,v,i,b,y,t,x,e,w,d,f,l,h,z,q,r,j,u,p,s,c,m
m,c,s,p,u,j,r,q,z,h,l,f,d,w,e,x,t,y,b,i,v,n,g,k,a,o
l,p,s,a,i,c,y,m,v,o,d,g,e,n,z,r,b,k,h,f,j,q,x,u,t,w
w,t,u,x,q,j,f,h,k,b,r,z,n,e,g,d,o,v,m,y,c,i,a,s,p,l
w,k,h,e,x,t,f,l,c,s,p,v,a,g,o,q,y,u,j,m,i,z,n,b,d,r
r,d,b,n,z,i,m,j,u,y,q,o,g,a,v,p,s,c,l,f,t,x,e,h,k,w
l,c,t,z,h,y,k,f,n,e,u,m,b,g,q,x,r,a,s,i,v,w,p,d,j,o
o,j,d,p,w,v,i,s,a,r,x,q,g,b,m,u,e,n,f,k,y,h,z,t,c,l
u,g,x,b,p,h,f,w,m,o,e,s,a,r,l,c,k,y,q,z,n,d,v,i,j,t
t,j,i,v,d,n,z,q,y,k,c,l,r,a,s,e,o,m,w,f,h,p,b,x,g,u
n,k,e,o,p,c,q,w,b,x,s,y,h,v,f,t,d,j,u,i,r,l,z,a,m,g
g,m,a,z,l,r,i,u,j,d,t,f,v,h,y,s,x,b,w,q,c,p,o,e,k,n
g,b,k,l,c,w,q,v,f,s,r,m,o,t,n,i,j,x,p,a,e,u,h,y,d,z
z,d,y,h,u,e,a,p,x,j,i,n,t,o,m,r,s,f,v,q,w,c,l,k,b,g
y,t,f,i,o,w,m,h,k,b,s,x,u,g,d,c,z,a,l,p,r,e,v,j,q,n
n,q,j,v,e,r,p,l,a,z,c,d,g,u,x,s,b,k,h,m,w,o,i,f,t,y
s,e,f,x,k,t,m,i,l,j,a,r,n,g,c,y,b,p,d,o,q,u,v,h,z,w
w,z,h,v,u,q,o,d,p,b,y,c,g,n,r,a,j,l,i,m,t,k,x,f,e,s
```

4-way sequence covering array file

```
a,b,c,d,e,f,g,h,i,j,k,l,m,n,o,p,q,r,s,t,u,v,w,x,y,z
z,y,x,w,v,u,t,s,r,q,p,o,n,m,l,k,j,i,h,g,f,e,d,c,b,a
t,m,h,k,n,s,r,g,x,u,e,b,w,a,p,i,j,z,c,y,d,v,l,q,f,o
o,f,q,l,v,d,y,c,z,j,i,p,a,w,b,e,u,x,g,r,s,n,k,h,m,t
i,p,g,m,r,h,l,u,y,b,s,a,q,n,x,t,f,d,z,c,o,k,w,e,v,j
j,v,e,w,k,o,c,z,d,f,t,x,n,q,a,s,b,y,u,l,h,r,m,g,p,i
q,e,s,a,j,h,y,x,r,z,b,g,l,c,t,p,k,f,m,v,w,o,i,d,u,n
n,u,d,i,o,w,v,m,f,k,p,t,c,l,g,b,z,r,x,y,h,j,a,s,e,q
z,c,k,m,i,a,o,s,t,v,e,u,l,y,w,f,p,g,n,j,q,r,d,h,b,x
x,b,h,d,r,q,j,n,g,p,f,w,y,l,u,e,v,t,s,o,a,i,m,k,c,z
t,u,p,k,m,d,z,h,y,f,o,v,w,e,a,x,b,q,c,i,r,n,l,g,s,j
j,s,g,l,n,r,i,c,q,b,x,a,e,w,v,o,f,y,h,z,d,m,k,p,u,t
t,l,v,g,b,s,f,m,j,w,u,i,h,a,o,c,x,q,k,n,d,z,r,y,e,p
```

p,e,y,r,z,d,n,k,q,x,c,o,a,h,i,u,w,j,m,f,s,b,g,v,l,t
b,s,t,c,q,z,u,g,y,v,n,k,h,l,d,j,x,p,m,r,a,i,o,e,w,f
f,w,e,o,i,a,r,m,p,x,j,d,l,h,k,n,v,y,g,u,z,q,c,t,s,b
w,f,g,n,d,r,y,s,v,l,h,k,i,z,t,e,c,o,b,u,q,a,p,m,j,x
x,j,m,p,a,q,u,b,o,c,e,t,z,i,k,h,l,v,s,y,r,d,n,g,f,w
h,p,c,v,a,q,l,m,j,g,z,n,s,d,i,w,x,f,t,r,o,e,k,u,y,b
b,y,u,k,e,o,r,t,f,x,w,i,d,s,n,z,g,j,m,l,q,a,v,c,p,h
z,l,u,h,j,r,c,d,k,t,w,p,e,q,m,i,b,y,o,g,v,n,f,s,a,x
x,a,s,f,n,v,g,o,y,b,i,m,q,e,p,w,t,k,d,c,r,j,h,u,l,z
a,w,j,k,q,d,r,u,m,b,i,t,x,c,v,n,f,e,h,s,p,g,z,y,o,l
l,o,y,z,g,p,s,h,e,f,n,v,c,x,t,i,b,m,u,r,d,q,k,j,w,a
i,m,n,b,j,d,u,z,v,y,e,c,a,g,t,h,w,k,p,o,q,s,f,l,x,r
r,x,l,f,s,q,o,p,k,w,h,t,g,a,c,e,y,v,z,u,d,j,b,n,m,i
g,h,e,m,v,z,o,b,d,k,s,p,r,y,l,j,f,x,n,i,c,w,a,q,t,u
u,t,q,a,w,c,i,n,x,f,j,l,y,r,p,s,k,d,b,o,z,v,m,e,h,g
y,k,f,b,c,s,x,u,h,a,v,m,z,n,i,r,j,t,w,q,d,g,p,e,o,l
l,o,e,p,g,d,q,w,t,j,r,i,n,z,m,v,a,h,u,x,s,c,b,f,k,y
p,i,q,w,t,s,y,m,c,e,o,f,l,u,x,j,b,a,h,r,z,n,g,k,d,v
v,d,k,g,n,z,r,h,a,b,j,x,u,l,f,o,e,c,m,y,s,t,w,q,i,p
e,s,j,o,a,u,q,g,f,k,v,d,h,x,m,z,w,l,i,n,p,r,b,y,t,c
c,t,y,b,r,p,n,i,l,w,z,m,x,h,d,v,k,f,g,q,u,a,o,j,s,e
y,m,q,t,k,a,j,g,i,w,v,d,r,l,s,b,u,f,h,p,e,z,c,o,x,n
n,x,o,c,z,e,p,h,f,u,b,s,l,r,d,v,w,i,g,j,a,k,t,q,m,y
g,z,q,r,f,d,a,p,i,s,t,v,j,o,x,y,u,e,c,n,w,m,l,k,b,h
h,b,k,l,m,w,n,c,e,u,y,x,o,j,v,t,s,i,p,a,d,f,r,q,z,g
n,d,l,j,y,q,f,w,s,x,e,b,k,m,p,g,t,o,i,z,u,h,r,v,c,a
a,c,v,r,h,u,z,i,o,t,g,p,m,k,b,e,x,s,w,f,q,y,j,l,d,n
s,x,d,n,t,w,c,m,a,h,l,q,v,k,o,e,z,j,f,g,p,i,y,b,r,u
u,r,b,y,i,p,g,f,j,z,e,o,k,v,q,l,h,a,m,c,w,t,n,d,x,s
o,i,x,w,z,u,g,j,p,s,d,k,b,a,y,v,h,n,c,q,t,f,l,m,r,e
e,r,m,l,f,t,q,c,n,h,v,y,a,b,k,d,s,p,j,g,u,z,w,x,i,o
j,w,d,l,b,a,t,p,z,s,f,i,o,y,r,m,k,g,c,e,x,q,h,n,v,u
u,v,n,h,q,x,e,c,g,k,m,r,y,o,i,f,s,z,p,t,a,b,l,d,w,j
v,i,q,s,d,b,a,w,p,e,j,h,z,n,m,l,f,u,y,r,o,x,k,c,t,g
g,t,c,k,x,o,r,y,u,f,l,m,n,z,h,j,e,p,w,a,b,d,s,q,i,v
z,j,f,k,w,i,h,g,v,c,p,s,b,l,t,r,y,q,x,u,e,m,a,n,d,o
o,d,n,a,m,e,u,x,q,y,r,t,l,b,s,p,c,v,g,h,i,w,k,f,j,z
i,l,k,h,s,o,q,v,n,m,r,t,a,j,y,u,x,b,z,w,c,e,d,p,g,f
f,g,p,d,e,c,w,z,b,x,u,y,j,a,t,r,m,n,v,q,o,s,h,k,l,i
b,a,t,r,v,w,g,o,k,c,s,l,u,e,h,q,d,n,j,p,z,y,f,i,x,m
m,x,i,f,y,z,p,j,n,d,q,h,e,u,l,s,c,k,o,g,w,v,r,t,a,b
i,y,v,k,j,f,o,g,h,t,l,z,x,n,d,a,b,e,p,m,u,q,w,c,s,r
r,s,c,w,q,u,m,p,e,b,a,d,n,x,z,l,t,h,g,o,f,j,k,v,y,i
b,w,y,q,h,g,j,a,s,c,d,i,e,o,n,u,v,z,r,x,l,m,p,f,k,t
t,k,f,p,m,l,x,r,z,v,u,n,o,e,i,d,c,s,a,j,g,h,q,y,w,b
v,r,e,y,m,w,d,s,j,c,k,b,t,g,x,i,o,z,p,n,f,h,a,l,u,q
q,u,l,a,h,f,n,p,z,o,i,x,g,t,b,k,c,j,s,d,w,m,y,e,r,v
u,l,n,a,z,h,x,g,t,q,y,m,j,d,v,f,c,i,e,w,b,r,k,p,s,o
o,s,p,k,r,b,w,e,i,c,f,v,d,j,m,y,q,t,g,x,h,z,a,n,l,u
c,u,w,s,p,n,y,v,e,j,b,l,x,q,o,g,m,t,r,d,i,f,k,a,h,z
z,h,a,k,f,i,d,r,t,m,g,o,q,x,l,b,j,e,v,y,n,p,s,w,u,c
a,n,o,w,s,z,g,m,h,v,b,r,u,p,f,c,t,q,d,i,y,j,k,e,l,x
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c,g,h,w,s,j,f,u,l,o,r,m,z,n,k,q,v,a,e,x,d,b,p,t,i,y
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v,h,i,e,p,f,u,o,k,r,b,c,g,d,x,a,j,l,n,t,w,m,y,q,z,s
s,z,q,y,m,w,t,n,l,j,a,x,d,g,c,b,r,k,o,u,f,p,e,i,h,v
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m,q,c,b,p,e,y,u,f,t,l,d,o,k,w,v,s,z,r,j,h,i,n,g,a,x
x,e,n,g,u,m,k,c,s,w,q,o,i,b,t,d,j,f,l,y,a,z,r,v,p,h
h,p,v,r,z,a,y,l,f,j,d,t,b,i,o,q,w,s,c,k,m,u,g,n,e,x
z,c,v,t,o,e,x,k,b,q,h,n,g,y,a,w,f,p,i,m,s,u,d,j,l,r
r,l,j,d,u,s,m,i,p,f,w,a,y,g,n,h,q,b,k,x,e,o,t,v,c,z
d,t,j,o,h,l,n,u,b,i,s,e,k,m,g,p,x,y,w,r,a,q,v,z,c,f
f,c,z,v,q,a,r,w,y,x,p,g,m,k,e,s,i,b,u,n,l,h,o,j,t,d

p,o,g,a,y,d,j,v,b,c,w,i,r,z,l,u,q,n,t,h,e,k,x,s,f,m
m,f,s,x,k,e,h,t,n,q,u,l,z,r,i,w,c,b,v,j,d,y,a,g,o,p
c,h,w,i,k,n,p,q,x,z,f,v,y,e,l,j,g,o,s,b,a,m,r,t,d,u
u,d,t,r,m,a,b,s,o,g,j,l,e,y,v,f,z,x,q,p,n,k,i,w,h,c
t,n,v,d,c,a,w,s,x,u,f,g,p,j,q,z,h,i,o,e,l,y,k,r,m,b
b,m,r,k,y,l,e,o,i,h,z,q,j,p,g,f,u,x,s,w,a,c,d,v,n,t
o,w,e,t,b,x,v,h,c,m,y,p,r,a,g,q,k,i,f,s,n,z,d,j,l,u
u,l,j,d,z,n,s,f,i,k,q,g,a,r,p,y,m,c,h,v,x,b,t,e,w,o
g,w,y,h,z,i,p,t,n,x,a,s,m,l,e,d,b,c,o,u,j,k,v,f,r,q
q,r,f,v,k,j,u,o,c,b,d,e,l,m,s,a,x,n,t,p,i,z,h,y,w,g
o,n,b,p,k,l,q,t,h,m,w,f,r,a,e,c,j,x,y,z,u,d,g,i,s,v
v,s,i,g,d,u,z,y,x,j,c,e,a,r,f,w,m,h,t,q,l,k,p,b,n,o
l,k,w,x,u,o,y,r,d,z,i,g,h,v,b,m,e,a,s,j,f,q,n,t,c,p
p,c,t,n,q,f,j,s,a,e,m,b,v,h,g,i,z,d,r,y,o,u,x,w,k,l
f,y,n,s,l,r,c,q,u,z,t,g,e,a,v,o,b,x,p,j,k,i,m,d,w,h
h,w,d,m,i,k,j,p,x,b,o,v,a,e,g,t,z,u,q,c,r,l,s,n,y,f
s,i,c,m,z,r,d,l,o,y,x,q,a,j,n,v,t,p,u,k,b,h,f,e,w,g
g,w,e,f,h,b,k,u,p,t,v,n,j,a,q,x,y,o,l,d,r,z,m,c,i,s
j,q,r,x,n,z,i,b,l,m,u,d,e,t,w,o,g,v,a,c,p,h,y,s,f,k
k,f,s,y,h,p,c,a,v,g,o,w,t,e,d,u,m,l,b,i,z,n,x,r,q,j
y,o,s,p,n,j,u,w,c,f,h,z,r,i,x,t,v,l,d,e,m,k,b,g,a,q
q,a,g,b,k,m,e,d,l,v,t,x,i,r,z,h,f,c,w,u,j,n,p,s,o,y
k,e,w,l,x,i,z,r,s,n,u,f,d,t,m,g,y,p,v,j,a,o,q,h,c,b
b,c,h,q,o,a,j,v,p,y,g,m,t,d,f,u,n,s,r,z,i,x,l,w,e,k
z,v,e,a,i,w,d,q,l,g,y,p,u,s,c,r,m,b,f,t,h,k,n,x,j,o
o,j,x,n,k,h,t,f,b,m,r,c,s,u,p,y,g,l,q,d,w,i,a,e,v,z
u,i,m,o,q,e,x,c,j,d,g,k,n,l,r,p,y,h,s,z,a,w,f,v,b,t
t,b,v,f,w,a,z,s,h,y,p,r,l,n,k,g,d,j,c,x,e,q,o,m,i,u
j,l,h,a,t,w,c,k,m,s,g,x,u,d,i,v,z,e,o,n,b,q,f,r,p,y
y,p,r,f,q,b,n,o,e,z,v,i,d,u,x,g,s,m,k,c,w,t,a,h,l,j
i,x,d,s,u,v,f,b,z,r,l,g,m,n,t,p,j,w,e,o,q,c,y,a,k,h
h,k,a,y,c,q,o,e,w,j,p,t,n,m,g,l,r,z,b,f,v,u,s,d,x,i
s,m,d,r,h,j,b,f,o,w,l,a,z,v,e,t,p,q,u,k,c,y,n,x,i,g
g,i,x,n,y,c,k,u,q,p,t,e,v,z,a,l,w,o,f,b,j,h,r,d,m,s
w,z,l,v,x,m,b,c,r,q,j,p,g,n,o,d,f,e,h,u,i,t,s,y,k,a
a,k,y,s,t,i,u,h,e,f,d,o,n,g,p,j,q,r,c,b,m,x,v,l,z,w
p,a,e,j,v,x,u,q,r,h,m,w,k,c,s,d,n,f,i,t,l,g,b,o,y,z
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r,o,f,v,e,u,l,k,g,p,t,a,z,w,y,h,j,d,s,q,i,b,x,c,m,n
n,m,c,x,b,i,q,s,d,j,h,y,w,z,a,t,p,g,k,l,u,e,v,f,o,r
z,q,d,i,n,o,y,l,b,e,h,m,u,g,f,v,p,j,k,s,x,w,r,t,a,c
c,a,t,r,w,x,s,k,j,p,v,f,g,u,m,h,e,b,l,y,o,n,i,d,q,z
z,k,p,f,b,a,h,u,y,c,x,g,m,l,j,t,o,n,w,d,r,i,s,v,q,e
e,q,v,s,i,r,d,w,n,o,t,j,l,m,g,x,c,y,u,h,a,b,f,p,k,z
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u,m,x,p,t,g,o,f,s,j,i,n,q,v,b,l,y,d,z,r,a,h,c,w,k,e
z,v,f,e,t,q,d,x,h,w,o,u,b,j,k,p,s,g,c,y,m,l,r,a,n,i
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u,d,b,z,v,t,e,g,h,k,o,a,n,r,c,i,m,l,f,w,q,y,s,p,j,x
h,e,u,l,k,g,m,x,f,t,s,p,b,z,o,a,d,c,q,v,y,w,r,j,n,i
i,n,j,r,w,y,v,q,c,d,a,o,z,b,p,s,t,f,x,m,g,k,l,u,e,h
y,k,a,l,e,x,u,d,j,h,r,i,c,t,f,z,n,g,s,v,m,o,q,b,p,w
w,p,b,q,o,m,v,s,g,n,z,f,t,c,i,r,h,j,d,u,x,e,l,a,k,y
c,y,s,a,g,o,e,m,p,z,u,j,r,w,t,q,l,k,f,n,x,v,d,h,b,i
i,b,h,d,v,x,n,f,k,l,q,t,w,r,j,u,z,p,m,e,o,g,a,s,y,c
h,t,b,j,i,n,f,s,o,c,r,y,z,d,e,v,a,q,g,u,p,x,w,k,l,m
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p,b,k,r,e,y,q,a,d,h,j,w,g,v,o,z,s,f,c,x,l,m,t,n,i,u
u,i,n,t,m,l,x,c,f,s,z,o,v,g,w,j,h,d,a,q,y,e,r,k,b,p
e,h,r,o,z,x,l,s,p,b,v,y,j,c,k,f,d,w,u,n,a,g,m,q,t,i
i,t,q,m,g,a,n,u,w,d,f,k,c,j,y,v,b,p,s,l,x,z,o,r,h,e