

1. The first Linux tool you should check out is the very simple tool `free`. First, type `man free` and read its entire manual page; it's short, don't worry!
2. Now, run `free`, perhaps using some of the arguments that might be useful (e.g., `-m`, to display memory totals in megabytes). How much memory is in your system? How much is free? Do these numbers match your intuition?

```
vl161bra@ct-bsys-ws20-12:~$ free -m -w
```

	total	used	free	shared	buffers	cache	available
Mem:	2048	328	1589	17	0	130	1719
Swap:	3072	212	2859				

Free Command in Linux | Linuxize

Wie viel Speicher ist in System? $2048 + 3072 = 5120$ Megabyte

Wie viel ist frei? 3105 MB

$\text{used} = \text{total} - \text{free} - \text{buffers} - \text{cache}$

Passt es zur deiner Intuition? Ja, es scheint nach einem realistischen Speicher

Available ist Speicher fürs starten von neuen Applikationen das verfügbar ist, ohne swapping

Buffers wird von kernel buffers verwendet.

Cache wird von page cache and slabs verwendet.

3. Next, create a little program that uses a certain amount of memory, called `memory-user.c`. This program should take one commandline argument: the number of megabytes of memory it will use. When run, it should allocate an array, and constantly stream through the array, touching each entry. The program should do this indefinitely, or, perhaps, for a certain amount of time also specified at the command line.
4. Now, while running your `memory-user` program, also (in a different terminal window, but on the same machine) run the `free` tool. How do the memory usage totals change when your program is running? How about when you kill the `memory-user` program? Do the numbers match your expectations? Try this for different amounts of memory usage. What happens when you use really large amounts of memory?

Versuch 1:

→ Beobachtungen nach dem ersten Laufen:

```
./memory-user 1000 100000
```

Davor!

```
vl161bra@ct-bsys-ws20-12:~$ free -m
              total        used         free       shared    buff/cache   available
Mem:           2048          725         1029          67         292        1322
Swap:          3072           1         3070
vl161bra@ct-bsys-ws20-12:~$ free -m
              total        used         free       shared    buff/cache   available
Mem:           2048          730         1024          67         292        1317
Swap:          3072           1         3070
```

Ersten 4

```
vl161bra@ct-bsys-ws20-12:~$ free -m
              total        used         free       shared    buff/cache   available
Mem:           2048         1675           79          67         292         372
Swap:          3072           2         3069
vl161bra@ct-bsys-ws20-12:~$ free -m
              total        used         free       shared    buff/cache   available
Mem:           2048         1728           26          67         292         319
Swap:          3072           1         3070
vl161bra@ct-bsys-ws20-12:~$ free -m
              total        used         free       shared    buff/cache   available
Mem:           2048         1728           26          67         292         319
Swap:          3072           1         3070
vl161bra@ct-bsys-ws20-12:~$ free -m
              total        used         free       shared    buff/cache   available
Mem:           2048         1728           26          67         292         319
Swap:          3072           1         3070
```

Letzten 4

```
vl161bra@ct-bsys-ws20-12:~$ free -m
              total        used         free       shared    buff/cache   available
Mem:           2048         1727           27          67         292         320
Swap:          3072           1         3070
vl161bra@ct-bsys-ws20-12:~$ free -m
              total        used         free       shared    buff/cache   available
Mem:           2048         1727           27          67         292         320
Swap:          3072           1         3070
vl161bra@ct-bsys-ws20-12:~$ free -m
              total        used         free       shared    buff/cache   available
Mem:           2048         1730           24          67         292         317
Swap:          3072           1         3070
vl161bra@ct-bsys-ws20-12:~$ free -m
              total        used         free       shared    buff/cache   available
Mem:           2048         1727           27          67         292         320
Swap:          3072           1         3070
```

- Die Spalten total, shared und buff/cache haben sich gar nicht geändert!
- Memory used wird um 1000 gesteigert.
- Memory free wird um 1000 verkleinert
- available wird um 1000 verkleinert

Versuch 2:

```
vl161bra@ct-bsys-ws20-12:~$ top

top - 07:34:09 up 22 days, 20:38,  2 users,  load average: 3,08, 2,98, 3,01
Tasks:  62 total,   2 running,  60 sleeping,   0 stopped,   0 zombie
%Cpu(s): 23,5 us,  0,0 sy,  0,0 ni, 76,5 id,  0,0 wa,  0,0 hi,  0,0 si,  0,0 st
MiB Mem :  2048,0 total,   22,6 free,  1738,0 used,   287,3 buff/cache
MiB Swap:  3072,0 total,  3070,0 free,    2,0 used.   310,0 avail Mem

  PID USER      PR  NI   VIRT   RES   SHR  S  %CPU  %MEM     TIME+ COMMAND
26727 vl161bra  20   0 1026276  1,0g 1164 R  91,7  48,9   0:22.46 memory-user
   1 root      20   0  169520 10348  8036 S   0,0   0,5   0:08.81 systemd
  52 root      20   0   74844 48180 46804 S   0,0   2,3   0:17.00 systemd-journal
  75 root      20   0    9840  5988  4324 S   0,0   0,3   0:06.32 dhclient
  77 root      20   0    5508  2296  2084 S   0,0   0,1   0:02.59 cron
  78 root      20   0  239124  8504  7400 S   0,0   0,4   0:26.16 accounts-daemon
  79 root      20   0  225820  3784  3008 S   0,0   0,2   0:03.30 rsyslogd
  80 root      20   0   19508  7136  6168 S   0,0   0,3   0:02.75 systemd-logind
```

Memory vor dem Kill:

```
vl161bra@ct-bsys-ws20-12:~$ free -m
              total        used        free      shared  buff/cache   available
Mem:           2048          1759           1           68         287         288
Swap:          3072           1        3070

vl161bra@ct-bsys-ws20-12:~$ free -m
              total        used        free      shared  buff/cache   available
Mem:           2048          1737           22           68         287         310
Swap:          3072           1        3070
```

Nachdem kill:

```
vl161bra@ct-bsys-ws20-12:~$ kill 26727
vl161bra@ct-bsys-ws20-12:~$ free -m
              total        used        free      shared  buff/cache   available
Mem:           2048           742        1017           68         287        1305
Swap:          3072           1        3070

vl161bra@ct-bsys-ws20-12:~$ free -m
              total        used        free      shared  buff/cache   available
Mem:           2048           735        1024           68         287        1312
Swap:          3072           1        3070

vl161bra@ct-bsys-ws20-12:~$ free -m
              total        used        free      shared  buff/cache   available
Mem:           2048           735        1025           68         287        1312
Swap:          3072           1        3070
```

→ Alles wird zurückgesetzt, also ja es entspricht meiner Erwartungen

Versuch 3:

Wenn man mehr Speicher allokieren will, als man freier Speicher hat:

```
vl161bra@ct-bsys-ws20-12:~/htwg/S3/BS/BSCode/c13_vm-intro$ ./memory-user 2500 100000
```

Speicher davor:

```
vl161bra@ct-bsys-ws20-12:~$ free -m
              total        used        free      shared  buff/cache   available
Mem:           2048           735        1025           67         286        1312
Swap:          3072           1        3070
```

Speicher danach und zum Ende:

```
vl161bra@ct-bsys-ws20-12:~$ free -m
              total        used        free      shared  buff/cache   available
Mem:           2048          735         1025          67         286        1312
Swap:          3072           1         3070
vl161bra@ct-bsys-ws20-12:~$ free -m
              total        used        free      shared  buff/cache   available
Mem:           2048          735         1025          67         286        1312
Swap:          3072           1         3070
vl161bra@ct-bsys-ws20-12:~$ free -m
              total        used        free      shared  buff/cache   available
Mem:           2048          736         1025          67         286        1312
Swap:          3072           1         3070
vl161bra@ct-bsys-ws20-12:~$ free -m
              total        used        free      shared  buff/cache   available
Mem:           2048          735         1025          67         286        1312
Swap:          3072           1         3070
```

Nach dem Killen:

```
vl161bra@ct-bsys-ws20-12:~$ free -m
              total        used        free      shared  buff/cache   available
Mem:           2048          754         1006          67         286        1293
Swap:          3072           1         3070
vl161bra@ct-bsys-ws20-12:~$ free -m
              total        used        free      shared  buff/cache   available
Mem:           2048          734         1026          67         286        1313
Swap:          3072           1         3070
```

Versuch 4:

```
vl161bra@ct-bsys-ws20-12:~/htwg/S3/BS/BSCode/c13_vm-intro$ ./memory-user 10000 100000
Terminated
```

Erstes ist vor dem Befehl, letzte zwei nach dem Befehl

```
vl161bra@ct-bsys-ws20-12:~$ free -m -w
              total        used        free      shared  buffers       cache   available
Mem:           2048          172         1832          17           0          43        1875
Swap:          3072          275         2796
vl161bra@ct-bsys-ws20-12:~$
vl161bra@ct-bsys-ws20-12:~$
vl161bra@ct-bsys-ws20-12:~$ free -m -w
              total        used        free      shared  buffers       cache   available
Mem:           2048         1984          10         17           0          52          63
Swap:          3072          274         2797
vl161bra@ct-bsys-ws20-12:~$ free -m -w
              total        used        free      shared  buffers       cache   available
Mem:           2048         1982           21         11           0          43          65
Swap:          3072          283         2788
```

```
vl161bra@ct-bsys-ws20-12:~$ kill 29667
vl161bra@ct-bsys-ws20-12:~$
vl161bra@ct-bsys-ws20-12:~$
vl161bra@ct-bsys-ws20-12:~$ free -m -w
              total        used        free      shared  buffers       cache   available
Mem:           2048          171         1833          10           0          42        1876
Swap:          3072          283         2788
```

Versuch 5:

```

vl161bra@ct-bsys-ws20-12:~/htwg/S3/BS/BSCode/c13_vm-intro$ ./memory-user 2000 100000
^C
vl161bra@ct-bsys-ws20-12:~$ free -m
              total        used        free      shared  buff/cache   available
Mem:           2048          330        1586           17          131        1717
Swap:          3072          212        2859
vl161bra@ct-bsys-ws20-12:~$ free -m
              total        used        free      shared  buff/cache   available
Mem:           2048        1915           1           17          131         132
Swap:          3072          212        2859

```

1. Vor dem Programm
2. Während dem Programm

Versuch 6:

```

vl161bra@ct-bsys-ws20-12:~/htwg/S3/BS/BSCode/c13_vm-intro$ ./memory-user 2500 100000
^C
vl161bra@ct-bsys-ws20-12:~$ free -m
              total        used        free      shared  buff/cache   available
Mem:           2048          239        1736           9           71        1808
Swap:          3072          227        2844
vl161bra@ct-bsys-ws20-12:~$ free -m
              total        used        free      shared  buff/cache   available
Mem:           2048          231        1744           9           72        1816
Swap:          3072          227        2844
vl161bra@ct-bsys-ws20-12:~$ free -m
              total        used        free      shared  buff/cache   available
Mem:           2048          231        1744          10           72        1816
Swap:          3072          227        2844

```

1. Vor dem Program
2. + 3. während dem Programm

Versuch 7:

```

vl161bra@ct-bsys-ws20-12:~/htwg/S3/BS/BSCode/c13_vm-intro$ ./memory-user 5000 100000
^C
vl161bra@ct-bsys-ws20-12:~$ free -m
              total        used        free      shared  buff/cache   available
Mem:           2048          231        1744          10           72        1816
Swap:          3072          227        2844
vl161bra@ct-bsys-ws20-12:~$ free -m
              total        used        free      shared  buff/cache   available
Mem:           2048        1993           0          10           54          54
Swap:          3072          286        2785

```

Versuch 8:

```

vl161bra@ct-bsys-ws20-12:~/htwg/S3/BS/BSCode/c13_vm-intro$ ./memory-user 10000 100000
^C

```

```

vl161bra@ct-bsys-ws20-12:~$ free -m
              total        used        free      shared  buff/cache   available
Mem:           2048          233         1752           10           62         1814
Swap:          3072          227         2844
vl161bra@ct-bsys-ws20-12:~$ free -m
              total        used        free      shared  buff/cache   available
Mem:           2048         1776          209           10           62          271
Swap:          3072          227         2844
vl161bra@ct-bsys-ws20-12:~$ free -m
              total        used        free      shared  buff/cache   available
Mem:           2048          222         1775            8           49         1825
Swap:          3072          237         2834

```

1. Vor dem Programm
2. Während dem Programm
3. Nach dem kill

→ Irgendwie wird beim 2500 nichts allokiert, aber bei 1000, 2000, 5000, 10000 schon!

5. Let's try one more tool, known as pmap. Spend some time, and read the pmap manual page in detail.

<https://docs.oracle.com/cd/E19253-01/816-5165/pmap-1/index.html#:~:text=for%20more%20information.,Usage,address%20space%20of%20a%20process.&text=By%20default%2C%20pmap%20displays%20the,mapped%20object%20name%20are%20shown.>

6. To use pmap, you have to know the process ID of the process you're interested in. Thus, first run ps auxw to see a list of all processes; then, pick an interesting one, such as a browser. You can also use your memory-user program in this case (indeed, you can even have that program call getpid() and print out its PID for your convenience).

```

vl161bra@ct-bsys-ws20-12:~/htwg/S3/BS/BSCode/c13_vm-intro$ ./memory-user 1000 100000

```

```

vl161bra@ct-bsys-ws20-12:~$ pmap -x 22783
22783:  ./memory-user 1000 100000
Address      Kbytes      RSS      Dirty  Mode  Mapping
00005634c7632000      4          4          0  r---- memory-user
00005634c7633000      4          4          0  r-x-- memory-user
00005634c7634000      4          0          0  r---- memory-user
00005634c7635000      4          4          4  r---- memory-user
00005634c7636000      4          4          4  rw--- memory-user
00005634c773b000     132          4          4  rw--- [ anon ]
00007f5f7cc17000  1024004  1024004  1024004  rw--- [ anon ]
00007f5fbb418000     136         136          0  r---- libc-2.28.so
00007f5fbb43a000    1312         640          0  r-x-- libc-2.28.so
00007f5fbb582000     304         100          0  r---- libc-2.28.so
00007f5fbb5ce000      4           0          0  ----- libc-2.28.so
00007f5fbb5cf000     16          16         16  r---- libc-2.28.so
00007f5fbb5d3000      8           8          8  rw--- libc-2.28.so
00007f5fbb5d5000     24          20         20  rw--- [ anon ]
00007f5fbb5eb000      4           4          0  r---- ld-2.28.so
00007f5fbb5ec000    120         120          0  r-x-- ld-2.28.so
00007f5fbb60a000     32          32          0  r---- ld-2.28.so
00007f5fbb612000      4           4          4  r---- ld-2.28.so
00007f5fbb613000      4           4          4  rw--- ld-2.28.so
00007f5fbb614000      4           4          4  rw--- [ anon ]
00007ffed7950000    132          12         12  rw--- [ stack ]
00007ffed79c4000     12           0          0  r---- [ anon ]
00007ffed79c7000      4           4          0  r-x-- [ anon ]
ffffffffffff600000      4           0          0  --x-- [ anon ]
-----
total kB      1026280  1025128  1024084

```

Address: start address of map
 Kbytes: size of map in kilobytes
 RSS: resident set size in kilobytes
 Dirty: dirty pages (both shared and private) in kilobytes
 Mode: permissions on map: read, write, execute, shared, private (copy on write)
 Mapping: file backing the map, or '[anon]' for allocated memory, or '[stack]' for the program stack
 Offset: offset into the file
 Device: device name (major:minor)

Resident memory is the real physical memory that processes utilize in the current state. The resident physical memory is a pool of memory used, representing the SAP HANA, operating system, and other programs.

[How to master memory management in SAP Hana - a simplified guide to help you get started](#)

- Now run pmap on some of these processes, using various flags (like -X) to reveal many details about the process. What do you see? How many different entities make up a modern address space, as opposed to our simple conception of codestackheap?


```
vl161bra@ct-bsys-ws20-12:~$ pmap -x 28852
```

```
28852:    vim memory-user.c
```

Address	Kbytes	RSS	Dirty	Mode	Mapping
00005568fce2f000	164	164	0	r----	vim.basic
00005568fce58000	1924	1908	0	r-x--	vim.basic
00005568fd039000	400	156	0	r----	vim.basic
00005568fd09d000	52	52	52	r----	vim.basic
00005568fd0aa000	104	104	80	rw---	vim.basic
00005568fd0c4000	44	44	44	rw---	[anon]
00005568fd289000	2836	2676	2676	rw---	[anon]
00007f8c10337000	12	12	0	r----	libnss_files-2.28.so
00007f8c1033a000	28	28	0	r-x--	libnss_files-2.28.so
00007f8c10341000	8	8	0	r----	libnss_files-2.28.so
00007f8c10343000	4	0	0	-----	libnss_files-2.28.so
00007f8c10344000	4	4	4	r----	libnss_files-2.28.so
00007f8c10345000	4	4	4	rw---	libnss_files-2.28.so
00007f8c10346000	24	0	0	rw---	[anon]
00007f8c1034c000	3296	544	0	r----	locale-archive
00007f8c10684000	8	8	8	rw---	[anon]
00007f8c10686000	24	24	0	r----	libpthread-2.28.so
00007f8c1068c000	60	60	0	r-x--	libpthread-2.28.so
00007f8c1069b000	24	0	0	r----	libpthread-2.28.so
00007f8c106a1000	4	4	4	r----	libpthread-2.28.so
00007f8c106a2000	4	4	4	rw---	libpthread-2.28.so
00007f8c106a3000	16	4	4	rw---	[anon]
00007f8c106a7000	8	8	0	r----	libattr.so.1.1.2448
00007f8c106a9000	12	12	0	r-x--	libattr.so.1.1.2448
00007f8c106ac000	4	0	0	r----	libattr.so.1.1.2448
00007f8c106ad000	4	4	4	r----	libattr.so.1.1.2448
00007f8c106ae000	4	4	4	rw---	libattr.so.1.1.2448
00007f8c106af000	8	8	0	r----	libpcre.so.3.13.3
00007f8c106b1000	328	64	0	r-x--	libpcre.so.3.13.3
00007f8c10703000	120	0	0	r----	libpcre.so.3.13.3
00007f8c10721000	4	4	4	r----	libpcre.so.3.13.3
00007f8c10722000	4	4	4	rw---	libpcre.so.3.13.3
00007f8c10723000	136	136	0	r----	libc-2.28.so
00007f8c10745000	1312	1092	0	r-x--	libc-2.28.so
00007f8c1088d000	304	120	0	r----	libc-2.28.so
00007f8c108d9000	4	0	0	-----	libc-2.28.so
00007f8c108da000	16	16	16	r----	libc-2.28.so
00007f8c108de000	8	8	8	rw---	libc-2.28.so
00007f8c108e0000	24	24	24	rw---	[anon]
00007f8c108e6000	4	4	0	r----	libdl-2.28.so
00007f8c108e7000	4	4	0	r-x--	libdl-2.28.so
00007f8c108e8000	4	0	0	r----	libdl-2.28.so
00007f8c108e9000	4	4	4	r----	libdl-2.28.so
00007f8c108ea000	4	4	4	rw---	libdl-2.28.so
00007f8c108eb000	20	20	0	r-x--	libgpm.so.2
00007f8c108f0000	2048	0	0	-----	libgpm.so.2
00007f8c10af0000	4	4	4	r----	libgpm.so.2
00007f8c10af1000	4	4	4	rw---	libgpm.so.2

00007f8c10af2000	8	8	0	r----	libacl.so.1.1.2253
00007f8c10af4000	20	20	0	r-x--	libacl.so.1.1.2253
00007f8c10af9000	8	0	0	r----	libacl.so.1.1.2253
00007f8c10afb000	4	4	4	r----	libacl.so.1.1.2253
00007f8c10afc000	4	4	4	rw---	libacl.so.1.1.2253
00007f8c10afd000	148	128	0	r-x--	libselinux.so.1
00007f8c10b22000	2044	0	0	-----	libselinux.so.1
00007f8c10d21000	4	4	4	r----	libselinux.so.1
00007f8c10d22000	4	4	4	rw---	libselinux.so.1
00007f8c10d23000	8	4	4	rw---	[anon]
00007f8c10d25000	56	56	0	r----	libtinfo.so.6.1
00007f8c10d33000	56	56	0	r-x--	libtinfo.so.6.1
00007f8c10d41000	52	52	0	r----	libtinfo.so.6.1
00007f8c10d4e000	16	16	16	r----	libtinfo.so.6.1
00007f8c10d52000	4	4	4	rw---	libtinfo.so.6.1
00007f8c10d53000	52	52	0	r----	libm-2.28.so
00007f8c10d60000	636	300	0	r-x--	libm-2.28.so
00007f8c10dff000	852	0	0	r----	libm-2.28.so
00007f8c10ed4000	4	4	4	r----	libm-2.28.so
00007f8c10ed5000	4	4	4	rw---	libm-2.28.so
00007f8c10ed6000	8	8	8	rw---	[anon]
00007f8c10ee8000	4	4	0	r----	ld-2.28.so
00007f8c10ee9000	120	120	0	r-x--	ld-2.28.so
00007f8c10f07000	32	32	0	r----	ld-2.28.so
00007f8c10f0f000	4	4	4	r----	ld-2.28.so
00007f8c10f10000	4	4	4	rw---	ld-2.28.so
00007f8c10f11000	4	4	4	rw---	[anon]
00007fffc8d8d4000	132	60	60	rw---	[stack]
00007fffc8d9ef000	12	0	0	r----	[anon]
00007fffc8d9f2000	4	4	0	r-x--	[anon]
ffffffffffff600000	4	0	0	--x--	[anon]
-----	-----	-----	-----	-----	-----
total kB	17752	8316	3088		

→ Libraries, heap, code, stack

9. Finally, let's run pmap on your memory-user program, with different amounts of used memory. What do you see here? Does the output from pmap match your expectations?

→ [anon] vom Prozess ändert sich je nach allokierten Speicher

→ Offene Fragen: Was ist RSS, Anonymous memory? Was ist eigentlich mapping? Warum RSS manchmal kleiner als map gröÙe

→ RSS gibt die Portion an Speicher, das sich in RAM befindet. Der Rest der memory kann auf dem swap space sein oder in file system.

