Advanced Embedded Software Development

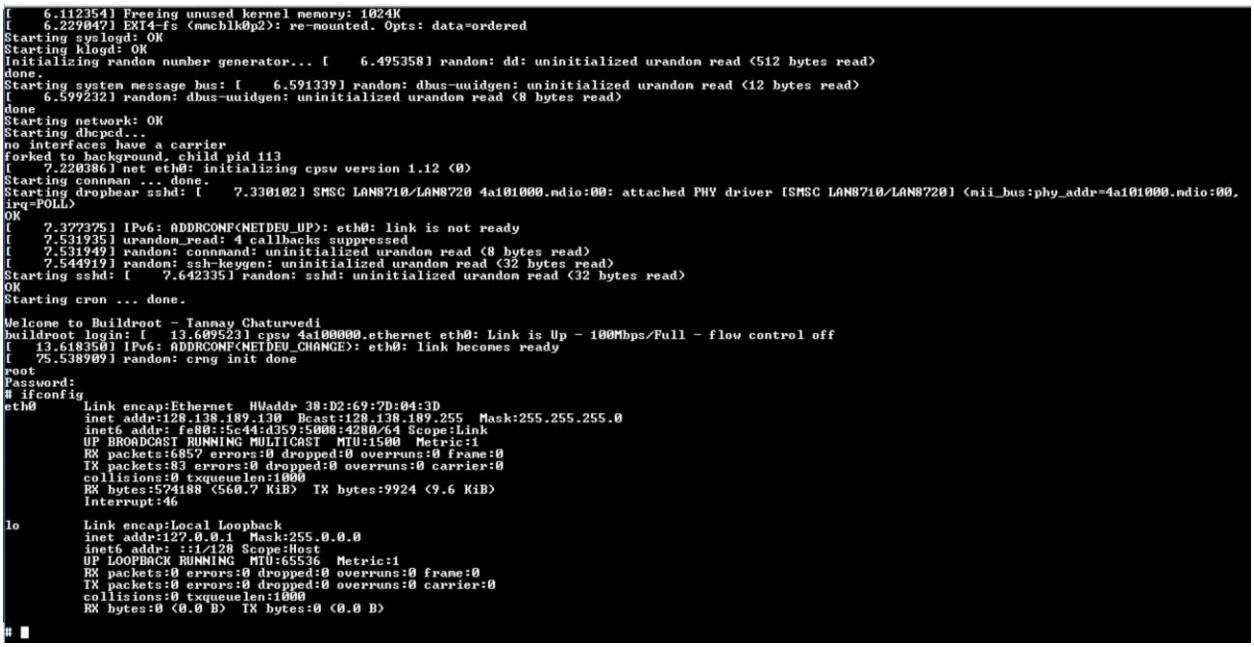
Homework 3
Tanmay Chaturvedi

Date: Feb 17, 2019

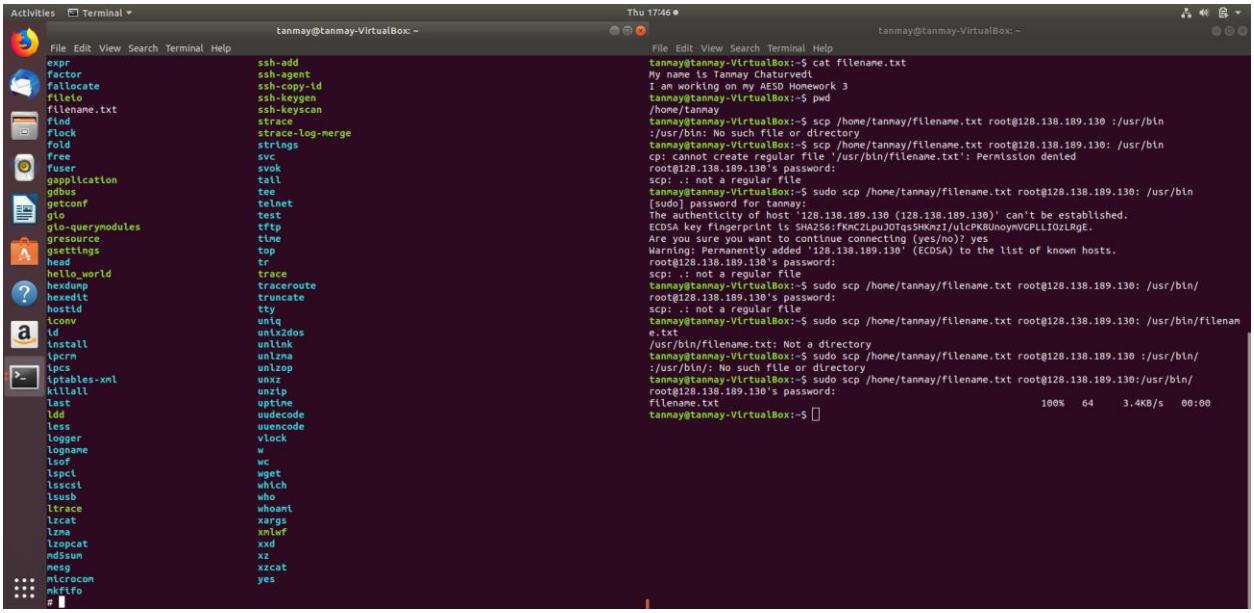
1. Github Repository: https://github.com/TanmayChaturvedi1/Advanced-Embedded-Software-Development/tree/master/Assignment3_Linux_Kernel_Modules

Problem 1.

console boot sequence/dmesg log



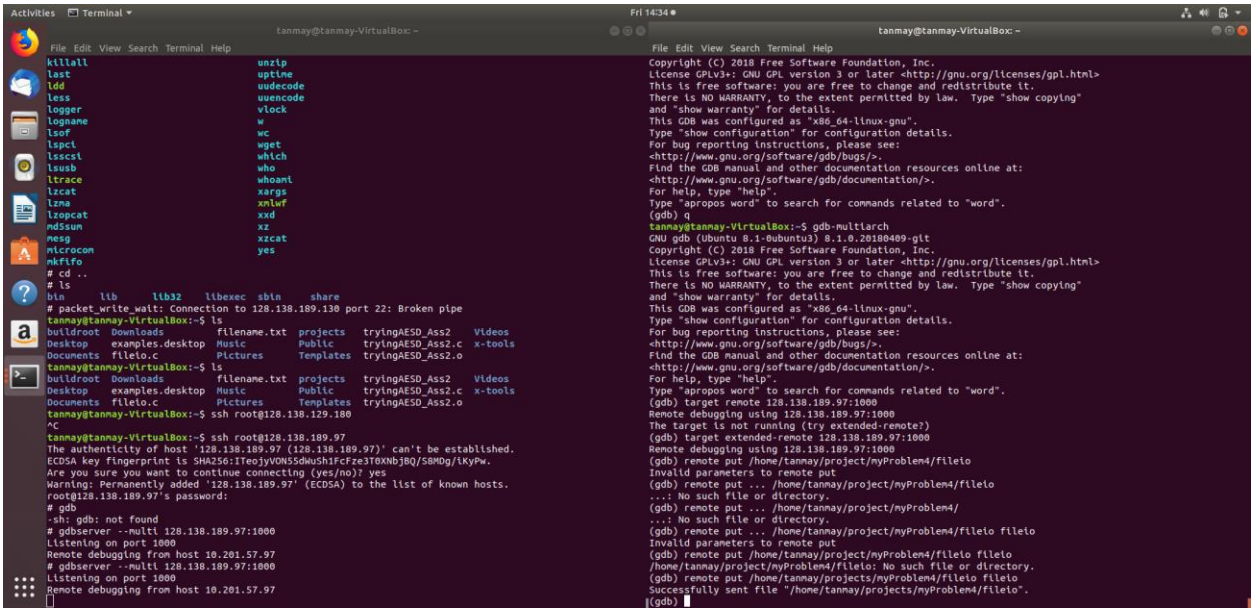
SCP to BBG Successful:



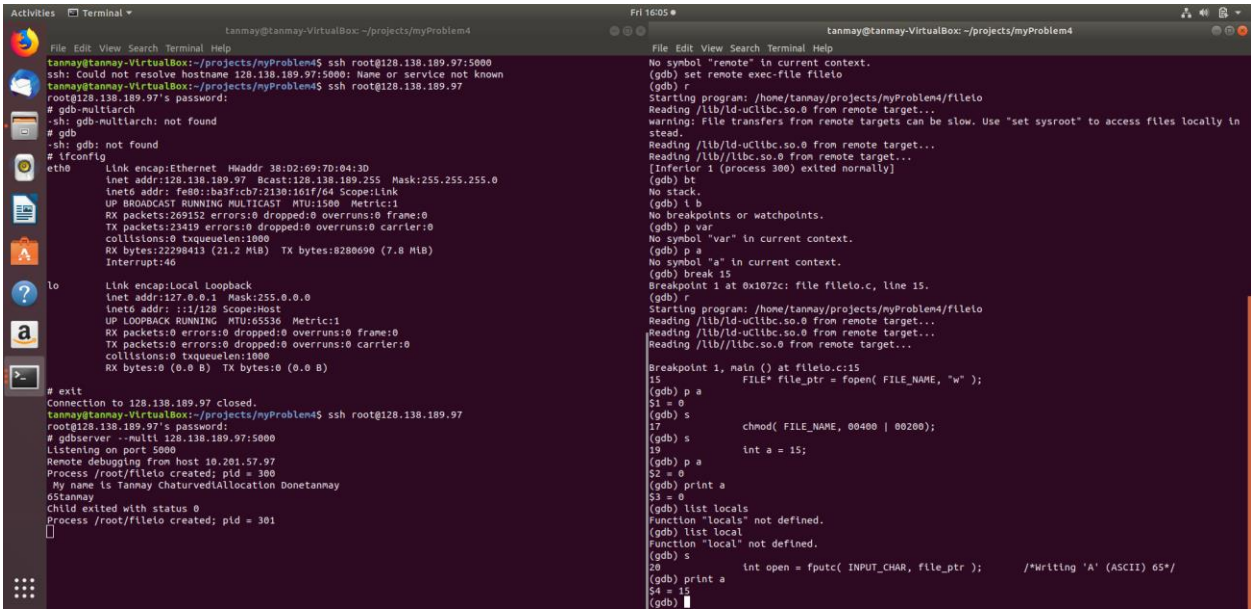
Question 2.

Manual GDB execution:

1. GDB Server Connection



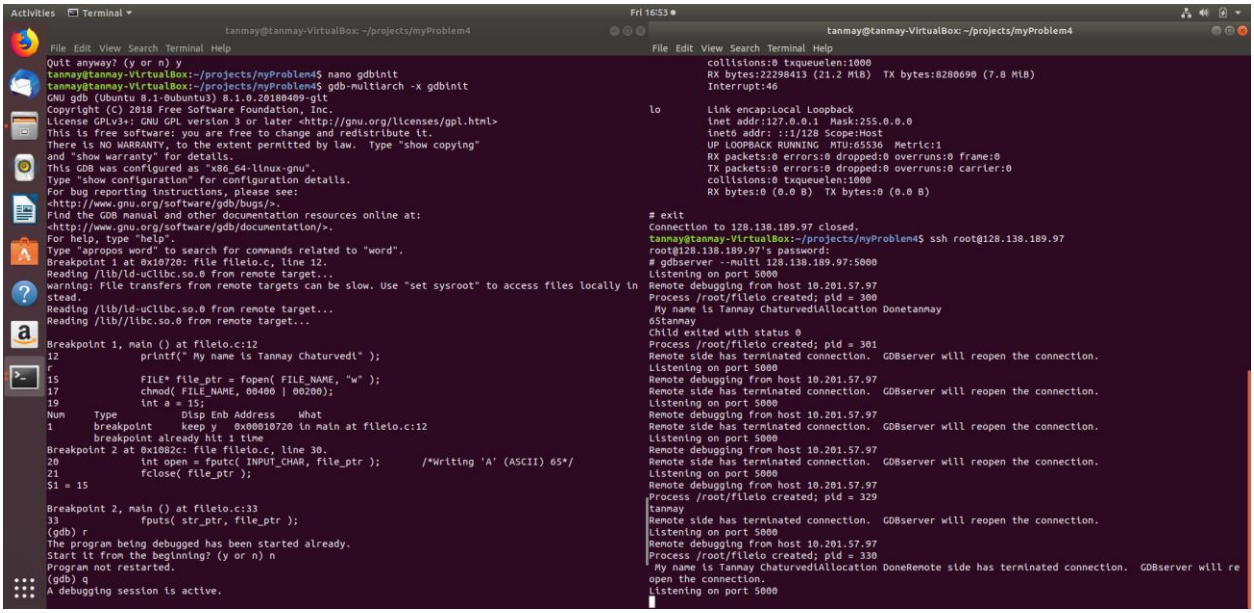
2. Manual Debugging on GDB



3. Gdbinit file:

```
tanmay@tanmay-VirtualBox:~/projects/myProblem4$ cat gdbinit
target extended-remote 128.138.189.97:5000

remote put /home/tanmay/projects/myProblem4/fileio fileio

file fileio

set remote exec-file fileio


break main
r
s
s
s
i b
b 30
s
s
p a
c

tanmay@tanmay-VirtualBox:~/projects/myProblem4$
```

4. Gdbinit auto debugging execution:



Question 3

1. **Timer Load with Param: Input period = 1000msec and input string = “tanny”**

```
# insmod tanmay_kernel.ko input_string=Tanny input_period=1000
[  103.234068] tanmay_kernel: loading out-of-tree module taints kernel.
[  103.242732] Entered the kernel module
# [  104.322277] Name is Tanny  and count is 0
```

2. **Dmesg log**

```
[    1.709904] Registering SWP/SWPB emulation handler
[    1.715010] SmartReflex Class3 initialized
[    1.720551]  mmcblk0: p1 p2
[    1.780413] mmc1: new high speed MMC card at address 0001
[    1.788829] mmcblk1: mmc1:0001 P1XXXX 3.60 GiB
[    1.796475] mmcblk1boot0: mmc1:0001 P1XXXX partition 1 2.00 MiB
[    1.803962] random: fast init done
[    1.808070] mmcblk1boot1: mmc1:0001 P1XXXX partition 2 2.00 MiB
[    1.815385] mmcblk1rpmb: mmc1:0001 P1XXXX partition 3 128 KiB
[    1.825994]  mmcblk1: p1
[    1.852390] tps65217 0-0024: TPS65217 ID 0xe version 1.2
[    1.858659] omap_i2c 44e0b000.i2c: bus 0 rev0.11 at 400 kHz
[    1.868288] omap_i2c 4819c000.i2c: bus 2 rev0.11 at 100 kHz
[    1.875650] hctosys: unable to open rtc device (rtc0)
[    1.881084] sr_init: No PMIC hook to init smartreflex
[    1.886607] sr_init: platform driver register failed for SR
[    2.040496] EXT4-fs (mmcblk0p2): recovery complete
[    2.051210] EXT4-fs (mmcblk0p2): mounted filesystem with ordered data mode. Opts: (null)
[    2.059864] VFS: Mounted root (ext4 filesystem) on device 179:2.
[    2.072364] devtmpfs: mounted
[    2.078081] Freeing unused kernel memory: 1024K
[    2.201550] EXT4-fs (mmcblk0p2): re-mounted. Opts: data=ordered
[    2.464563] random: dd: uninitialized urandom read (512 bytes read)
[    2.562417] random: dbus-uuidgen: uninitialized urandom read (12 bytes read)
[    2.569968] random: dbus-uuidgen: uninitialized urandom read (8 bytes read)
[    3.176005] net eth0: initializing cpsw version 1.12 (0)
[    3.284173] SMSC LAN8710/LAN8720 4a101000.mdio:00: attached PHY driver [SMSC LAN8710/LAN8720] (mii_bus:phy_addr=4a101000.mdio:00, irq=POLL)
[    3.336671] IPv6: ADDRCONF(NETDEV_UP): eth0: link is not ready
[    3.483765] urandom_read: 4 callbacks suppressed
[    3.483779] random: ssh-keygen: uninitialized urandom read (32 bytes read)
[    3.497227] random: connmand: uninitialized urandom read (8 bytes read)
[    3.603742] random: sshd: uninitialized urandom read (32 bytes read)
[    9.522500] cpsw 4a100000.ethernet eth0: Link is Up - 100Mbps/Full - flow control off
[    9.532101] IPv6: ADDRCONF(NETDEV_CHANGE): eth0: link becomes ready
[   89.372350] random: crng init done
[  103.234068] tanmay_kernel: loading out-of-tree module taints kernel.
[  103.242732] Entered the kernel module
[  104.322277] Name is Tanny  and count is 0
[  105.361800] Name is Tanny  and count is 1
[  106.401806] Name is Tanny  and count is 2
[  107.441810] Name is Tanny  and count is 3
[  108.481822] Name is Tanny  and count is 4
[  109.521835] Name is Tanny  and count is 5
[  110.561840] Name is Tanny  and count is 6
[  111.601846] Name is Tanny  and count is 7
[  112.641853] Name is Tanny  and count is 8
[  113.681862] Name is Tanny  and count is 9
[  114.721876] Name is Tanny  and count is 10
[  115.761884] Name is Tanny  and count is 11
[  116.801889] Name is Tanny  and count is 12
[  117.841895] Name is Tanny  and count is 13
[  118.227598] Exited the kernel module
#
```

3. **Module info:**

```
tanmay@tanmay-VirtualBox:~/projects/Homework3$ modinfo tanmay_kernel.ko
filename:       /home/tanmay/projects/Homework3/tanmay_kernel.ko
version:        1.0
description:    A Kernel Module that works on Linux Timer
author:         Tanmay Chaturvedi
license:        GPL
srcversion:     4660ED467C2BE0BAD45EBA2
depends:
name:           tanmay_kernel
vermagic:       4.14.40 SMP mod_unload modversions ARMv6 p2v8
parm:           input_period:int
parm:           input_string:charp
```

4. **Module exit**

```
# rmmod tanmay_kernel.ko [  116.801889] Name is Tanny  and count is 12
[  117.841895] Name is Tanny  and count is 13

[  118.227598] Exited the kernel module
```

5. **Timer Load with Param: Input period = 3000msec and input string = “AESD”**

```
# insmod tanmay_kernel.ko input_string=AESD_HW3 input_period=3000
[  356.382135] Entered the kernel module
# [  359.443595] Name is AESD_HW3  and count is 0
[  362.483116] Name is AESD_HW3  and count is 1
[  365.523124] Name is AESD_HW3  and count is 2
[  368.563132] Name is AESD_HW3  and count is 3
[  371.603140] Name is AESD_HW3  and count is 4
[  374.643154] Name is AESD_HW3  and count is 5
# rmmod tanmay_kernel.ko
[  376.784480] Exited the kernel module
```

6. **DMESG Log**

```
[  356.382135] Entered the kernel module
[  359.443595] Name is AESD_HW3  and count is 0
[  362.483116] Name is AESD_HW3  and count is 1
[  365.523124] Name is AESD_HW3  and count is 2
[  368.563132] Name is AESD_HW3  and count is 3
[  371.603140] Name is AESD_HW3  and count is 4
[  374.643154] Name is AESD_HW3  and count is 5
[  376.784480] Exited the kernel module
#
```

7. **Module Info:**

```
tanmay@tanmay-VirtualBox:~/projects/Homework3$ modinfo tanmay_kernel.ko
filename:       /home/tanmay/projects/Homework3/tanmay_kernel.ko
version:        1.0
description:    A Kernel Module that works on Linux Timer
author:         Tanmay Chaturvedi
license:        GPL
srcversion:     4660ED467C2BE0BAD45EBA2
depends:
name:           tanmay_kernel
vermagic:       4.14.40 SMP mod_unload modversions ARMv6 p2v8
parm:           input_period:int
parm:           input_string:charp
```

8. **Module exit:**

```
# rmmod tanmay_kernel.ko
[  376.784480] Exited the kernel module
```

9. **Dmesg when no argument given**

```
tanmay@tanmay-VirtualBox:~/projects/Homework3$ modinfo tanmay_kernel.ko
filename:       /home/tanmay/projects/Homework3/tanmay_kernel.ko
version:        1.0
description:    A Kernel Module that works on Linux Timer
author:         Tanmay Chaturvedi
license:        GPL
srcversion:     4660ED467C2BE0BAD45EBA2
depends:
name:           tanmay_kernel
vermagic:       4.14.40 SMP mod_unload modversions ARMv6 p2v8
parm:           input_period:int
parm:           input_string:charp
```

Question 4.

Section 1. Ecosystem:

Data structure used: Linked List

Entries:

{"Cat", "Cat", "Dog", "Dog", "Alligator", "Mouse", "Tiger", "Zebra", "Donkey", "Rabbit", \

"Cat", "Cat", "Dog", "Dog", "Alligator", "Mouse", "Tiger", "Zebra", "Anteater", "Rabbit", \

"Cat", "Cat", "Dog", "Dog", "Alligator", "Mouse", "Tiger", "Zebra", "Ape", "Rabbit", \

"Cat", "Cat", "Dog", "Dog", "Alligator", "Mouse", "Tiger", "Zebra", "Deer", "Rabbit", \

"Cat", "Cat", "Dog", "Dog", "Alligator", "Mouse", "Tiger", "Zebra", "Gorilla", "Rabbit", };

Output generated after sorting, reporting number of nodes generated and dynamic memory allocated.

```
[ 3903.483149] Sorted Element = Dog
[ 3903.486561] Sorted Element = Dog
[ 3903.489925] Sorted Element = Dog
[ 3903.493295] Sorted Element = Dog
[ 3903.496704] Sorted Element = Dog
[ 3903.500071] Sorted Element = Dog
[ 3903.503485] Sorted Element = Dog
[ 3903.506866] Sorted Element = Dog
[ 3903.510242] Sorted Element = Dog
[ 3903.513657] Sorted Element = Donkey
[ 3903.517301] Sorted Element = Gorilla
[ 3903.521034] Sorted Element = Mouse
[ 3903.524624] Sorted Element = Mouse
[ 3903.528181] Sorted Element = Mouse
[ 3903.531737] Sorted Element = Mouse
[ 3903.535327] Sorted Element = Mouse
[ 3903.538880] Sorted Element = Rabbit
[ 3903.542530] Sorted Element = Rabbit
[ 3903.546214] Sorted Element = Rabbit
[ 3903.549856] Sorted Element = Rabbit
[ 3903.553536] Sorted Element = Rabbit
[ 3903.557186] Sorted Element = Tiger
[ 3903.560744] Sorted Element = Tiger
[ 3903.564333] Sorted Element = Tiger
[ 3903.567885] Sorted Element = Tiger
[ 3903.571431] Sorted Element = Tiger
[ 3903.575020] Sorted Element = Zebra
[ 3903.578576] Sorted Element = Zebra
[ 3903.582122] Sorted Element = Zebra
[ 3903.585714] Sorted Element = Zebra
[ 3903.589267] Sorted Element = Zebra
[ 3903.592851] Animal Name: = Alligator and Respective Count = 5
[ 3903.598902] Animal Name: = Anteater and Respective Count = 1
[ 3903.604852] Animal Name: = Ape and Respective Count = 1
[ 3903.610307] Animal Name: = Cat and Respective Count = 10
[ 3903.615896] Animal Name: = Deer and Respective Count = 1
[ 3903.621443] Animal Name: = Dog and Respective Count = 10
[ 3903.627022] Animal Name: = Donkey and Respective Count = 1
[ 3903.632756] Animal Name: = Gorilla and Respective Count = 1
[ 3903.638620] Animal Name: = Mouse and Respective Count = 5
[ 3903.644298] Animal Name: = Rabbit and Respective Count = 5
[ 3903.650040] Animal Name: = Tiger and Respective Count = 5
[ 3903.655721] Animal Name: = Zebra and Respective Count = 5
[ 3903.661365] Total Nodes = 12
[ 3903.661376] Total amount of memory dynamically allocated for nodes = 192 bytes
[ 3908.673104] Exited the kernel module
#
```

Section 2.:

a. When command line argument is **: insmod tanmay_kernel1.ko**

➔ **Default value, means no input argument for animal name and count**

```
File  Edit  View  Search  Terminal  Help
[  158.610197] Sorted Element = Mouse
[  158.613788] Sorted Element = Mouse
[  158.617335] Sorted Element = Mouse
[  158.620926] Sorted Element = Mouse
[  158.624474] Sorted Element = Mouse
[  158.628029] Sorted Element = Rabbit
[  158.631708] Sorted Element = Rabbit
[  158.635346] Sorted Element = Rabbit
[  158.638985] Sorted Element = Rabbit
[  158.642664] Sorted Element = Rabbit
[  158.646305] Sorted Element = Tiger
[  158.649853] Sorted Element = Tiger
[  158.653438] Sorted Element = Tiger
[  158.656989] Sorted Element = Tiger
[  158.660541] Sorted Element = Tiger
[  158.664133] Sorted Element = Zebra
[  158.667683] Sorted Element = Zebra
[  158.671268] Sorted Element = Zebra
[  158.674816] Sorted Element = Zebra
[  158.678364] Sorted Element = Zebra
[  158.681980] Animal Name: = Alligator and Respective Count = 5
[  158.687979] Animal Name: = Anteater and Respective Count = 1
[  158.693925] Animal Name: = Ape and Respective Count = 1
[  158.699379] Animal Name: = Cat and Respective Count = 10
[  158.704964] Animal Name: = Deer and Respective Count = 1
[  158.710505] Animal Name: = Dog and Respective Count = 10
[  158.716084] Animal Name: = Donkey and Respective Count = 1
[  158.721848] Animal Name: = Gorilla and Respective Count = 1
[  158.727663] Animal Name: = Mouse and Respective Count = 5
[  158.733342] Animal Name: = Rabbit and Respective Count = 5
[  158.739065] Animal Name: = Tiger and Respective Count = 5
[  158.744741] Animal Name: = Zebra and Respective Count = 5
[  158.750375] Total Nodes = 12
[  158.750385] Total amount of memory dynamically allocated for nodes = 192 bytes
[  158.753431] Previous Animal Name: = Alligator and Respective Count = 5
[  158.767808] Previous Animal Name: = Anteater and Respective Count = 1
[  158.774567] Previous Animal Name: = Ape and Respective Count = 1
[  158.780871] Previous Animal Name: = Cat and Respective Count = 10
[  158.787235] Previous Animal Name: = Deer and Respective Count = 1
[  158.793627] Previous Animal Name: = Dog and Respective Count = 10
[  158.799983] Previous Animal Name: = Donkey and Respective Count = 1
[  158.806558] Previous Animal Name: = Gorilla and Respective Count = 1
[  158.813232] Previous Animal Name: = Mouse and Respective Count = 5
[  158.819691] Previous Animal Name: = Rabbit and Respective Count = 5
[  158.826271] Previous Animal Name: = Tiger and Respective Count = 5
[  158.832764] Previous Animal Name: = Zebra and Respective Count = 5
#
```

When module is exited, total memory freed is 192 bytes

```
[  266.094542] Exited the kernel module
[  266.098326] Total size freed = 192 bytes
```

b. When command line argument is **: insmod tanmay_kernel1.ko input_animal_type=Dog**

➔ **Only name given as argument**

```
[  886.261690] Sorted Element = Dog
[  886.265061] Sorted Element = Dog
[  886.268435] Sorted Element = Dog
[  886.271838] Sorted Element = Dog
[  886.275207] Sorted Element = Dog
[  886.278574] Sorted Element = Dog
[  886.281982] Sorted Element = Donkey
[  886.285622] Sorted Element = Gorilla
[  886.289352] Sorted Element = Mouse
[  886.292941] Sorted Element = Mouse
[  886.296492] Sorted Element = Mouse
[  886.300045] Sorted Element = Mouse
[  886.303632] Sorted Element = Mouse
[  886.307180] Sorted Element = Rabbit
[  886.310858] Sorted Element = Rabbit
[  886.314506] Sorted Element = Rabbit
[  886.318149] Sorted Element = Rabbit
[  886.321829] Sorted Element = Rabbit
[  886.325473] Sorted Element = Tiger
[  886.329029] Sorted Element = Tiger
[  886.332617] Sorted Element = Tiger
[  886.336166] Sorted Element = Tiger
[  886.339719] Sorted Element = Tiger
[  886.343308] Sorted Element = Zebra
[  886.346857] Sorted Element = Zebra
[  886.350410] Sorted Element = Zebra
[  886.353998] Sorted Element = Zebra
[  886.357551] Sorted Element = Zebra
[  886.361165] Animal Name: = Alligator and Respective Count = 5
[  886.367162] Animal Name: = Anteater and Respective Count = 1
[  886.373110] Animal Name: = Ape and Respective Count = 1
[  886.378566] Animal Name: = Cat and Respective Count = 10
[  886.384154] Animal Name: = Deer and Respective Count = 1
[  886.389701] Animal Name: = Dog and Respective Count = 10
[  886.395279] Animal Name: = Donkey and Respective Count = 1
[  886.401049] Animal Name: = Gorilla and Respective Count = 1
[  886.406862] Animal Name: = Mouse and Respective Count = 5
[  886.412532] Animal Name: = Rabbit and Respective Count = 5
[  886.418259] Animal Name: = Tiger and Respective Count = 5
[  886.423933] Animal Name: = Zebra and Respective Count = 5
[  886.429568] Total Nodes = 12
[  886.429578] Total amount of memory dynamically allocated for nodes = 192 bytes
```

Only “Dog” and its respective count is stored in the filtered linked list.

```
[  886.432629] Filtered Node # is 1, Name: = Dog and Respective Count = 10
[  889.449263] Exited the kernel module
[  889.453299] Total size freed = 192 bytes
[  889.457393] Total size freed = 16 bytes
```

When module is freed 192 bytes freed from first linkedlist and 16bytes freed from filtered linked list.

c. When command line argument is **: insmod tanmay_kernel1.ko count_greater_than=6**

➔ **Only count given as argument**

```
[  592.469677] Sorted Element = Donkey
[  592.473355] Sorted Element = Gorilla
[  592.477088] Sorted Element = Mouse
[  592.480638] Sorted Element = Mouse
[  592.484228] Sorted Element = Mouse
[  592.487782] Sorted Element = Mouse
[  592.491371] Sorted Element = Mouse
[  592.494927] Sorted Element = Rabbit
[  592.498567] Sorted Element = Rabbit
[  592.502249] Sorted Element = Rabbit
[  592.505886] Sorted Element = Rabbit
[  592.509525] Sorted Element = Rabbit
[  592.513212] Sorted Element = Tiger
[  592.516767] Sorted Element = Tiger
[  592.520316] Sorted Element = Tiger
[  592.523909] Sorted Element = Tiger
[  592.527469] Sorted Element = Tiger
[  592.531059] Sorted Element = Zebra
[  592.534610] Sorted Element = Zebra
[  592.538155] Sorted Element = Zebra
[  592.541750] Sorted Element = Zebra
[  592.545305] Sorted Element = Zebra
[  592.548883] Animal Name: = Alligator and Respective Count = 5
[  592.554920] Animal Name: = Anteater and Respective Count = 1
[  592.560871] Animal Name: = Ape and Respective Count = 1
[  592.566333] Animal Name: = Cat and Respective Count = 10
[  592.571918] Animal Name: = Deer and Respective Count = 1
[  592.577467] Animal Name: = Dog and Respective Count = 10
[  592.583054] Animal Name: = Donkey and Respective Count = 1
[  592.588790] Animal Name: = Gorilla and Respective Count = 1
[  592.594651] Animal Name: = Mouse and Respective Count = 5
[  592.600289] Animal Name: = Rabbit and Respective Count = 5
[  592.606063] Animal Name: = Tiger and Respective Count = 5
[  592.611737] Animal Name: = Zebra and Respective Count = 5
[  592.617379] Total Nodes = 12
[  592.617390] Total amount of memory dynamically allocated for nodes = 192 bytes
```

Only elements with count > 6 and are stored in the filtered list.

```
[  797.026914] Node # is 1, Name: = Cat and Respective Count = 10
[  797.040579] Node # is 2, Name: = Dog and Respective Count = 10
[  799.346942] Exited the kernel module
[  799.350972] Total size freed = 192 bytes
[  799.355077] Total size freed = 32 bytes
```

When module is freed 192 bytes freed from first linkedlist and 32 bytes freed from filtered linked list.

d. When command line argument is **: insmod tanmay_kernel1.ko input_animal_type=Tiger count_greater_than=3**

➔ **Name and count given as argument**

```
[  592.469677] Sorted Element = Donkey
[  592.473355] Sorted Element = Gorilla
[  592.477088] Sorted Element = Mouse
[  592.480638] Sorted Element = Mouse
[  592.484228] Sorted Element = Mouse
[  592.487782] Sorted Element = Mouse
[  592.491371] Sorted Element = Mouse
[  592.494927] Sorted Element = Rabbit
[  592.498567] Sorted Element = Rabbit
[  592.502249] Sorted Element = Rabbit
[  592.505886] Sorted Element = Rabbit
[  592.509525] Sorted Element = Rabbit
[  592.513212] Sorted Element = Tiger
[  592.516767] Sorted Element = Tiger
[  592.520316] Sorted Element = Tiger
[  592.523909] Sorted Element = Tiger
[  592.527469] Sorted Element = Tiger
[  592.531059] Sorted Element = Zebra
[  592.534610] Sorted Element = Zebra
[  592.538155] Sorted Element = Zebra
[  592.541750] Sorted Element = Zebra
[  592.545305] Sorted Element = Zebra
[  592.548883] Animal Name: = Alligator and Respective Count = 5
[  592.554920] Animal Name: = Anteater and Respective Count = 1
[  592.560871] Animal Name: = Ape and Respective Count = 1
[  592.566333] Animal Name: = Cat and Respective Count = 10
[  592.571918] Animal Name: = Deer and Respective Count = 1
[  592.577467] Animal Name: = Dog and Respective Count = 10
[  592.583054] Animal Name: = Donkey and Respective Count = 1
[  592.588790] Animal Name: = Gorilla and Respective Count = 1
[  592.594651] Animal Name: = Mouse and Respective Count = 5
[  592.600289] Animal Name: = Rabbit and Respective Count = 5
[  592.606063] Animal Name: = Tiger and Respective Count = 5
[  592.611737] Animal Name: = Zebra and Respective Count = 5
[  592.617379] Total Nodes = 12
[  592.617390] Total amount of memory dynamically allocated for nodes = 192 bytes
```

Elements with name = Tiger OR Count>3 are stored in filtered array.

```
[  592.620402] Node # is 1, Name: = Alligator and Respective Count = 5
[  592.634550] Node # is 2, Name: = Cat and Respective Count = 10
[  592.640644] Node # is 3, Name: = Dog and Respective Count = 10
[  592.646771] Node # is 4, Name: = Mouse and Respective Count = 5
[  592.652990] Node # is 5, Name: = Rabbit and Respective Count = 5
[  592.659256] Filtered Node # is 6, Name: = Tiger and Respective Count = 5
[  592.666297] Node # is 7, Name: = Zebra and Respective Count = 5
[  597.057370] Exited the kernel module
[  597.061413] Total size freed = 192 bytes
[  597.065511] Total size freed = 112 bytes
```

Total 192 bytes freed in the original linkedlist and 112 bytes in the filtered linked list.

e. Time to load kernel module:

```
[  112.982355] linkedlist_kernel_module: loading out-of-tree module taints kernel.
[  112.990983] initialize kernel module
```

= 112.990983-112.982355

= 0.008628 sec

f. Time to exit kernel module

```
[  266.094542] Exited the kernel module
[  266.098326] Total size freed = 192 bytes
[  266.102663] Total size freed = 192 bytes
```

= 166.102663 – 266.094542 = 0.008121 sec