

CS3003D
Operating Systems
ASSIGNMENT 2

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Problem Statement

1. Create a loadable kernel module BINARY SEARCH TREE where you can take the input values as 11, 6, 8, 19, 4, 10, 5, 17, 43, 49, 31 and perform the insertion operation using the C programming in the Linux operating systems.
2. Then remove the created kernel module BINARY SEARCH TREE from the existing list of modules.

Procedure:

1. Save the Binary search tree code as BST.c.
2. Create a Makefile.

```
obj-m += BST.o
all:
    make -C /lib/modules/$(shell uname -r)/build M=$(PWD) modules
clean:
    make -C /lib/modules/$(shell uname -r)/build M=$(PWD) clean
```

3. Execute the make command in this directory. This creates a number of output files including the **BST.ko** which is the kernel module to be loaded.
4. Load the kernel module using the insmod command.

```
sudo insmod BST.ko
```

5. List the kernel modules currently loaded in the machine using the lsmod command.

```
sudo lsmod
```

The newly loaded kernel module BST is visible with the other modules.

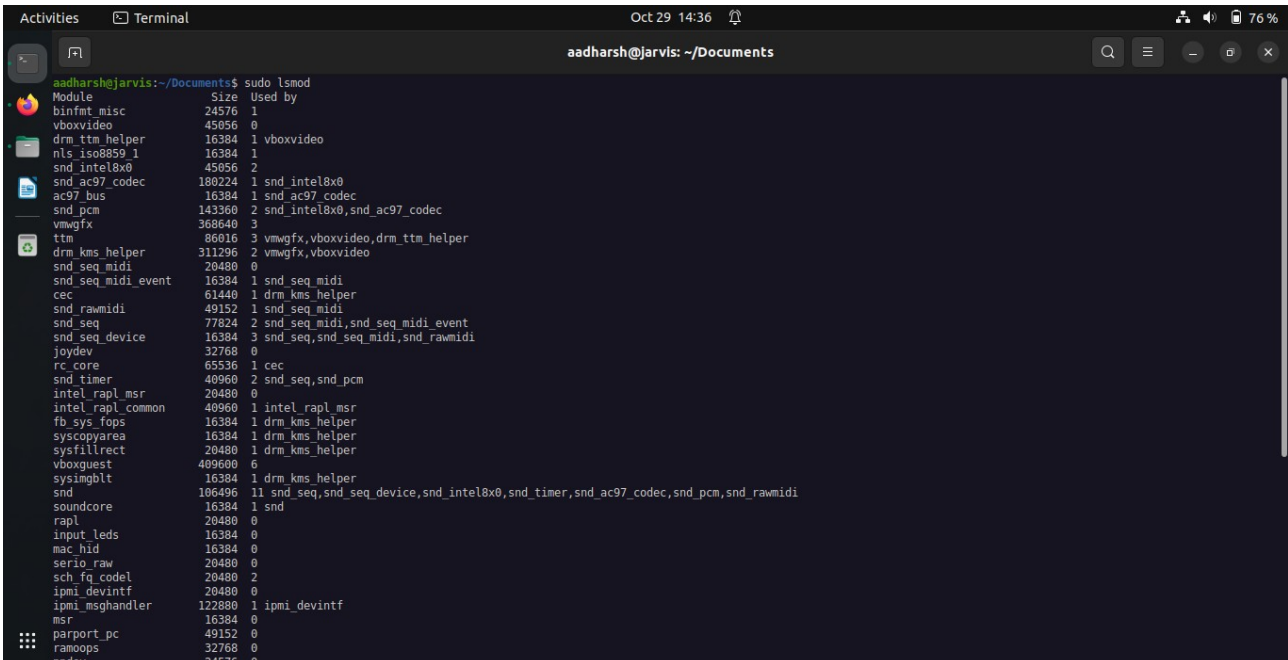
```
Oct 29 14:35
aadhharsh@jarvis: ~/Documents

aadhharsh@jarvis:~/Documents$ sudo lsmod
Module                  Size  Used by
BST                     16384  0
binfmt_misc            24576  1
vboxvideo              45056  0
drm_ttm_helper         16384  1 vboxvideo
nls_iso8859_1          16384  1
snd_intel8x0           45056  2
snd_ac97_codec         180224  1 snd_intel8x0
ac97_bus               16384  1 snd_ac97_codec
snd_pcm                143360  2 snd_intel8x0,snd_ac97_codec
vmwgfx                 368640  3
ttm                    86016  3 vmwgfx,vboxvideo,drm_ttm_helper
drm_kms_helper         311296  2 vmwgfx,vboxvideo
snd_seq_midi           20480  0
snd_seq_midi_event     16384  1 snd_seq_midi
cec                    61440  1 drm_kms_helper
snd_rawmidi            49152  1 snd_seq_midi
snd_seq                77824  2 snd_seq_midi,snd_seq_midi_event
snd_seq_device         16384  3 snd_seq,snd_seq_midi,snd_rawmidi
joydev                 32768  0
rc_core                65536  1 cec
snd_timer              40960  2 snd_seq,snd_pcm
intel_rapl_msr         20480  0
intel_rapl_common     40960  1 intel_rapl_msr
fb_sys_fops            16384  1 drm_kms_helper
syscopyarea            16384  1 drm_kms_helper
sysfillrect            20480  1 drm_kms_helper
vboxguest              409600  6
sysimgblt              16384  1 drm_kms_helper
snd                    106496  11 snd_seq,snd_seq_device,snd_intel8x0,snd_timer,snd_ac97_codec,snd_pcm,snd_rawmidi
soundcore              16384  1 snd
rapl                   20480  0
input_leds             16384  0
mac_hid                16384  0
serio_raw              20480  0
sch_fq_codel           20480  2
ipmi_devintf           20480  0
ipmi_msghandler        122880  1 ipmi_devintf
msr                    16384  0
parport_pc             49152  0
ramoops                32768  0
```

6. Remove the kernel module using the `rmmod` command.

```
sudo rmmod BST
```

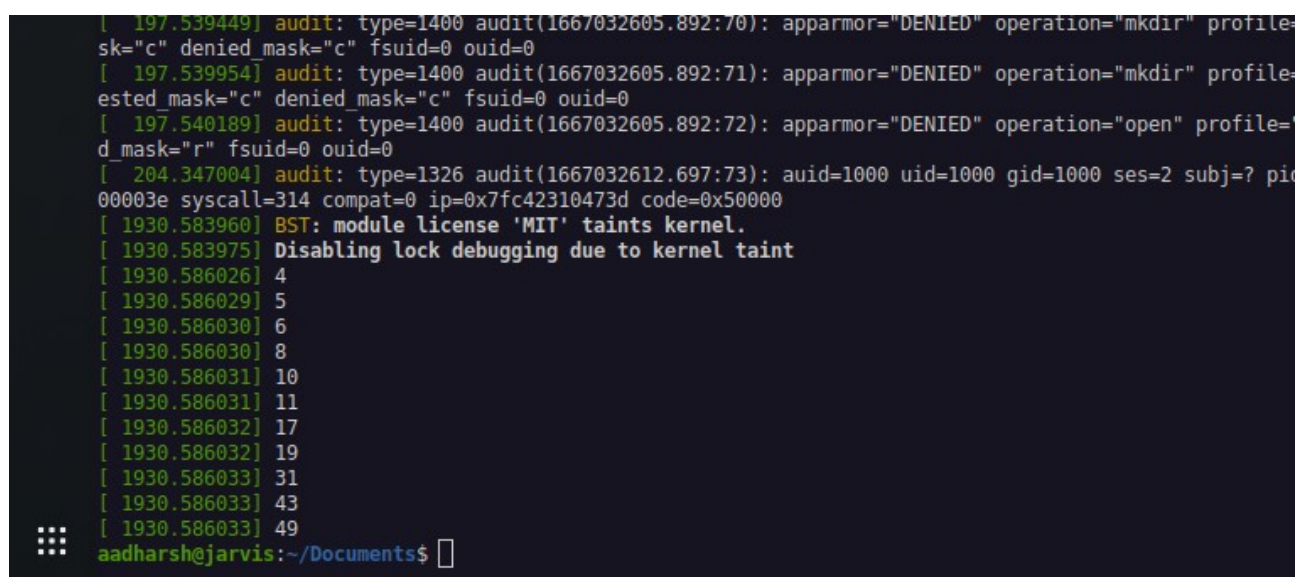
7. When the `lsmod` command is executed again, BST module is no longer present as the module has been successfully removed.



```
adharsh@jarvis:~/Documents$ sudo lsmod
Module                  Size      Used by
binfmt_misc             24576    1
vboxvideo               45056    0
drm_ttm_helper          16384    1 vboxvideo
nls_iso8859_1           16384    1
snd_intel8x0            45056    2
snd_ac97_codec          180224    1 snd_intel8x0
ac97_bus                16384    1 snd_ac97_codec
snd_pcm                 143860    2 snd_intel8x0,snd_ac97_codec
vmwgfx                  368640    3
ttm                     86016    3 vmwgfx,vboxvideo,drm_ttm_helper
drm_kms_helper          311296    2 vmwgfx,vboxvideo
snd_seq_midi            20480    0
snd_seq_midi_event      16384    1 snd_seq_midi
cec                     61440    1 drm_kms_helper
snd_rawmidi             49152    1 snd_seq_midi
snd_seq                 77824    2 snd_seq_midi,snd_seq_midi_event
snd_seq_device          16384    3 snd_seq,snd_seq_midi,snd_rawmidi
joydev                  32768    0
rc_core                 65536    1 cec
snd_timer               40960    2 snd_seq,snd_pcm
intel_rapl_msr          20480    0
intel_rapl_common       40960    1 intel_rapl_msr
fb_sys_fops             16384    1 drm_kms_helper
syscopyarea            16384    1 drm_kms_helper
sysfillrect             20480    1 drm_kms_helper
vboxguest               409600    0
sysimgblt              16384    1 drm_kms_helper
snd                     106496    11 snd_seq,snd_seq_device,snd_intel8x0,snd_timer,snd_ac97_codec,snd_pcm,snd_rawmidi
soundcore               16384    1 snd
rapl                    20480    0
input_leds              16384    0
mac_hid                 16384    0
serio_raw               20480    0
sch_fq_codel            20480    2
ipmi_devintf            20480    0
ipmi_msghandler         122880    1 ipmi_devintf
msr                     16384    0
parport_pc              49152    0
ramoops                 32768    0
pccdev                  24576    0
```

8. The inorder traversal of the Binary search tree after insertion is printed into the kernel log buffer. To confirm whether the operation was successful, execute the `dmesg` command which displays the contents of the kernel log buffer.

```
sudo dmesg
```



```
[ 197.539449] audit: type=1400 audit(1667032605.892:70): apparmor="DENIED" operation="mkdir" profile=
sk="c" denied_mask="c" fsuid=0 ouid=0
[ 197.539954] audit: type=1400 audit(1667032605.892:71): apparmor="DENIED" operation="mkdir" profile=
ested_mask="c" denied_mask="c" fsuid=0 ouid=0
[ 197.540189] audit: type=1400 audit(1667032605.892:72): apparmor="DENIED" operation="open" profile=
d_mask="r" fsuid=0 ouid=0
[ 204.347004] audit: type=1326 audit(1667032612.697:73): auid=1000 uid=1000 gid=1000 ses=2 subj=? pi
00003e syscall=314 compat=0 ip=0x7fc42310473d code=0x50000
[ 1930.583960] BST: module license 'MIT' taints kernel.
[ 1930.583975] Disabling lock debugging due to kernel taint
[ 1930.586026] 4
[ 1930.586029] 5
[ 1930.586030] 6
[ 1930.586030] 8
[ 1930.586031] 10
[ 1930.586031] 11
[ 1930.586032] 17
[ 1930.586032] 19
[ 1930.586033] 31
[ 1930.586033] 43
[ 1930.586033] 49
adharsh@jarvis:~/Documents$
```

9. Inorder traversal has been printed correctly which implies module creation was successful.