

Fusion of Odometry, IMU, and GPS

Plot of EKF and UKF

1. Topic published by ekf node: /odometry/filtered_map_ekf (red line)
2. Topic published by ukf node: /odometry/filtered_map_ukf (green line)
3. Case 1: Linear plot
 - a) In fig. 1 and 2 both filters approximations are similar
4. Case 2: Curvy plot
 - a) In fig. 3, 4, 5, and 6 even in this case both filters approximations are similar
5. From the plot, for our dataset, we can say both ekf and ukf plots are similar i.e. both are producing similar trajectory
6. This is because, since both filteres can handle non-linear functions(eg: orientation, which has diamentional variable angle)
7. As far as memory consumption is concerned ukf node is consuming more compared to ekf (please refer fig. 17 - fig. 24)
EKF: 4.6% - 4.7% of CPU memory
UKF: 5.2% - 6.9% of CPU memory
8. This is because in EKF, we use only single point(let say **mean**) to approximate a new value. In case of UKF to approximate a new value we use $2n+1$ (let say **mean + covariance**) number of sigma points, hence require more memory consumption.

Where, n = number of variables in state vector.

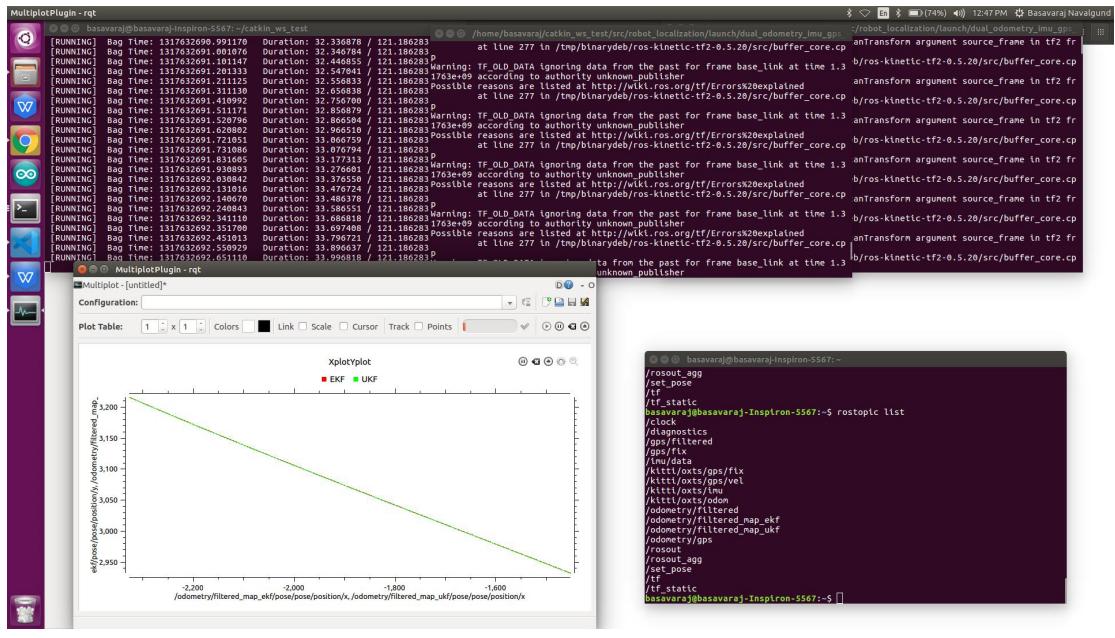


Fig. 1

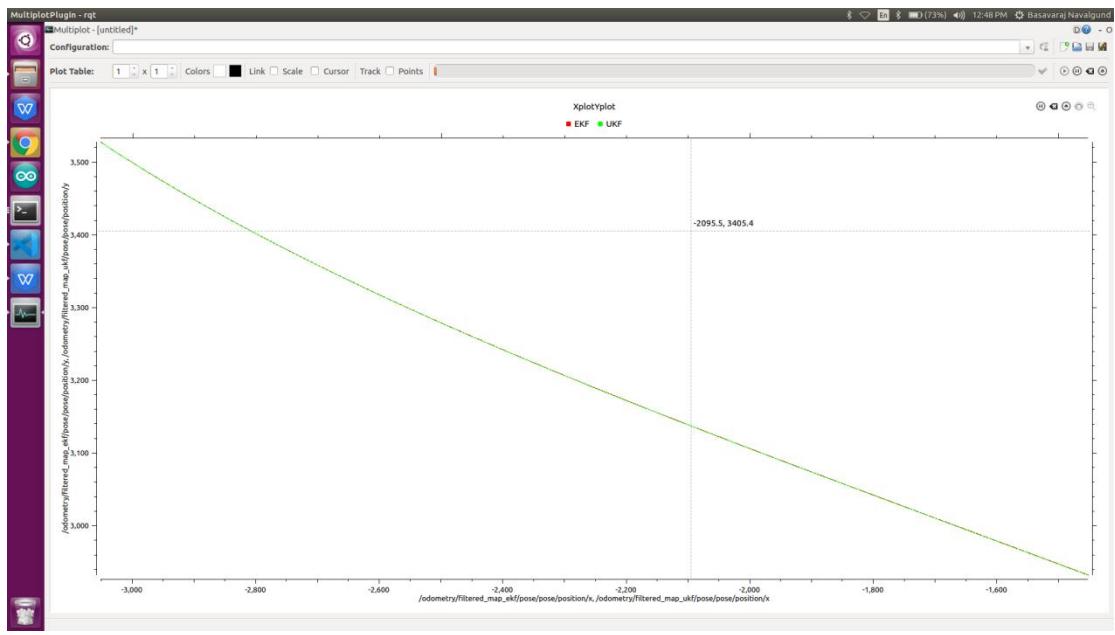


Fig. 2

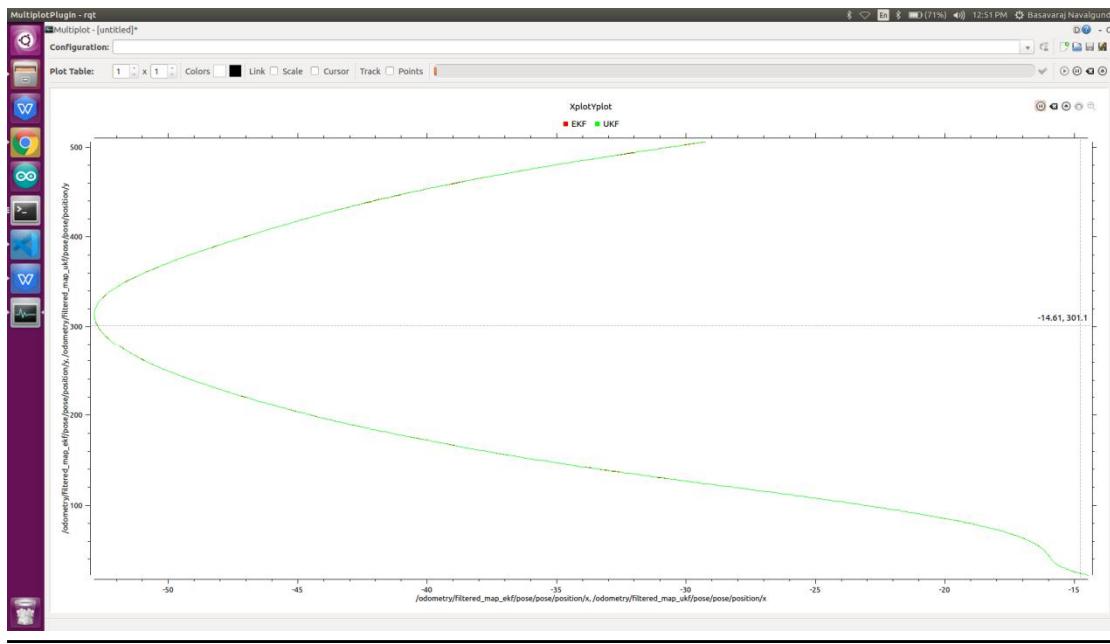


Fig. 3

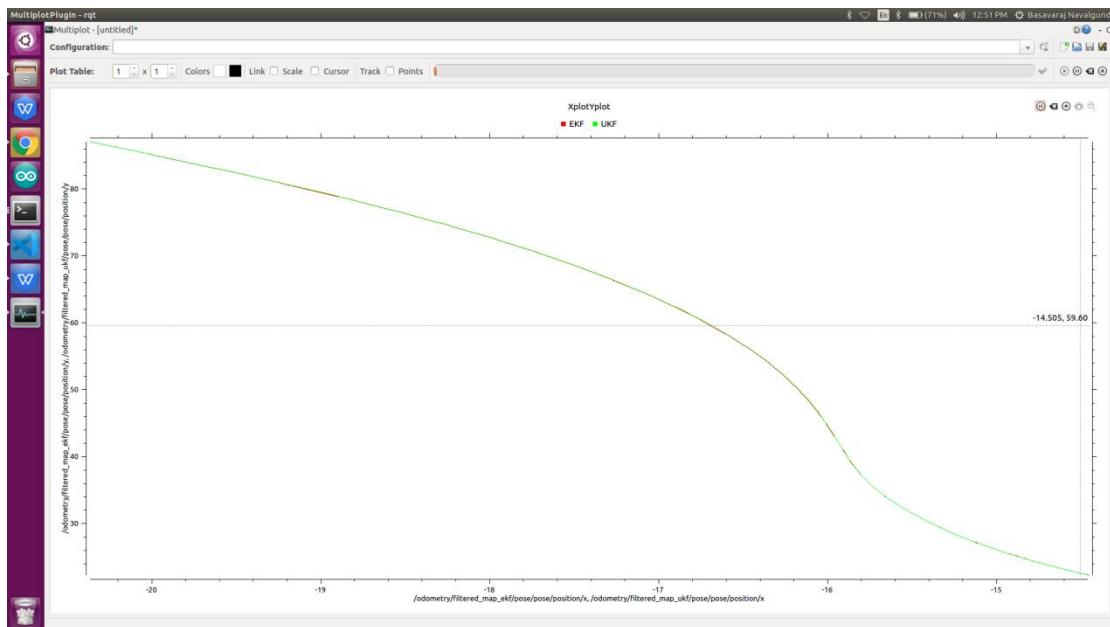


Fig. 4

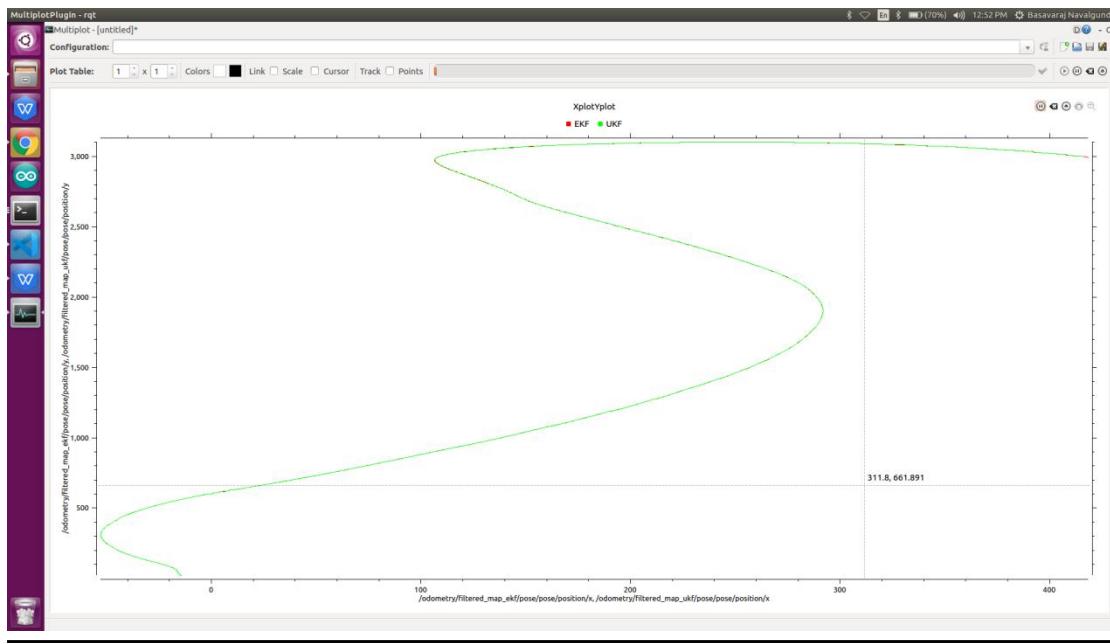


Fig. 5

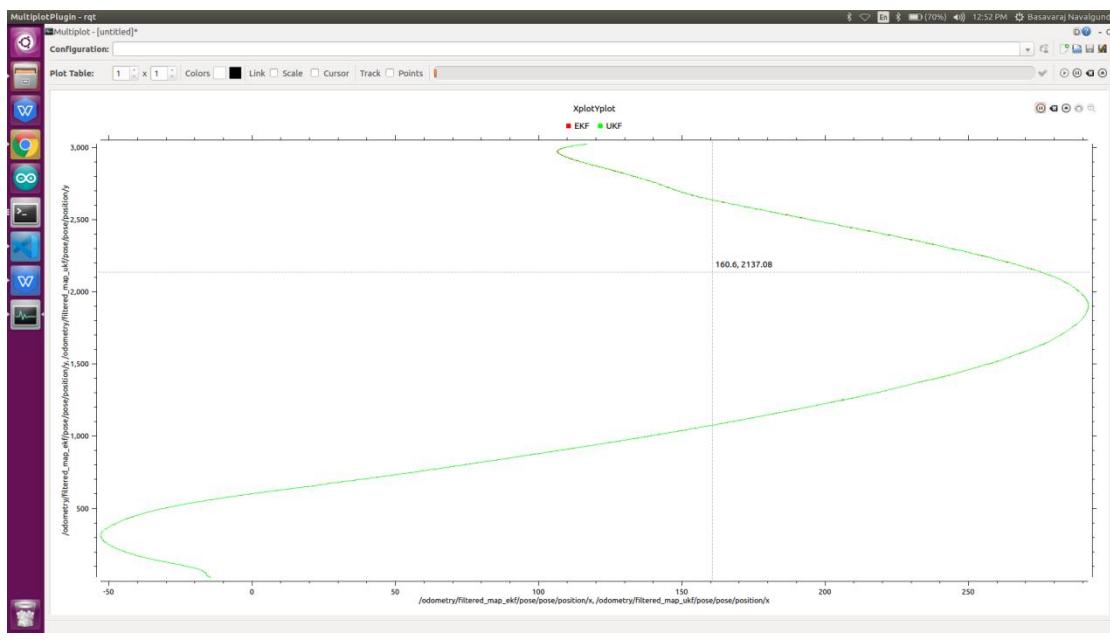


Fig. 6

Plot of EKF separate

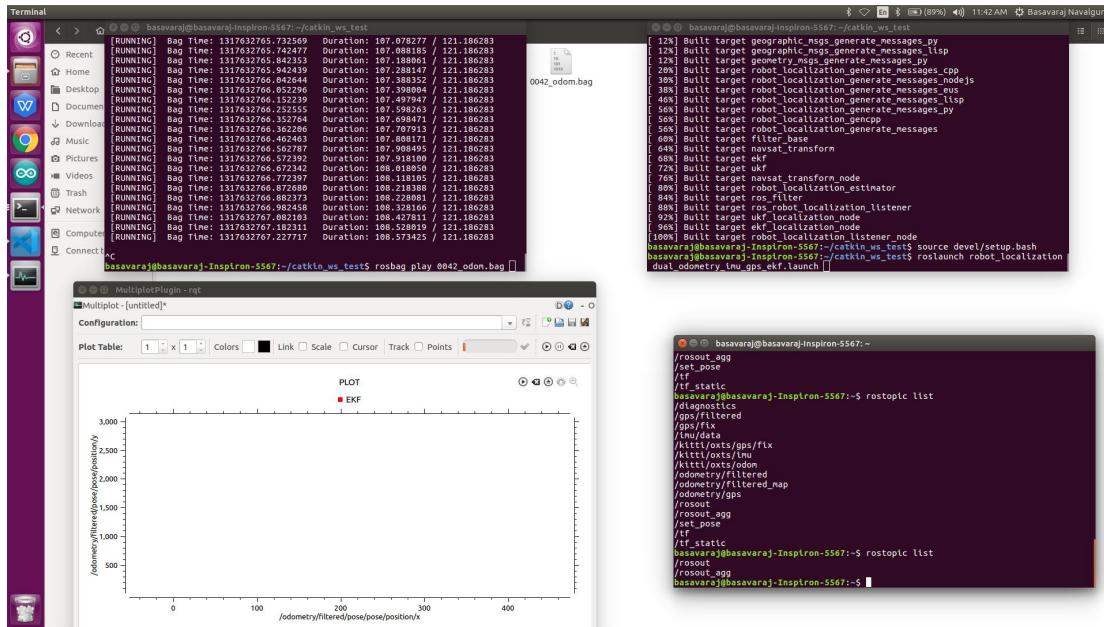


Fig. 7

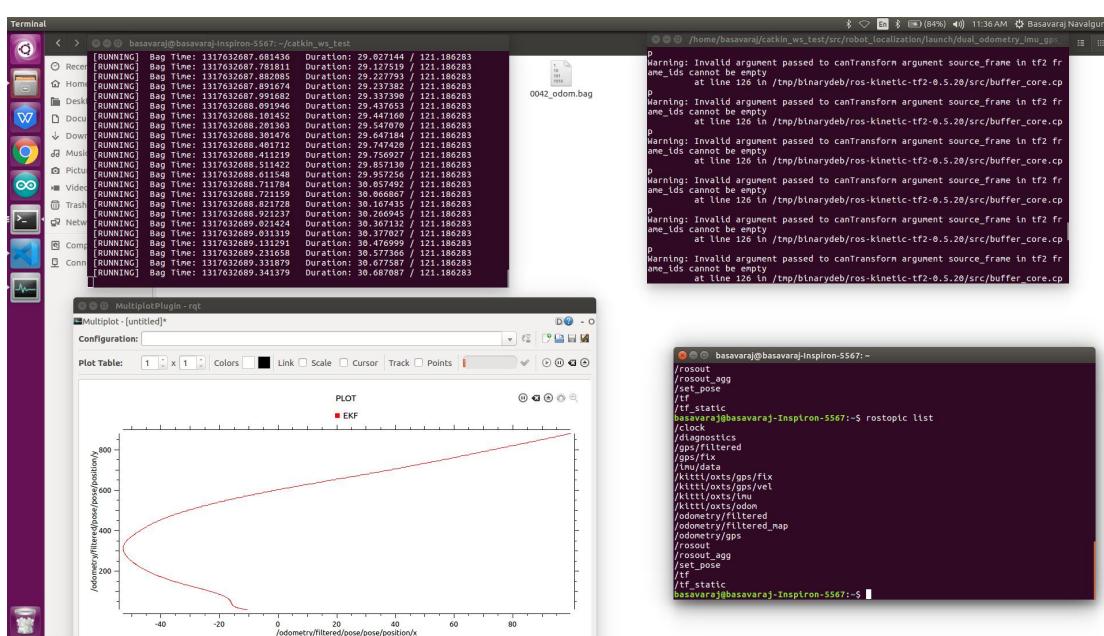


Fig. 8

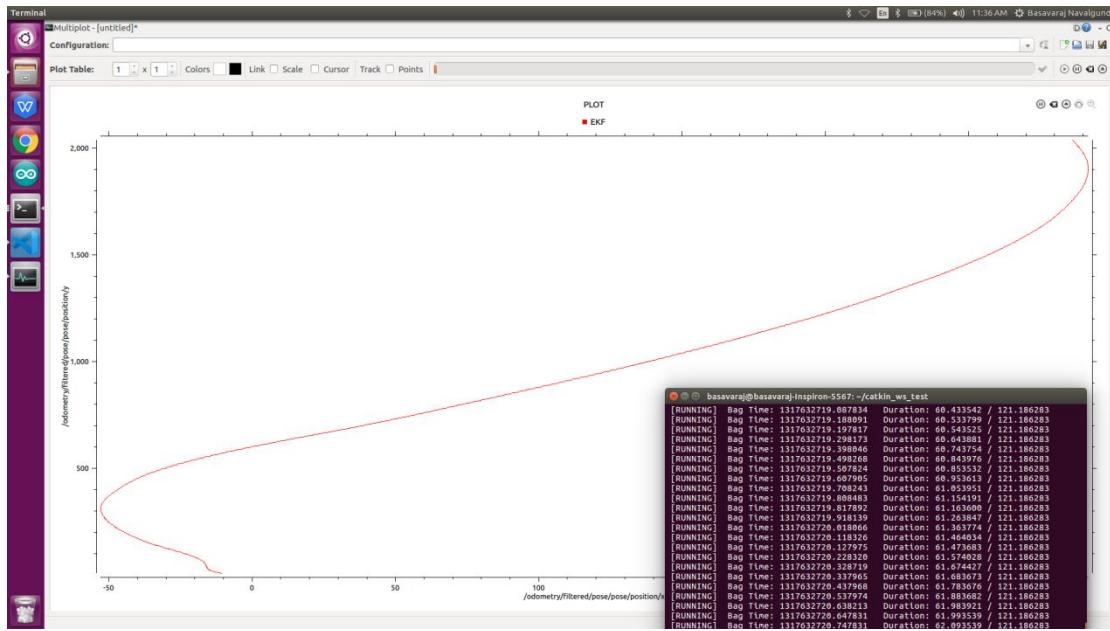


Fig. 9

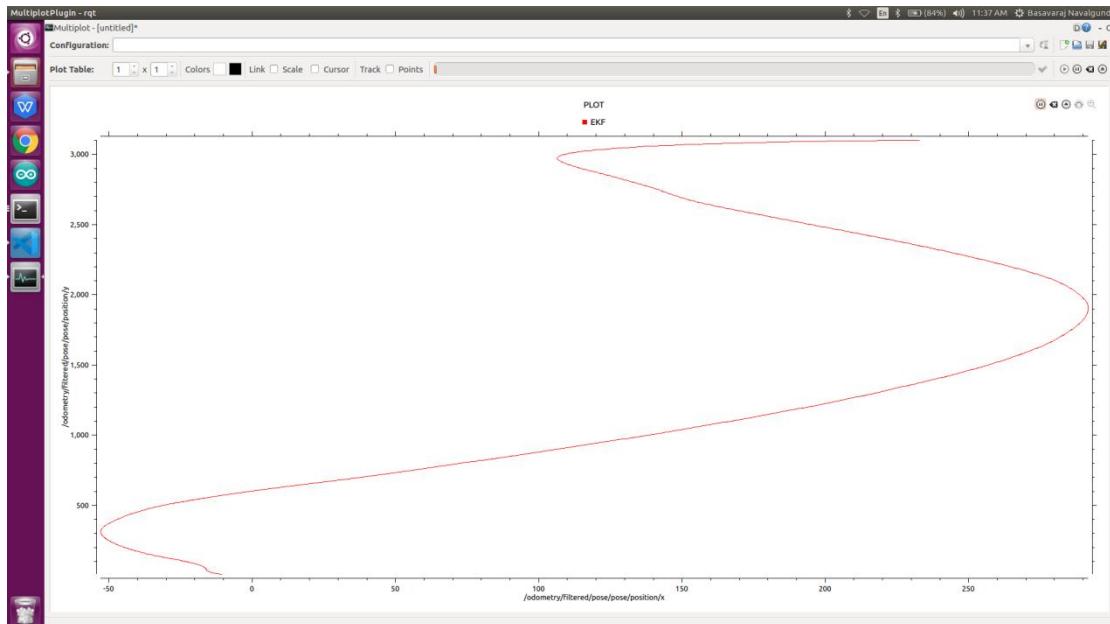


Fig. 10

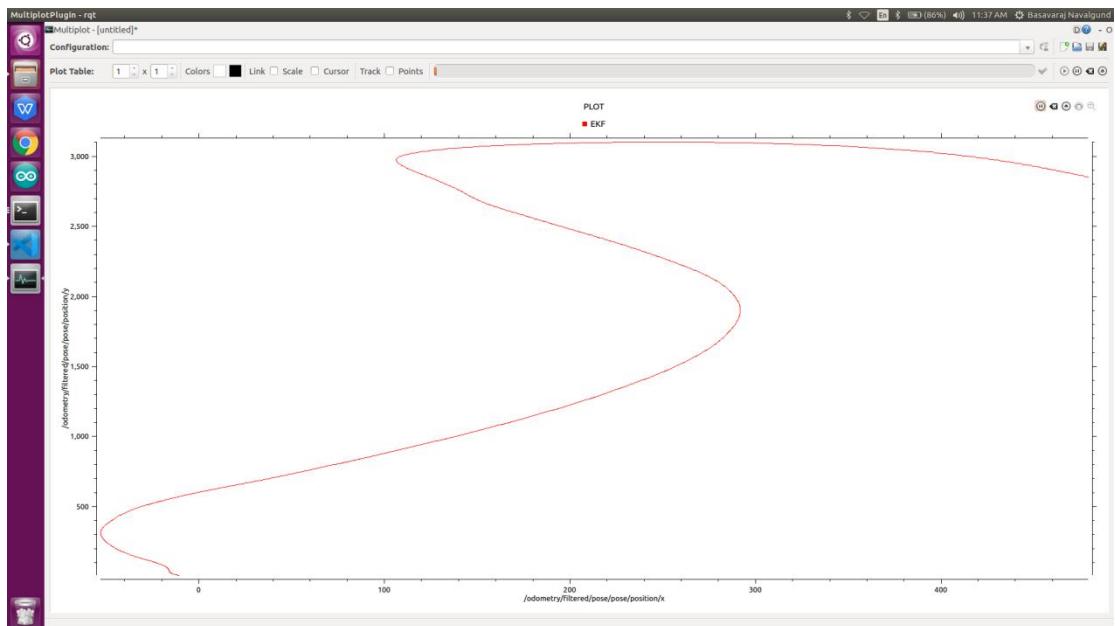


Fig. 11

Plot of UKF seperate

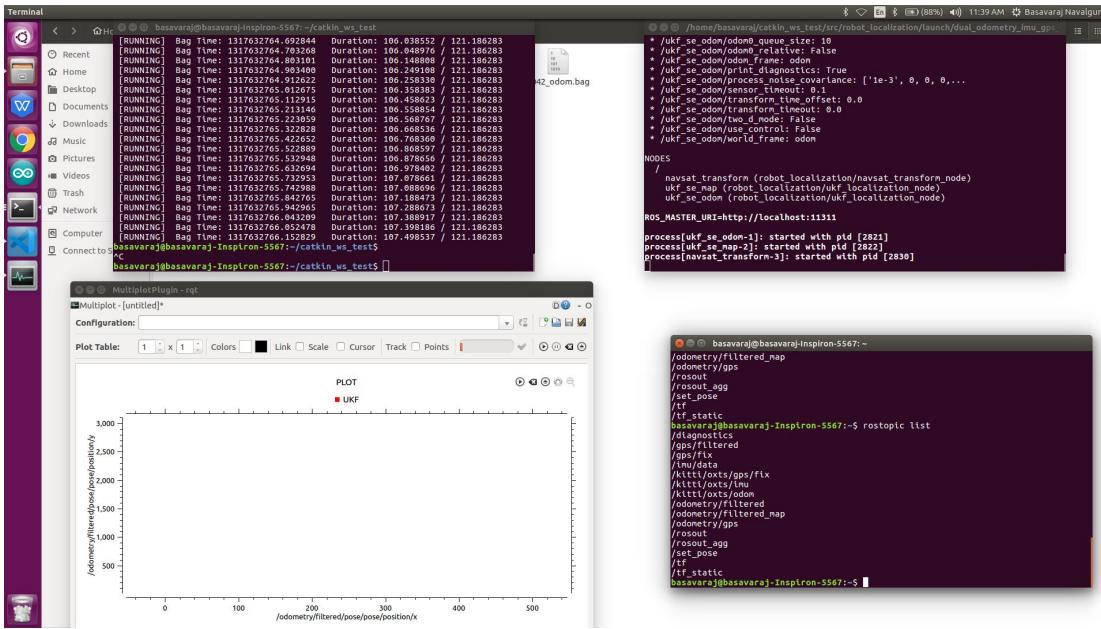


Fig. 12

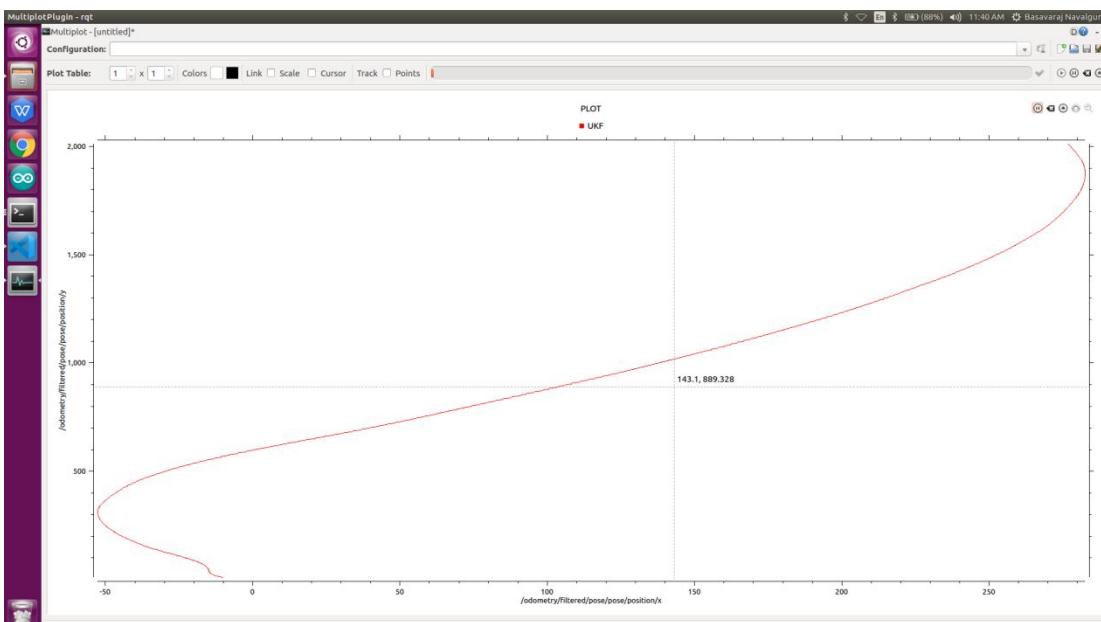


Fig. 13

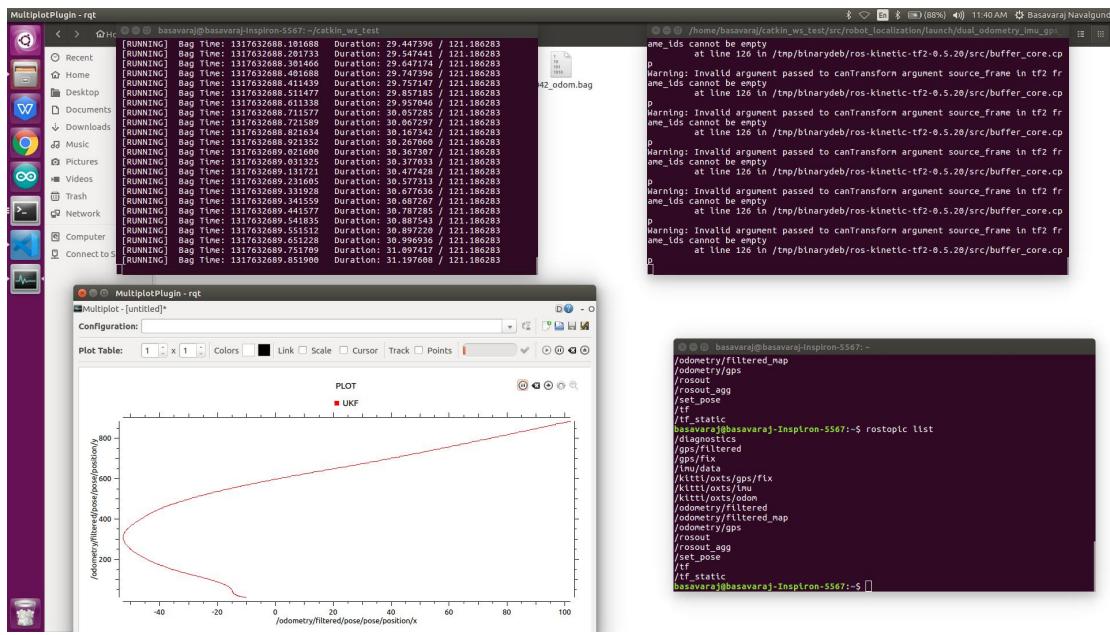


Fig. 14

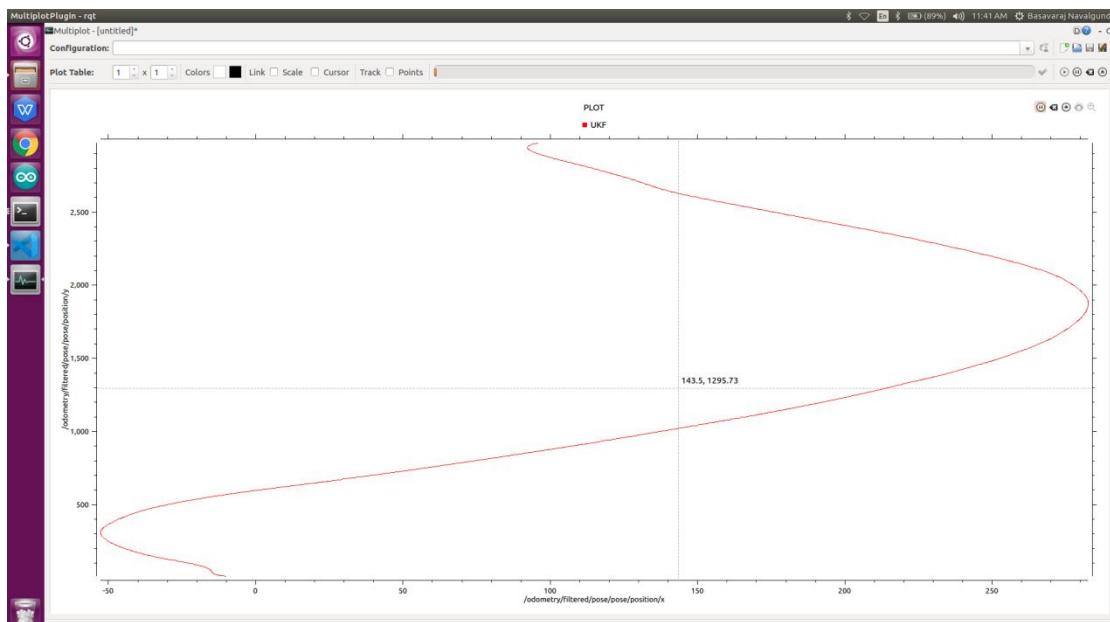


Fig. 15

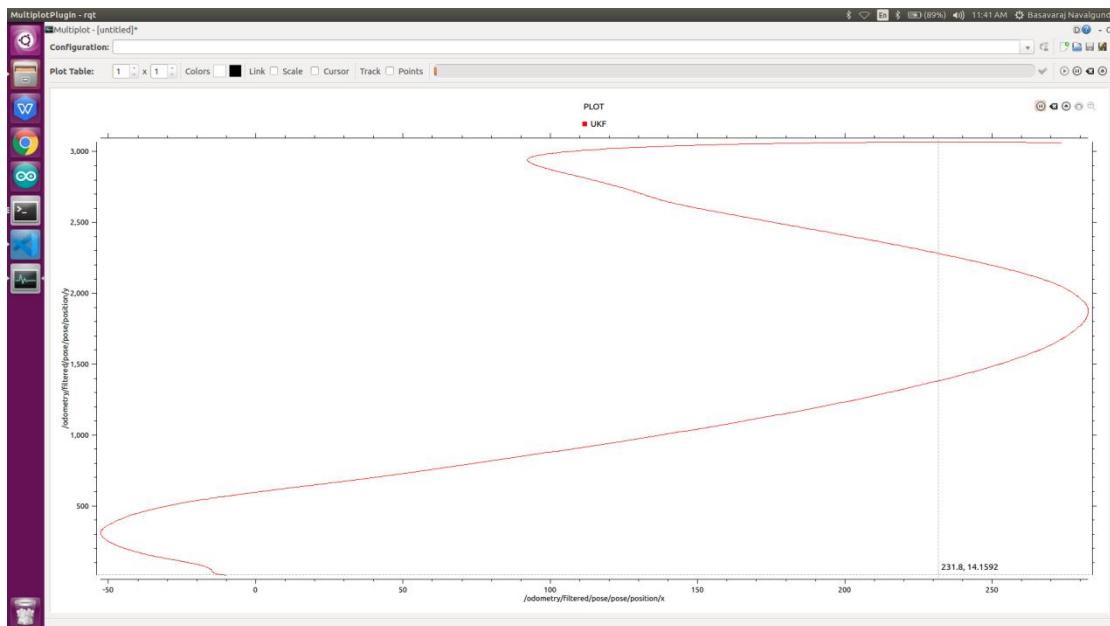


Fig. 16

Memory consumption of EKF

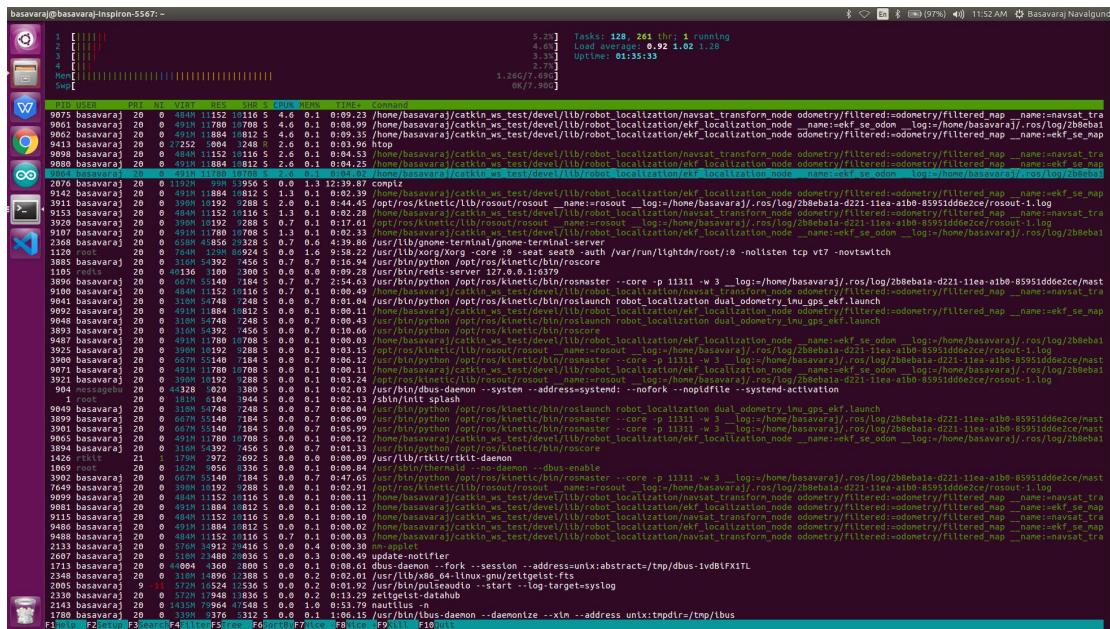


Fig. 17

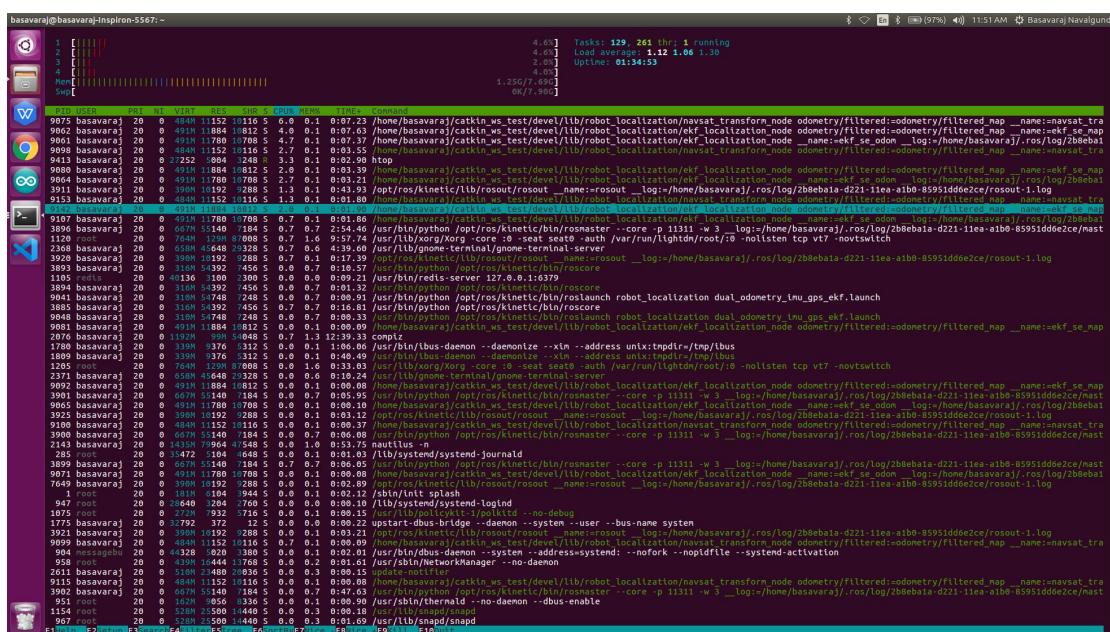


Fig. 18

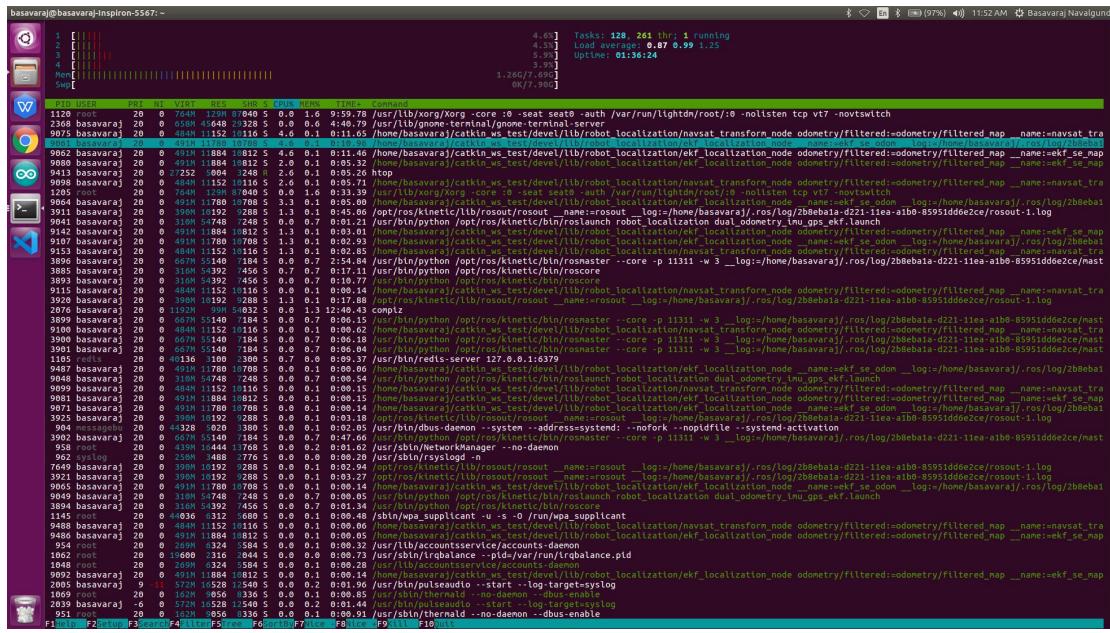


Fig. 19

EKF node is consuming 4.6% - 4.7% of CPU memory

Memory consumption of UKF

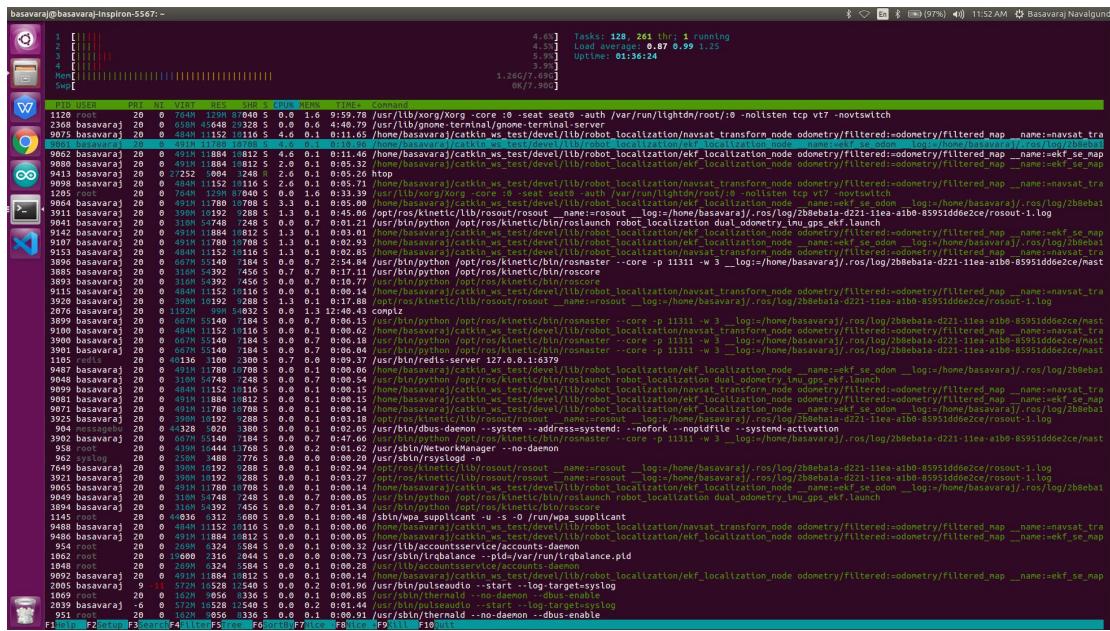


Fig. 20

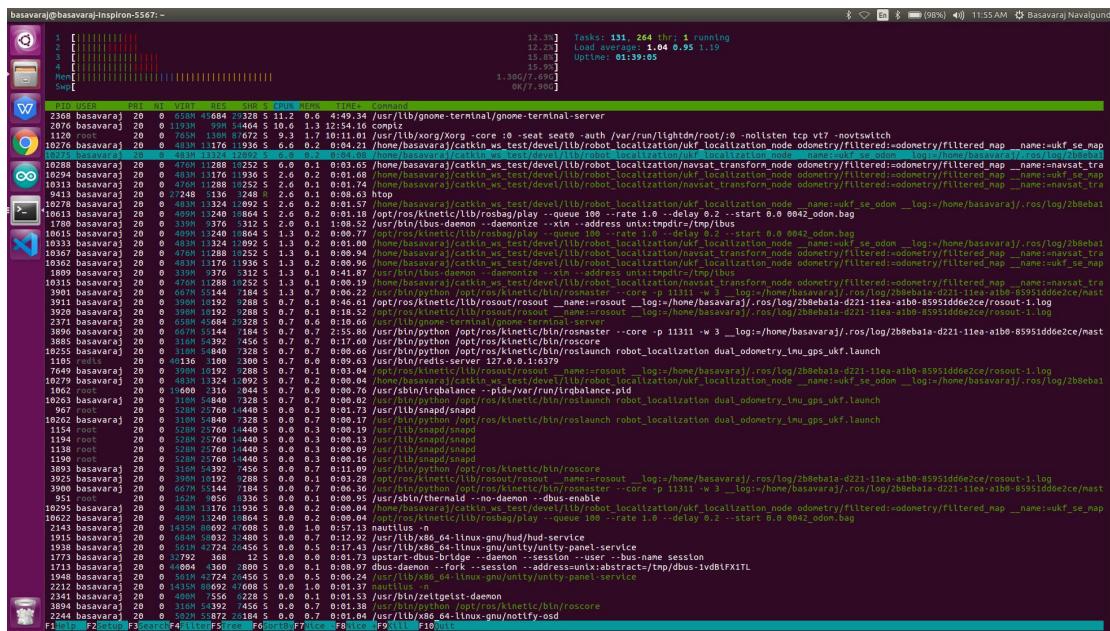


Fig. 21

```
basavaraj@basavaraj-insprion-5567: ~
```

1 [] Tasks: 131, 263 thr; 2 running
12.4% Load average: 0.98 0.93 1.18
14:44 Uptime: 01:38:48
13.4%
1.36G/1.69G
0K/7.9G

PID	USER	PRI	NI	VIRT	RES	SHR	%CPU	MEHR	TIME+	Command	
2368	basavaraj	20	0	658B	46219	7328B	18.8	0.6	0:47.64	/usr/lib/gnome-terminal/gnome-terminal-server	
20	basavaraj	20	0	755M	1308	6286 B	5.6	1.7	10:09.37	/usr/lib/xorg/Xorg -core :0 -seat seat0 -auth /var/run/lightdm/root:0 -nolisten tcp vt7 -novtswitch	
1268	basavaraj	20	0	755M	1308	6286 B	5.6	1.7	10:09.37	/usr/lib/xorg/Xorg -core :0 -seat seat0 -auth /var/run/lightdm/root:0 -nolisten tcp vt7 -novtswitch	
10276	basavaraj	20	0	483K	1170	1393E	6.6	0.2	0:03.22	/home/basavaraj/.catkin_ws/test/_dev/lib/robot_localization/ukf_localization_node odometry/filtered_map _name:=ukf_se_map	
10288	basavaraj	20	0	476K	1170	1288B	2.5	0.1	0:02.76	/home/basavaraj/.catkin_ws/test/_dev/lib/robot_localization/navsat_transform_node odometry/filtered:_odometry/filtered_map _name:=navsat_tra	
10313	basavaraj	20	0	476K	1170	1288B	3.3	0.1	0:01.32	/home/basavaraj/.catkin_ws/test/_dev/lib/robot_localization/navsat_transform_node odometry/filtered:_odometry/filtered_map _name:=navsat_tra	
10294	basavaraj	20	0	476K	1170	1393 E	2.7	0.0	0:01.22	/home/basavaraj/.catkin_ws/test/_dev/lib/robot_localization/ukf_localization_node odometry/filtered:_odometry/filtered_map _name:=ukf_se_map	
10278	basavaraj	20	0	483K	1170	1393E	6.6	0.2	0:01.19	/home/basavaraj/.catkin_ws/test/_dev/lib/robot_localization/ukf_localization_node odometry/filtered:_odometry/filtered_map _name:=ukf_se_map	
1788	basavaraj	20	0	339K	5376	3132 E	2.8	0.1	1:08.15	/usr/bin/lbus-daemon --daemonize -xterm -address unix:/tmp/rplbus	
10295	basavaraj	20	0	339K	5376	3132 E	2.8	0.1	1:08.15	/usr/bin/lbus-daemon --daemonize -xterm -address unix:/tmp/rplbus	
10299	basavaraj	20	0	339K	5376	3132 E	1.3	0.1	0:41.65	/usr/bin/python /opt/ros/kinetic/bin/roscore	
10615	basavaraj	20	0	489K	1240	13864 S	1.3	0.2	0:00.58	/opt/ros/kinetic/lib/librosbag/lib -queue 100 -rate 1.0 -delay 0.2 --start 0.0042 _odon.bag	
10331	basavaraj	20	0	483K	1324	13892 S	2.8	0.1	0:00.70	/home/basavaraj/.catkin_ws/test/_dev/lib/robot_localization/ukf_localization_node odometry/filtered:_odometry/filtered_map _name:=navsat_tra	
10367	basavaraj	20	0	476K	1170	1288B	1.3	0.1	0:00.72	/home/basavaraj/.catkin_ws/test/_dev/lib/robot_localization/navsat_transform_node odometry/filtered:_odometry/filtered_map _name:=navsat_tra	
3920	basavaraj	20	0	390K	1170	1288B	1.3	0.1	0:00.43	/opt/ros/kinetic/lib/librosout/lib -name=rosout _log:=/home/basavaraj/.ros/log/2b8eb1a-d221-11ea-a1b0-85951ddce2ce/roscore-1.log	
10525	basavaraj	20	0	316K	54392	4556 S	0.7	0.7	0:17.54	/usr/bin/python /opt/ros/kinetic/bin/roscore	
2371	basavaraj	20	0	658K	2142	2328B	0.6	0.6	0:00.58	/usr/lib/gnome-terminal/gnome-terminal-server	
10315	basavaraj	20	0	476K	1170	1288B	2.5	0.1	0:00.14	/home/basavaraj/.catkin_ws/test/_dev/lib/robot_localization/navsat_transform_node odometry/filtered:_odometry/filtered_map _name:=navsat_tra	
10329	basavaraj	20	0	476K	1170	1288B	2.5	0.1	0:00.14	/home/basavaraj/.catkin_ws/test/_dev/lib/robot_localization/navsat_transform_node odometry/filtered:_odometry/filtered_map _name:=navsat_tra	
1205	root	20	0	755K	1308	6286 B	0.8	1.7	0:34.02	/usr/lib/xorg/Xorg -core :0 -seat seat0 -auth /var/run/lightdm/root:0 -nolisten tcp vt7 -novtswitch	
1069	root	20	0	162K	955K	3336 S	0.9	0.1	0:00.89	/usr/sbin/thermal -d -n -noaud -dbus-enable	
10255	basavaraj	20	0	318K	5408	3228 S	0.6	0.7	0:00.60	/usr/bin/python /opt/ros/kinetic/bin/roslaunch robot_localization dual_odometry_imu_ gps_ukf.launch	
3896	basavaraj	20	0	667K	55144	184 S	0.7	0.7	0:55.79	/usr/bin/python /opt/ros/kinetic/bin/rosmaster --core p_1111 -w 3 _log:=/home/basavaraj/.ros/log/2b8eb1a-d221-11ea-a1b0-85951ddce2ce/mast	
10290	basavaraj	20	0	318K	5408	3228 S	0.6	0.7	0:00.39	/usr/bin/python /opt/ros/kinetic/bin/roslaunch robot_localization dual_odometry_imu_ gps_ukf.launch	
10279	basavaraj	20	0	667K	55144	184 S	0.6	0.7	0:00.39	/usr/bin/python /opt/ros/kinetic/bin/rosmaster --core p_1111 -w 3 _log:=/home/basavaraj/.ros/log/2b8eb1a-d221-11ea-a1b0-85951ddce2ce/mast	
3901	basavaraj	20	0	667K	55144	184 S	0.6	0.7	0:00.19	/usr/bin/python /opt/ros/kinetic/bin/rosmaster --core p_1111 -w 3 _log:=/home/basavaraj/.ros/log/2b8eb1a-d221-11ea-a1b0-85951ddce2ce/mast	
3908	basavaraj	20	0	667K	55144	184 S	0.7	0.7	0:00.33	/usr/bin/python /opt/ros/kinetic/bin/rosmaster --core p_1111 -w 3 _log:=/home/basavaraj/.ros/log/2b8eb1a-d221-11ea-a1b0-85951ddce2ce/mast	
1103	basavaraj	20	0	483K	1170	1393E	6.6	0.2	0:00.14	/usr/bin/python /opt/ros/kinetic/bin/roslaunch robot_localization dual_odometry_imu_ gps_ukf.launch	
1241	basavaraj	20	0	480K	8712	4698 S	0.6	1.9	0:50.92	auttius -n	
3921	basavaraj	20	0	390K	1170	1288B	0.8	0.1	0:03.36	/opt/ros/kinetic/lib/librosout/_rosout _name:=rosout _log:=/home/basavaraj/.ros/log/2b8eb1a-d221-11ea-a1b0-85951ddce2ce/roscore-1.log	
2889	basavaraj	9	0	727K	1522	5408 S	0.8	0.2	0:00.82	/usr/bin/python /opt/ros/kinetic/bin/rospack --load zeitgeist -r . --tag -target syslog	
2103	basavaraj	20	0	1193K	594	4325 S	0.6	1.3	0:04.34	comzip	
10304	basavaraj	20	0	483K	1170	1393 E	0.6	0.2	0:00.03	/home/basavaraj/.catkin_ws/test/_dev/lib/robot_localization/ukf_localization_node odometry/filtered:_odometry/filtered_map _name:=ukf_se_map	
1938	basavaraj	20	0	561K	4724	2455 S	0.6	0.5	0:01.35	/usr/lib/x86_64-linux-gnu/ply/unity-panel-service	
1948	basavaraj	20	0	561K	4724	2455 S	0.6	0.5	0:06.23	/usr/lib/x86_64-linux-gnu/ply/unity-panel-service	
1713	basavaraj	20	0	480K	1170	1393E	0.6	0.2	0:00.14	/usr/bin/abus-daemon --fork --session --address unix:/abstract:/tmp/dbus-1vdBtFX1Tl	
2131	basavaraj	20	0	480K	7556	2228 S	0.6	0.1	0:01.52	/usr/bin/zeitgeist-daemon	
2338	basavaraj	20	0	572K	1749	1835 S	0.6	0.2	0:13.77	zeitgeist-database	
1533	basavaraj	20	0	572K	1749	1835 S	0.6	0.2	0:13.77	zeitgeist-database	
2348	basavaraj	20	0	318K	14890	3388 S	0.6	0.2	0:02.11	/usr/lib/x86_64-linux-gnu/zeitgeist-fs	
2079	basavaraj	20	0	664K	3248	3248 S	0.6	0.7	0:02.42	/usr/lib/x86_64-linux-gnu/hud/service	
1084	basavaraj	20	0	483K	1170	1393E	0.6	0.2	0:00.14	/home/basavaraj/.catkin_ws/test/_dev/lib/robot_localization/ukf_localization_node odometry/filtered:_odometry/filtered_map _name:=ukf_se_map	
1854	basavaraj	20	0	432K	9881	4116 S	0.6	0.4	0:00.99	/usr/bin/dbus-daemon --config-file=/etc/xdg/autostart/dbus-abstract.conf --nofork --print-address 3	
10255	basavaraj	20	0	208K	2662	652 S	0.6	0.1	0:00.89	/usr/bin/gnome-keyring-daemon --daemonize --login	
F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12

Fig. 22

Fig. 23

```

basavaraj@basavaraj-Inspiron-5567: ~
[ 1 2 3 Mem Swap]
[ 14.3% ] Tasks: 131, 267 thr: 1 running
[ 12.5% ] Load average: 1.11 0.97 1.19
[ 15.7% ] Uptime: 01:59:14
[ 13.3% ] 1.30G/7.69G
[ 0K/7.96G ]

PID USER PRIO NI VIRT RES SWP S CPU% MEM% TIME+ COMMAND
2076 basavaraj 20 0 1193M 1990 54476 S 9.8 1.3 12:55:26 compiz
2234 basavaraj 20 0 740M 4500 87868 S 8.5 0.7 10:11:36 /usr/lib/xorg/Xorg -core :0 -seat seat0 -auth /var/run/lightdm/root/:0 -nolisten tcp vt7 -novtswitch
1120 basavaraj 20 0 765M 1000 87868 S 8.5 0.7 10:11:36 /usr/lib/xorg/Xorg -core :0 -seat seat0 -auth /var/run/lightdm/root/:0 -nolisten tcp vt7 -novtswitch
10275 basavaraj 20 0 483M 13324 12892 S 6.6 0.2 0:04:57 /home/basavaraj/catkin_ws/test/devel/lib/robot_localization/ukf_localization_node _name:=ukf_se_odom _log:=/home/basavaraj/.ros/log/2b8eb1a
10288 basavaraj 20 0 476M 11288 10252 S 5.2 0.1 0:04:07 /home/basavaraj/catkin_ws/test/devel/lib/robot_localization/navsat_transform_node odometry/filterd:=odometry/filterd:=odometry/filterd:_name:=navsat_transform_node _name:=navsat_transform_node _log:=/home/basavaraj/.ros/log/2b8eb1a
10294 basavaraj 20 0 483M 13276 11936 S 2.6 0.2 0:01:07 /home/basavaraj/catkin_ws/test/devel/lib/robot_localization/ukf_localization_node odometry/filterd:=odometry/filterd:=odometry/filterd:_name:=ukf_se_odom _log:=/home/basavaraj/.ros/log/2b8eb1a
9413 basavaraj 20 0 7248 5136 1248 S 2.6 0.1 0:08:85 httpd
2011 basavaraj 20 0 483M 13276 11936 S 2.6 0.1 0:08:85 /home/basavaraj/catkin_ws/test/devel/lib/robot_localization/ukf_localization_node odometry/filterd:=odometry/filterd:=odometry/filterd:_name:=ukf_se_odom _log:=/home/basavaraj/.ros/log/2b8eb1a
10278 basavaraj 20 0 483M 13324 12892 S 2.0 0.2 0:01:75 /home/basavaraj/catkin_ws/test/devel/lib/robot_localization/ukf_localization_node _name:=ukf_se_odom _log:=/home/basavaraj/.ros/log/2b8eb1a
1788 basavaraj 20 0 339M 9376 312 S 2.0 0.1 0:08:74 /usr/bin/busdaemon --daemonize --xim --address unix:tmpdir=/tmp/bus
10292 basavaraj 20 0 483M 13276 11936 S 1.9 0.2 0:01:07 /opt/ros/kinetic/lib/roslaunch/play -queue 100 --rate 1.0 --delay 0.2 --start 0.0 0042_odom.bag
1869 basavaraj 20 0 339M 9376 312 S 1.3 0.1 0:04:00 /opt/ros/kinetic/lib/roslaunch/play -queue 100 --rate 1.0 --delay 0.2 --start 0.0 0042_odom.bag
10333 basavaraj 20 0 483M 13324 12892 S 1.3 0.2 0:01:12 /home/basavaraj/catkin_ws/test/devel/lib/robot_localization/ukf_localization_node _name:=ukf_se_odom _log:=/home/basavaraj/.ros/log/2b8eb1a
10365 basavaraj 20 0 483M 13276 11936 S 1.3 0.2 0:01:07 /home/basavaraj/catkin_ws/test/devel/lib/robot_localization/ukf_localization_node odometry/filterd:=odometry/filterd:_name:=ukf_se_odom _log:=/home/basavaraj/.ros/log/2b8eb1a
10615 basavaraj 20 0 483M 13248 10864 S 1.3 0.2 0:08:86 /home/basavaraj/catkin_ws/test/devel/lib/robot_localization/ukf_localization_node odometry/filterd:=odometry/filterd:_name:=ukf_se_odom _log:=/home/basavaraj/.ros/log/2b8eb1a
3911 basavaraj 20 0 398M 10392 9288 S 1.3 0.1 0:04:72 /opt/ros/kinetic/lib/roslaunch/rosvout _name:=rosout _log:=/home/basavaraj/.ros/log/2b8eb1a-d221-11ea-aib0-85951ddde2ce/rosvout-1.log
10367 basavaraj 20 0 476M 11288 10252 S 1.3 0.1 0:01:07 /home/basavaraj/catkin_ws/test/devel/lib/robot_localization/navsat_transform_node odometry/filterd:=odometry/filterd:_name:=navsat_transform_node _log:=/home/basavaraj/.ros/log/2b8eb1a
10390 basavaraj 20 0 316M 54392 1456 S 0.6 0.2 0:08:90 /usr/bin/python /opt/ros/kinetic/bin/rosmaster --core -p 11311 -w 3 _log:=/home/basavaraj/.ros/log/2b8eb1a-d221-11ea-aib0-85951ddde2ce/mast
3885 basavaraj 20 0 316M 54392 1456 S 0.7 0.7 0:17:63 /usr/bin/python /opt/ros/kinetic/bin/roscore
3893 basavaraj 20 0 316M 54392 1456 S 0.7 0.7 0:11:32 /usr/bin/python /opt/ros/kinetic/bin/roscore
10293 basavaraj 20 0 316M 54392 1456 S 0.7 0.7 0:08:26 /usr/bin/python /opt/ros/kinetic/bin/roslaunch robot_localization dual_odometry_imu_gps.ukf.launch
3921 basavaraj 20 0 398M 10392 2898 S 0.7 0.1 0:03:38 /opt/ros/kinetic/lib/roslaunch/rosvout _name:=rosout _log:=/home/basavaraj/.ros/log/2b8eb1a-d221-11ea-aib0-85951ddde2ce/rosvout-1.log
10616 basavaraj 20 0 409M 13240 10864 S 0.7 0.2 0:08:04 /opt/ros/kinetic/lib/roslaunch/play -queue 100 --rate 1.0 --delay 0.2 --start 0.0 0042_odom.bag
3922 basavaraj 20 0 398M 10392 2898 S 0.7 0.1 0:03:38 /opt/ros/kinetic/lib/roslaunch/rosvout _name:=rosout _log:=/home/basavaraj/.ros/log/2b8eb1a-d221-11ea-aib0-85951ddde2ce/rosvout-1.log
10255 basavaraj 20 0 316M 54392 1328 S 0.6 0.7 0:08:09 /usr/bin/python /opt/ros/kinetic/bin/roslaunch robot_localization dual_odometry_imu_gps.ukf.launch
2039 basavaraj -6 572M 16528 12540 S 0.6 0.2 0:01:00 /usr/bin/pulseaudio -start --log-target=syslog
3275 basavaraj 20 0 658M 43688 29328 S 0.6 0.1 0:10:20 /usr/lib/xorg/Xorg -core :0 -seat seat0 -auth /var/run/lightdm/root/:0 -nolisten tcp vt7 -novtswitch
10115 basavaraj 20 0 483M 13276 11936 S 0.6 0.1 0:01:27 /home/basavaraj/catkin_ws/test/devel/lib/robot_localization/navsat_transform_node odometry/filterd:=odometry/filterd:_name:=navsat_transform_node _log:=/home/basavaraj/.ros/log/2b8eb1a
10279 basavaraj 20 0 483M 13276 12892 S 0.6 0.2 0:08:05 /home/basavaraj/catkin_ws/test/devel/lib/robot_localization/ukf_localization_node _name:=ukf_se_odom _log:=/home/basavaraj/.ros/log/2b8eb1a
2143 basavaraj 20 0 1435M 86692 47698 S 0.6 1.0 0:57:32 nautilus
1915 basavaraj 20 0 483M 13276 11936 S 0.6 0.1 0:08:33 /usr/bin/xdg-user-dirs-update
1938 basavaraj 20 0 561M 42724 26450 S 0.6 0.5 0:17:51 /usr/lib/x86_64-linux-gnu/unity/unity-panel-service
1948 basavaraj 20 0 561M 42724 26450 S 0.6 0.5 0:06:28 /usr/lib/x86_64-linux-gnu/unity/unity-panel-service
2079 basavaraj 20 0 483M 13276 11936 S 0.6 0.1 0:08:50 /usr/bin/xdg-user-dirs-update
1713 basavaraj 20 0 44064 3668 1809 S 0.6 0.1 0:09:02 dbus-daemon -fork -session --address=unix:/tmp/dbus-1vdbfx1tL
10622 basavaraj 20 0 409M 13240 10864 S 0.6 0.2 0:08:05 /opt/ros/kinetic/lib/roslaunch/play -queue 100 --rate 1.0 --delay 0.2 --start 0.0 0042_odom.bag
905 messagebus 20 0 4328 11288 3388 S 0.6 0.1 0:02:13 /usr/bin/dbus-daemon --system --address=systemd: --nofork --nopidfile --systemd-activation
958 messagebus 20 0 4328 11288 3388 S 0.6 0.1 0:02:13 /usr/bin/dbus-daemon --system --address=systemd: --nofork --nopidfile --systemd-activation
2005 basavaraj 9 -11 572M 16528 12540 S 0.6 0.2 0:02:17 /usr/bin/pulseaudio -start --log-target=syslog
3899 basavaraj 20 0 667M 55244 184 S 0.6 0.7 0:06:33 /usr/lib/xorg/Xorg -core :0 -seat seat0 -auth /var/run/lightdm/root/:0 -nolisten tcp vt7 -novtswitch
2139 basavaraj 20 0 483M 13276 11936 S 0.6 0.1 0:08:33 /home/basavaraj/catkin_ws/test/devel/lib/robot_localization/navsat_transform_node odometry/filterd:=odometry/filterd:_name:=navsat_transform_node _log:=/home/basavaraj/.ros/log/2b8eb1a-d221-11ea-aib0-85951ddde2ce/mast
1831 basavaraj 20 0 467M 30520 25304 S 0.6 0.4 0:14:38 /usr/lib/ibus/ibus-ut-gtk3
2343 basavaraj 20 0 409M 7556 2228 S 0.6 0.1 0:09:40 /usr/bin/zeitgeist-daemon
1830 basavaraj 20 0 467M 30520 25304 S 0.6 0.4 0:08:50 /usr/lib/x86_64-linux-gnu/bamf/bamfdaemon
1845 basavaraj 20 0 467M 30520 25304 S 0.6 0.4 0:08:50 /usr/lib/x86_64-linux-gnu/bamf/bamfdaemon
1898 basavaraj 20 0 183M 5268 9268 S 0.6 0.1 0:06:61 /usr/lib/x86_64-linux-gnu/zeitgeist-fs
2212 basavaraj 20 0 1435M 86692 47698 S 0.6 1.0 0:57:38 nautilus
2343 basavaraj 20 0 483M 13276 11936 S 0.6 0.2 0:08:38 /usr/bin/xdg-user-dirs-update
2103 basavaraj 20 0 119M 1000 54476 S 0.6 1.3 0:04:37 compiz
1888 basavaraj 20 0 183M 5268 9208 S 0.6 0.1 0:08:53 /usr/lib/x86_64-linux-gnu/zeitgeist-fs
10304 basavaraj 20 0 483M 13276 11936 S 0.6 0.2 0:08:04 /home/basavaraj/catkin_ws/test/devel/lib/robot_localization/ukf_localization_node odometry/filterd:=odometry/filterd:_name:=ukf_se_odom _log:=/home/basavaraj/.ros/log/2b8eb1a

```

Fig. 24

UKF node is consuming 5.2% - 6.9% of CPU memory