

标定d435i/d455双目+IMU

by fcl 2021.07.11

1. 安装realsense-SDK

1.1 使用指令安装 (如果不需要校准IMU可以用这个方式安装)

[官方教程](#)

注册服务器的公钥

```
sudo apt-key adv --keyserver keyserver.ubuntu.com --recv-key  
F6E65AC044F831AC80A06380C8B3A55A6F3EFCDE || sudo apt-key adv --keyserver  
hkps://keyserver.ubuntu.com:80 --recv-key  
F6E65AC044F831AC80A06380C8B3A55A6F3EFCDE
```

如果无法检索到公钥可以设置代理: `export http_proxy="http://<proxy>:<port>"`

将服务器添加到存储列表

```
sudo add-apt-repository "deb https://librealsense.intel.com/Debian/apt-repo  
$(lsb_release -cs) main" -u
```

安装库

```
sudo apt-get install librealsense2-dkms  
sudo apt-get install librealsense2-utils
```

开发包 (可选)

```
sudo apt-get install librealsense2-dev  
sudo apt-get install librealsense2-dbg
```

验证, 打开一个终端输入 `realsense-viewer` 看这个软件能否打开

1.2 使用源码安装 (后续可以用里面的包校准IMU)

安装地址, 选择[最新版](#)

[官方安装教程](#)

我个人装在了~/software/下

```
cd librealsense  
sudo apt-get install git libssl-dev libusb-1.0-0-dev libudev-dev pkg-config  
libgtk-3-dev  
sudo apt-get install libg1fw3-dev libgl1-mesa-dev libglu1-mesa-dev at  
.scripts/setup_udev_rules.sh  
.scripts/patch-realsense-ubuntu-lts.sh  
echo 'hid_sensor_custom' | sudo tee -a /etc/modules  
  
sudo add-apt-repository ppa:ubuntu-toolchain-r/test  
sudo apt-get update  
sudo apt-get install gcc-5 g++-5
```

```

sudo update-alternatives --install /usr/bin/gcc gcc /usr/bin/gcc-5 60 --slave
/usr/bin/g++ g++ /usr/bin/g++-5
sudo update-alternatives --set gcc "/usr/bin/gcc-5"

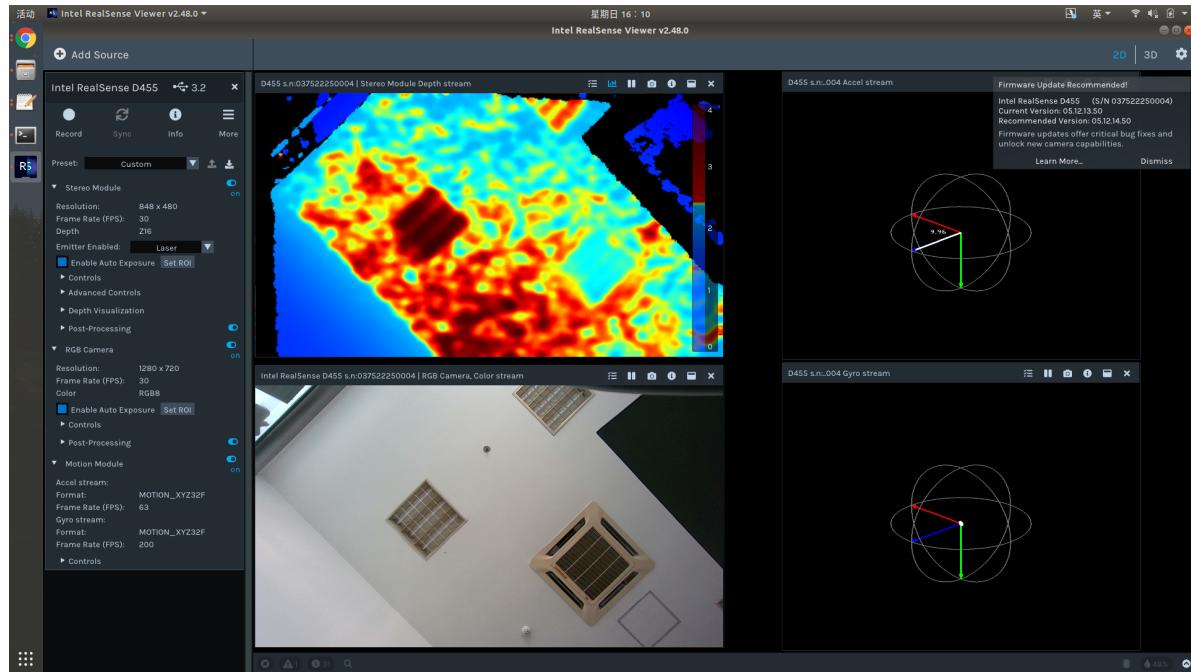
mkdir build && cd build
cmake ../
sudo make uninstall && make clean && make && sudo make install

```

使用D455相机的原装usb线到电脑(接口最好是usb3.0,否则可能导致数据传输过慢而使得数据无法实时传输, 出现画面卡住的现象)

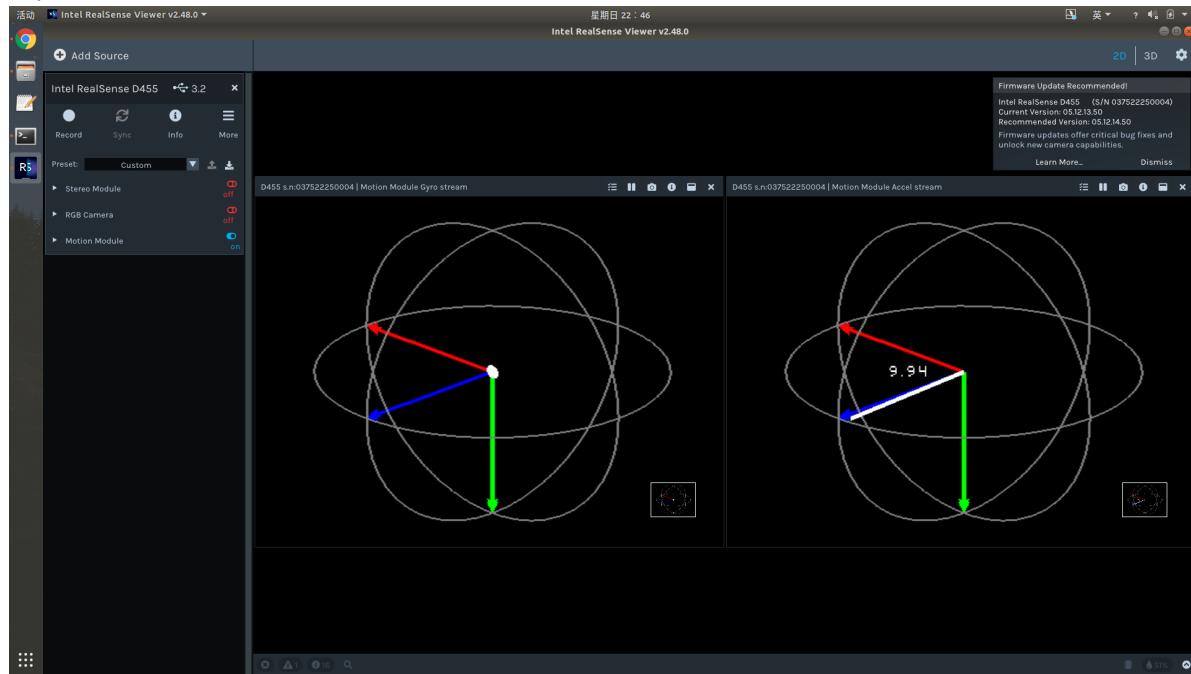
打开一个终端输入 `realsense-viewer` 看这个软件能否打开来验证是否成功安装。我们通过左边的选项打开imu, 双目和rgb相机模块, 同时可以查看各个模块的参数并进行设置

图示是在419



1.3 IMU校准

我们首先要看一下相机的加速度在静置的时候是不是正常的，正常的话我们加速度计的g_norm: 9.82左右（可以打开realsense-viewer，相机处于正常拍摄视角。开启Motion Module 鼠标放在Accel上面查看）



如果不正常，例如我校准前的g_norm为9.94左右，则进行以下校准过程：

使用SDK中的官方那个工具校准IMU

首先安装一个包 `pip install pyrealsense2`

校准工具的位置在`/home/fcl/software/librealsense/tools/rs-imu-calibration`

输入 `python rs-imu-calibration.py`

运行该脚本后从6个位置获取IMU 数据，在每个位置停留3-4秒时间。

具体操作如下：

```
活动 终端 星期一 00:27
fcl@fcl-ThinkPad-T480:~/software/librealsense/tools/rs-imu-calibration$ python rs-imu-calibration.py
waiting for realsense device...
Device PID: 0B3C
Device name: Intel RealSense D455
Serial number: 037522250004
Product line: D455
Firmware version: 05.12.13.50
Start interactive mode:
FOUND GYRO with fps=200
FOUND ACCEL with fps=63
...
*** Press ESC to Quit ***
.....
Align to direction: [ 0. -1. 0.] Mounting screw pointing down, device facing out
Status.collect_data[.....]
Direction data collected.
Align to direction: [1. 0. 0.] Mounting screw pointing left, device facing out
Status.collect_data[.....]
Direction data collected.
Align to direction: [0. 1. 0.] Mounting screw pointing up, device facing out
Status.collect_data[.....]
Direction data collected.
Align to direction: [-1. 0. 0.] Mounting screw pointing right, device facing out
Status.collect_data[.....]
Direction data collected.
Align to direction: [ 0. 0. -1.] Viewing direction facing down
Status.collect_data[.....]
Direction data collected.
Align to direction: [ 0. 0. 1.] Viewing direction facing up
Status.collect_data[.....]
Direction data collected.
Would you like to save the raw data? Enter footer for saving files (accel_<footer>.txt and gyro_<footer>.txt)
Enter nothing to not save raw data to disk. >2
Writing files:
accel_1.txt
gyro_1.txt
[-4.63748000e-05 5.06849285e-04 7.28357153e-04]
[1000 1000 1000 1000 1000 1000]
using 6000 measurements
[[ 1.02583226  0.003371  -0.01310287]
 [ 0.00122222  0.02720888  0.0153456 ]
 [-0.01080882 -0.01644608  1.01181132]
 [ 0.02473963  0.54594946  0.84291371]]
residuals: [ 1.33059343  7.62113422 166.28578448]
rank: 4
singular: [440.36306415 429.06278992 420.45035532 77.08783039]
```

```
活动 终端
文件(F) 编辑(E) 查看(V) 搜索(S) 终端(T) 帮助(H)
*** Press ESC to Quit ***
Align to direction: [ 0. -1. 0.] Mounting screw pointing down, device facing out
Status.collect_data[.....]
Direction data collected.
Align to direction: [1. 0. 0.] Mounting screw pointing left, device facing out
Status.collect_data[.....]
Direction data collected.
Align to direction: [0. 1. 0.] Mounting screw pointing up, device facing out
Status.collect_data[.....]
Direction data collected.
Align to direction: [-1. 0. 0.] Mounting screw pointing right, device Facing out
Status.collect_data[.....]
Direction data collected.
Align to direction: [ 0. 0. -1.] Viewing direction facing down
Status.collect_data[.....]
Direction data collected.
Align to direction: [ 0. 0. 1.] Viewing direction facing up
Status.collect_data[.....]
Direction data collected.
Would you like to save the raw data? Enter footer for saving files (accel_<footer>.txt and gyro_<footer>.txt)
Enter nothing to not save raw data to disk. >2

Writing files:
accel_2.txt
gyro_2.txt
[-4.63748000e-05 5.06849285e-04 7.28357153e-04]
[1e000 1000 1000 1000 1000 1000]
using 6000 measurements
[[ -0.00106571 0.03318287]
 [ 0.0210652 0.02750088 0.0151456]
 [-0.01080882 -0.01644608 0.0118132]
 [ 0.02473963 0.54594946 0.04291371]]
residuals: [ 1.33059343 7.62113422 166.28578448]
rank: 3
singular: [440.36306415 429.06278992 420.45035532 77.08703039]
norm (raw data ) : 9.668538
norm (fixed data): 9.884214 A good calibration will be near 9.806650
Would you like to write the results to the camera? (Y/N)
Mounting calibration to device.
Device PID: 0x8c
Device name: Intel RealSense D455
serial number: 037522250004
firmware version: 05.12.13.50
SUCCESS: saved calibration to camera.
Done.
fc1@fc1-ThinkPad-T480:~/software/librealsense/tools/rs-imu-calibration$
```

我和官方文档的人一样制作了一个简易盒子来实现90度的翻转。

方位如下：





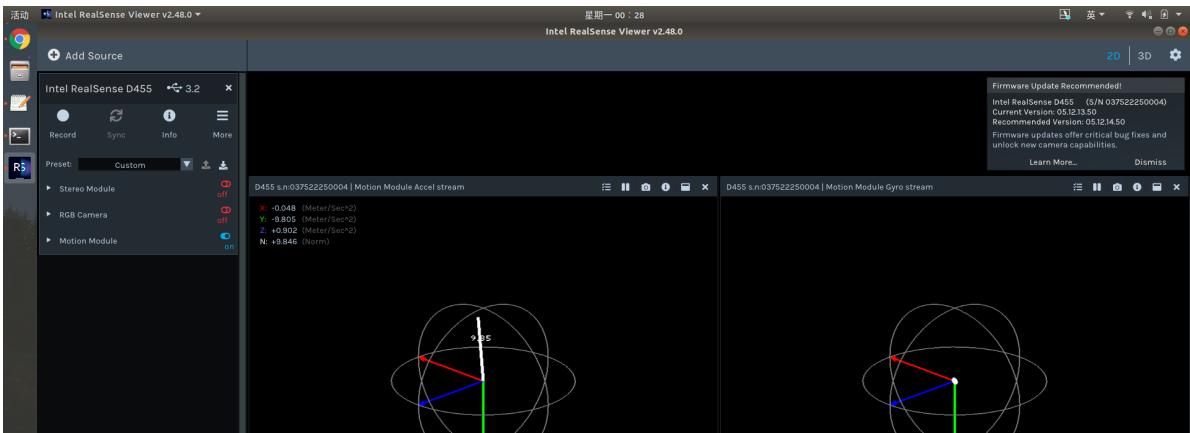


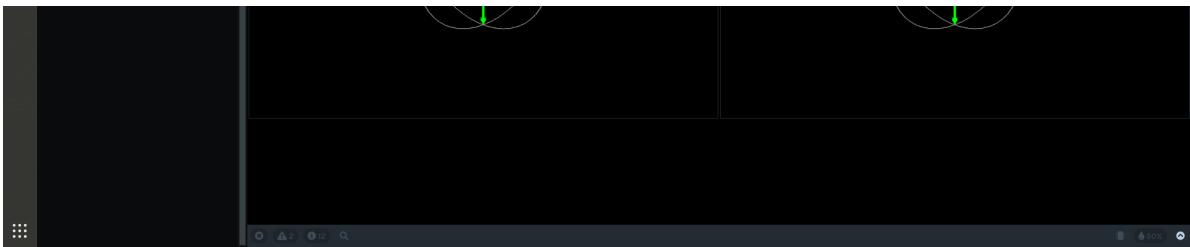






校准完之后发现加速度计的值变成9.85左右，恢复正常。注意在查看g_norm大小的时候，需要让相机上下正放，也就是正常拍摄视角。





2. 下载安装realsense-ROS-Wrapper

官网

补充安装 `sudo apt-get install ros-melodic-ddynamic-reconfigure`

创建工作空间

```
mkdir -p ~/software/realsense_roswrapper/src  
cd ~/software/realsense_roswrapper/src
```

下载源码

```
git clone https://github.com/IntelRealSense/realsense-ros.git  
cd realsense-ros/  
git checkout `git tag | sort -V | grep -P "^\d+\.\d+\.d+" | tail -1`  
cd ..
```

编译

```
catkin_init_workspace  
cd ..  
catkin_make clean  
catkin_make -DCATKIN_ENABLE_TESTING=False -DCMAKE_BUILD_TYPE=Release  
catkin_make install
```

添加环境变量

```
echo "source ~/software/realsense_roswrapper/devel/setup.bash" >> ~/.bashrc  
source ~/.bashrc
```

3. 标定相机和IMU

我们将使用kalibr对相机进行标定，使用code_utils和imu_utils对imu进行标定

3.1 下载编译Kalibr

1. 下载源文件并编译

官方地址<https://github.com/ethz-asl/kalibr>

安装教程<https://github.com/ethz-asl/kalibr/wiki/installation>

pre_environment

```
sudo apt-get install -y \
git wget autoconf automake nano \
libeigen3-dev libboost-all-dev libsuitesparse-dev \
doxygen libopencv-dev \
libpoco-dev libtbb-dev libblas-dev liblapack-dev libv4l-dev
```

```
sudo apt-get install -y python3-dev python-pip python-scipy \
python-matplotlib ipython python-wxgtk4.0 python-tk python-igraph
```

创建工作空间(这一步之前你得把ros装好,同时将opencv3.2配置好)

安装ros参考[链接](#)

安装ros, 已装好的可以跳过

```
sudo sh -c 'echo "deb http://packages.ros.org/ros/ubuntu $(lsb_release -sc) main" \
> /etc/apt/sources.list.d/ros-latest.list'
sudo apt install curl
curl -s https://raw.githubusercontent.com/ros/rosdistro/master/ros.asc | sudo
apt-key add -
sudo apt update
sudo apt install ros-melodic-desktop-full
echo "source /opt/ros/melodic/setup.bash" >> ~/.bashrc
source ~/.bashrc
sudo apt install python-rosdep python-rosinstall python-rosinstall-generator
python-wstool build-essential
sudo apt install python-rosdep
sudo rosdep init
rosdep update
```

继续

```
sudo apt-get install python-catkin-tools
mkdir -p ~/software/kalibr_workspace/src
cd ~/software/kalibr_workspace
export ROS1_DISTRO=melodic # kinetic=16.04, melodic=18.04, noetic=20.04
source /opt/ros/$ROS1_DISTRO/setup.bash
catkin init
catkin config --extend /opt/ros/$ROS1_DISTRO
catkin config --merge-devel # Necessary for catkin_tools >= 0.4.
catkin config --cmake-args -DCMAKE_BUILD_TYPE=Release
```

下载工程包

```
cd ~/software/kalibr_workspace/src
git clone https://github.com/ethz-asl/kalibr.git
```

编译kalibr

```
cd ~/software/kalibr_workspace/
catkin build -DCMAKE_BUILD_TYPE=Release -j4
```

3.2 下载编译code_utils

创建ros工作空间，用于code_utils以及后面的imu_utils，工作空间名和路径可以自己更改在。在software下的d455calib里面，/home/fcl/software/d455calib/imucalib_ws/src下放两个文件code_utils和imu_utils

1. 创建工作空间

```
mkdir -p ~/software/d455calib imu_catkin_ws/src  
cd ~/software/d455calib imu_catkin_ws/src  
catkin_init_workspace  
cd ..  
catkin_make  
source ~/software/d455calib//imu_catkin_ws/devel/setup.bash
```

2. 下载编译code_utils

```
cd ~/software/d455calib imu_catkin_ws/src  
git clone git@github.com:gaowenliang/code_utils.git(这一步可以直接复制手动下载解压好了的code_utils-master)  
cd ..  
catkin_make
```

我遇到的两个错误以及解决办法如下：

catkin_make时出现libdw.h没有找到

```
sudo apt-get install libdw-dev
```

catkin_make时出现backward.hpp没有找到

```
将sumpixel_test.cpp中# include "backward.hpp"改为: #include  
"code_utils/backward.hpp"
```

3.3 下载编译imu_utils

```
cd ~/software/d455calib imu_catkin_ws/src/  
git clone git@github.com:gaowenliang imu_utils.git(直接复制手动下载解压的imu_utils-  
master)  
cd ..  
catkin_make
```

3.4 IMU标定

1. 修改launch文件

找到realsense-ros包，进入/home/fcl/software/rs-ros-wrapper/catkin_ws/src/realsense-ros-development/realsense2_camera/launch，复制其中的rs_camera.launch，并重命名为rs_camera_imucalib.launch，并对里面的内容做如下更改

这样做的目的是将accel和gyro的数据合并得到imu话题，如不这样做发布的topic中只有加速计和陀螺仪分开的topic，没有合并的camera imu topic，并且让accel和gyro都设置成true

```
<arg name="unite_imu_method" default="linear_interpolation"/>
```

2. 运行启动文件

```
roslaunch realsense2_camera rs_camera_imucalib.launch
```

3. 编写启动文件

进入 /software/d455calib/imucalib_ws/src imu_utils-master/launch，打开终端运行

```
gedit d455_imu_calibration.launch
```

在里面写入

```
<launch>

<node pkg="imu_utils" type="imu_an" name="imu_an" output="screen">
    <!--TOPIC名称和上面一致-->
    <param name="imu_topic" type="string" value= "/camera imu"/>
    <!--imu_name 无所谓-->
    <param name="imu_name" type="string" value= "d455"/>
    <!--标定结果存放路径-->
    <param name="data_save_path" type="string" value= "$(find
imu_utils)/data"/>
    <!--数据录制时间-min-->
    <param name="max_time_min" type="int" value= "50"/>
    <!--采样频率，即是IMU频率，采样频率可以使用rostopic hz /camera imu查看，设置为
200，为后面的rosbag play播放频率-->
    <param name="max_cluster" type="int" value= "200"/>
</node>

</launch>
```

这里师弟们要注意可以把data文件夹修改为你们自己创建的文件夹，但是你要先创建文件夹，系统不好根据launch文件自动创建你写的文件夹，否则就没有标定的结果文件产生

4. 录制imu数据包

realsense静止放置，放置时间要稍大于d455_imu_calibration.launch中的录制时间，即大于50分钟
rosbag record -o imu_calibration /camera imu

其中imu_calibration是bag包的名字，可以更改，录的包在当前终端目录下
/camera imu是发布的IMU topic，可以通过 rostopic list 命令查看

5. 校准程序

包录制好之后，运行校准程序，首先激活imu_util工作空间的setup.bash

```
source /home/fcl/software/d455calib/imucalib_ws/devel/setup.bash
```

然后

```
roslaunch imu_utils d455_imu_calibration.launch
```

回放数据包

打开新的终端，cd到存放imu_calibration.bag的路径

```
cd ~/data/dataset/IMU标定录制的大于50min的包
rosbag play -r 200 imu_calibration.bag
```

标定结束后在 /home/fcl/software/d455calib/imucalib_ws/src imu_utils-master/data 中生成许多文件，其中 d455_imu_param.yaml 就是我们想要的结果，展示如下。作为对比，realsense自带的参数都是 0，d455_imu_param.yaml 文件内容如下：

```
%YAML:1.0
---
type: IMU
name: d455
Gyr:
```

```

unit: " rad/s"
avg-axis:
  gyr_n: 1.8120078954292167e-03
  gyr_w: 1.9468192818602672e-05
x-axis:
  gyr_n: 1.7014503941873895e-03
  gyr_w: 1.8929622045590070e-05
y-axis:
  gyr_n: 2.0863033939625092e-03
  gyr_w: 2.6649319246466860e-05
z-axis:
  gyr_n: 1.6482698981377512e-03
  gyr_w: 1.2825637163751080e-05
ACC:
unit: " m/s^2"
avg-axis:
  acc_n: 1.8783286176747332e-02
  acc_w: 8.8271097542303530e-04
x-axis:
  acc_n: 1.9176496923914592e-02
  acc_w: 1.2650034452525252e-03
y-axis:
  acc_n: 1.7240711086239993e-02
  acc_w: 7.3690326844879966e-04
z-axis:
  acc_n: 1.9932650520087410e-02
  acc_w: 6.4622621256778061e-04

```

3.5 双目相机标定

1. 标定板

[下载打印标定板](#)

下载Aprilgrid 66 0.80.8m(unscaled)，记住要缩放到40%，才能用A4纸就可以打印出来

原始pdf的格子参数是：

6*6的格子
 大格子边长： 5.5cm
 小格子边长： 1.65cm
 小格子与大格子边长比例： 0.3

调整后的格子参数是：

大格子边长： 2.1cm(我的经过实际测量是2.1)，一定要自己测量大格子边长，即tagsize
 小格子边长： 0.66cm
 小格子与大格子边长比例： 0.3

但这只是理想情况，实际情况还得实际测量。

新建april_6x6_A4.yaml文件，

在/home/fcl/software/d455calib/multicalib_yaml_data/april_6x6_A4.yaml文件里我设置的内容如下：

```

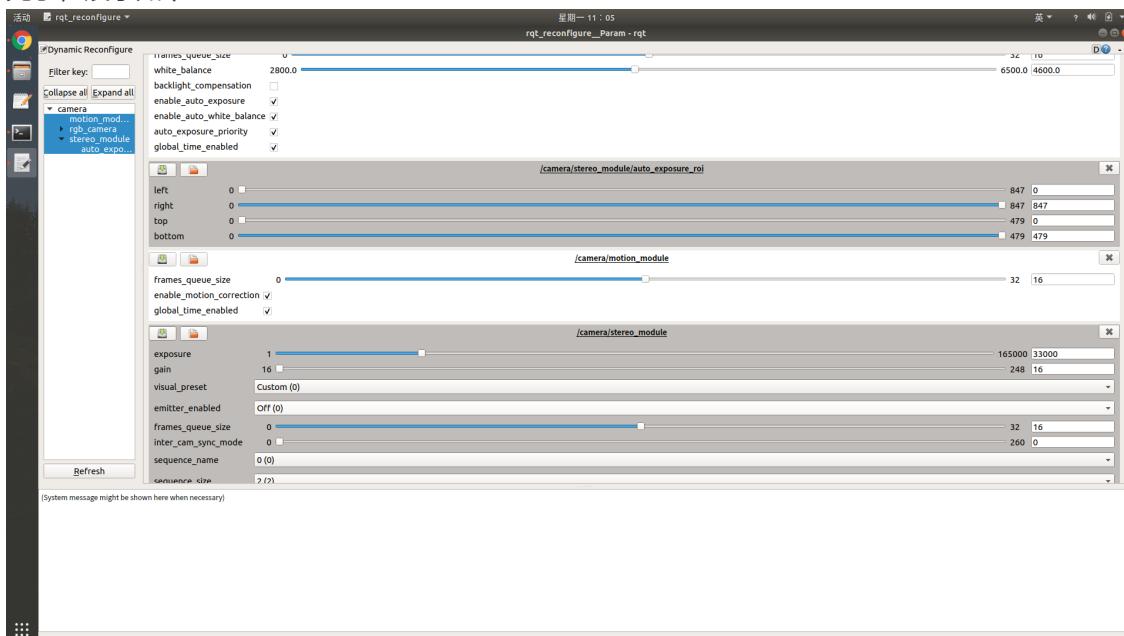
target_type: 'aprilgrid' #gridtype
tagCols: 6                 #number of apriltags
tagRows: 6                 #number of apriltags
tagSize: 0.021              #size of apriltag, edge to edge [m]
tagSpacing: 0.3             #ratio of space between tags to tagsize

```

2. 手动关闭结构光

默认开始结构光时，双目图像会有很多点，这些点可能对标定有影响，所以使用时需要关闭结构光。

方法一：先启动符合你需要的配置的launch文件，例如 rosrun realsense2_camera rs_camera.launch新打开终端，运行rosrun rqt_reconfigure rqt_reconfigure打开后将camera->stereo_module中的emitter_enabled设置为off(0)，可以通过肉眼看相机发射器已经不再发射IR光了，展示如下



方法二：realsense-viewer，打开双目模块的下拉选项，关闭结构光Emitter Enabled Off

3. 开始录制.bag文件

第一步：将realsense对准标定板放置

```
roslaunch realsense2_camera rs_camera_stereocalib.launch
```

运行rviz，fixed frame选择camera_link，之后在里面add rgb和双目对应的topic，三个相机在realsense上是一样大小的，彩色/camera/color/image_raw、左目/camera/infra1/image_rect_raw、右目/camera/infra2/image_rect_raw展示如下：

第二步：修改相机帧数（官方推荐是4Hz，尽管实际频率不完全准确，但是不影响结果）kalibr在处理标定数据的时候要求频率不能太高，一般为4Hz，我们可以使用如下命令来更改topic的频率，实际上是将原来的topic以新的频率转成新的topic，经过我实际测试infra1才是对应的左目相机

```

rosrun topic_tools throttle messages /camera/color/image_raw 4.0 /color
rosrun topic_tools throttle messages /camera/infra1/image_rect_raw 4.0
/infra_left
rosrun topic_tools throttle messages /camera/infra2/image_rect_raw 4.0
/infra_right

```

新出现的topic如下

```
fcl@fcl-ThinkPad-T480:~$ rostopic list
/home/fcl/software/rm-camera...
[cameras/infra1/camera_info
/camera/color/color_camera_info
/camera/infra1/color_camera_info
/camera/infra2/color_camera_info
/camera/color/color_camera_info
/camera/infra1/color_camera_info
/camera/infra2/color_camera_info
/camera/extrinsics/cs_depth_to_color
/camera/extrinsics/cs_depth_to_infra1
/camera/extrinsics/cs_depth_to_infra2
/camera/color/mu_info
/camera/infra1/mu_info
/camera/infra2/mu_info
/camera/color/image_rect
/camera/infra1/image_rect
/camera/infra2/image_rect
/camera/color/color_camera_info
/camera/infra1/color_camera_info
/camera/infra2/color_camera_info
/camera/color/color_camera_info
/camera/infra1/color_camera_info
/camera/infra2/color_camera_info
/camera/extrinsics/cs_depth_to_color
/camera/extrinsics/cs_depth_to_infra1
/camera/extrinsics/cs_depth_to_infra2
/camera/color/mu_info
/camera/infra1/mu_info
/camera/infra2/mu_info
/camera/color/image_rect
/camera/infra1/image_rect
/camera/infra2/image_rect
/camera/motion_module/parameter_descriptions
/camera/motion_module/parameter_updates
/camera/realsense_camera_manager/bond
/camera/rgb_camera/auto_exposure_roll/parameter_descriptions
/camera/rgb_camera/auto_exposure_roll/parameter_updates
/camera/rgb_camera/parameter_descriptions
/camera/rgb_camera/parameter_updates
/camera/stereo_module/auto_exposure_roll/parameter_descriptions
/camera/stereo_module/auto_exposure_roll/parameter_updates
/camera/stereo_module/parameter_descriptions
/camera/stereo_module/parameter_updates
/clicked_point
/color
/diagnostics
/infra_left
/infra_right
/initialpose
/move_base_simple/goal
/odom
/resout_agg
/tf
/tf_static
fcl@fcl-ThinkPad-T480:~$ ]
```

注意：这种方式可能导致不同摄像头的时间不同步，如果出现这个问题，可以尝试不做这个操作，不这样做意味着需要更多的处理时间，这样的话后面也要相应的更改。可以使用rqt或者rostopic hz 查看是不是设置频率成功。

查看频率

```
fcl@fcl-ThinkPad-T480:~$ rostopic hz
Usage: rostopic hz [options] [/topic_1 [topic_2 [...]]]

rostopic: error: topic must be specified
fcl@fcl-ThinkPad-T480:~$ rostopic hz /color
subscribed to [/color]
  average rate: 3.892
    min: 0.251s max: 0.290s std dev: 0.01672s window: 4
  average rate: 3.892
    min: 0.251s max: 0.290s std dev: 0.01432s window: 8
fcl@fcl-ThinkPad-T480:~$ rostopic hz /infra_left
subscribed to [/infra_left]
  average rate: 3.365
    min: 0.284s max: 0.320s std dev: 0.01650s window: 4
  average rate: 3.365
    min: 0.252s max: 0.320s std dev: 0.02233s window: 7
  average rate: 3.660
    min: 0.252s max: 0.320s std dev: 0.01941s window: 11
  Coverage estimate: 100.00%
    min: 0.250s max: 0.320s std dev: 0.01965s window: 12
fcl@fcl-ThinkPad-T480:~$ rostopic hz /infra_right
subscribed to [/infra_right]
  average rate: 3.736
    min: 0.280s max: 0.280s std dev: 0.01349s window: 4
  average rate: 3.767
    min: 0.249s max: 0.287s std dev: 0.01302s window: 8
  average rate: 3.724
    min: 0.249s max: 0.287s std dev: 0.01313s window: 11
  average rate: 3.762
    min: 0.249s max: 0.290s std dev: 0.01254s window: 15
  Coverage estimate: 100.00%
    min: 0.250s max: 0.290s std dev: 0.01071s window: 19
  ^Cnew messages
fcl@fcl-ThinkPad-T480:~$ rostopic hz /camera/color/image_rect_raw
subscribed to [/camera/color/image_rect_raw]
  average rate: 26.231
    min: 0.032s max: 0.042s std dev: 0.00254s window: 26
  average rate: 27.858
    min: 0.031s max: 0.042s std dev: 0.00237s window: 54
  ^Caverage rate: 26.231
fcl@fcl-ThinkPad-T480:~$ rostopic hz /cameras/infra1/image_rect_raw
subscribed to [/cameras/infra1/image_rect_raw]
  average rate: 29.865
    min: 0.000s max: 0.077s std dev: 0.01665s window: 29
  ^Caverage rate: 30.165
    min: 0.000s max: 0.077s std dev: 0.01421s window: 56
fcl@fcl-ThinkPad-T480:~$ rostopic hz /cameras/infra2/image_rect_raw
subscribed to [/cameras/infra2/image_rect_raw]
```

第三步：之后对准标定板，尝试移动realsense，同时要确保标定板一直在三个图像当中。

录制过程[参考](#)科学上网观看

总结下来就是偏航角左右摆动3次，俯仰角摆动3次，滚转角摆动3次，上下移动3次，左右移动3次，前后移动3次，然后自由移动一段时间，摆动幅度要大一点，让视角变化大一点，但是移动要缓慢一点，同时要保证标定板在3个相机视野内部，整个标定时间要在90s以上更好

录制ROS数据包

```
rosbag record -o multicameras_calibration /infra_left /infra_right /color
```

后面三个topic就是转换频率后的topic

4. 使用Kalibr标定

第一步：先激活环境变量

```
source software/kalibr_ws/devel/setup.bash
```

第二步：运行标定指令

```
kalibr_calibrate_cameras --target
/home/fcl/software/d455calib/multicalib_yaml_data/april_6x6_A4.yaml --bag
/home/fcl/software/d455calib/multicalib_yaml_data/multicameras_calibration.bag -
-models pinhole-radtan pinhole-radtan pinhole-radtan --topics /infra_left
/infra_right /color --bag-from-to 3 157 --show-extraction --approx-sync 0.04
```

其中

april_6x6_A4.yaml是标定板的配置文件

multicameras_calibration.bag 是录制的数据包

models pinhole-radtan pinhole-radtan pinhole-radtan表示三个摄像头的相机模型和畸变模型

--topics /infra_left /infra_right /color表示三个摄像头对应的拍摄的数据话题

--bag-from-to 3 157表示处理bag中3-157秒的数据

--show-extraction表示显示检测特征点的过程，这些参数可以相应的调整。

可以使用rosbag info 来参看录制的包的信息

```
fcl@fcl-ThinkPad-T480:~/software/d455calib/multicalib_yaml_data$ rosbag info
multicameras_calibration.bag
path:          multicameras_calibration.bag
version:       2.0
duration:     2:41s (161s)
start:        Jul 19 2021 13:44:55.21 (1626673495.21)
end:         Jul 19 2021 13:47:36.87 (1626673656.87)
size:         1.9 GB
messages:    1754
compression: none [1169/1169 chunks]
types:        sensor_msgs/Image [060021388200f6f0f447d0fc9c64743]
topics:      /color      584 msgs   : sensor_msgs/Image
             /infra_left  585 msgs   : sensor_msgs/Image
             /infra_right 585 msgs   : sensor_msgs/Image
fcl@fcl-ThinkPad-T480:~/software/d455calib/multicalib_yaml_data$
```

第三步：排查错误1

出现以下报错：cannot import name NavigationToolbar2Wx

解决办法：发现 matplotlib 中没有NavigationToolbar2Wx 而是换成了NavigationToolbar2WxAgg 所以修改源码，将PlotCollection.py中的NavigationToolbar2Wx换成NavigationToolbar2WxAgg
catkin_make一下

第四步：排查错误2

```
ImportError: No module named igraph
fcl@fcl-ThinkPad-T480:~$ sudo apt-get install python-igraph
```

第五步：排查错误3

报错找不到焦距，手动输入焦距，400

在终端输入

```
fcl@fcl-ThinkPad-T480:~$ source ~/software/kalibr_ws/devel/setup.bash
fcl@fcl-ThinkPad-T480:~$ export KALIBR_MANUAL_FOCAL_LENGTH_INIT=1
fcl@fcl-ThinkPad-T480:~$ kalibr_calibrate_cameras --target
/home/fcl/software/d455calib/multicalib_yaml_data/april_6x6_A4.yaml --bag
/home/fcl/software/d455calib/multicalib_yaml_data/multicameras_calibration.bag --
models pinhole-radtan pinhole-radtan pinhole-radtan --topics /infra_left
/infra_right /color --bag-from-to 3 157 --show-extraction --approx-sync 0.04
```

最终产生3个文件

3.6 双目相机和IMU的标定

1. 复制上面双目标定结果产生的camchain-homefc1softwared455calibmulticalib_yaml_datamulticameras_calibration.yaml文件为chain.yaml
其中T_cn_cnm1:表示的是左目相机到右目相机的旋转和平移
2. 新建一个文件imu.yaml, 参考上面imu标定步骤得到的d455_imu_param.yaml, 选取其中的

```
avg-axis:  
    gyr_n: 1.8120078954292167e-03  
    gyr_w: 1.9468192818602672e-05  
avg-axis:  
    acc_n: 1.8783286176747332e-02  
    acc_w: 8.8271097542303530e-04
```

最后得到的imu.yaml如下

```
#Accelerometers  
accelerometer_noise_density: 1.8783286176747332e-02 #Noise density (continuous-time)  
accelerometer_random_walk: 8.8271097542303530e-04 #Bias random walk  
  
#Gyroscopes  
gyroscope_noise_density: 1.8120078954292167e-03 #Noise density (continuous-time)  
gyroscope_random_walk: 1.9468192818602672e-05 #Bias random walk  
  
rostopic: /imu #the IMU ROS topic  
update_rate: 200.0 #Hz (for discretization of the values above)
```

3. 同样需要用到april_6x6_A4.yaml
4. 复制realsense-ros包中rs_camera.launch, 重命名为rs_camera_imucamcalib.launch, 更改内容如下
imu和双目数据时间对齐 `<arg name="enable_sync" default="true"/>`
合并加速计和陀螺仪的topic `<arg name="unite_imu_method" default="linear_interpolation"/>`
5. 启动realsense
`roslaunch realsense2_camera rs_camera_imucamcalib.launch`
6. 关闭IR结构光
7. 打开rviz, add imu topic和infra1 topic以及infra2 topic和color topic, 同时调整realsense位置, 要确保双目图像数据一直包含标定板全部内容
8. 调整imu和双目topic和color的发布频率以及以新的topic名发布它们, 其中双目图像的发布频率改为20Hz, imu发布频率改为200Hz

```
rosrun topic_tools throttle messages /camera/infra1/image_rect_raw 20.0
/infra_left
rosrun topic_tools throttle messages /camera/infra2/image_rect_raw 20.0
/infra_right
rosrun topic_tools throttle messages /camera/imu 200.0 /imu
rosrun topic_tools throttle messages /camera/color/image_raw 20.0 /color
```

这种调整频率的方式只是理想结果，通过rostopic hz topic名可以查看实际的频率，可以发现实际频率和设置的频率并不一定相同

9. 和上面一样开始采集数据包

```
rosbag record -o imu_stereo.bag /infra_left /infra_right /imu /color
查看bag包内容
```

```
fcl@fcl-ThinkPad-T480:~/software/d455calib/imu_stereo_data$ rosbag info
imu_stereo.bag
path:          imu_stereo.bag
version:       2.0
duration:     2:08s (128s)
start:        Jul 19 2021 16:33:19.32 (1626683599.32)
end:         Jul 19 2021 16:35:28.10 (1626683728.10)
size:         6.4 GB
messages:    7868
compression: none [3833/3833 chunks]
types:        sensor_msgs/Image [060021388200f6f0f447d0fc9c64743]
               sensor_msgs/Imu  [6a62c6daae103f4ff57a132d6f95cec2]
topics:       /color      1917 msgs   : sensor_msgs/Image
               /imu        2119 msgs   : sensor_msgs/Imu
               /infra_left  1916 msgs   : sensor_msgs/Image
               /infra_right 1916 msgs   : sensor_msgs/Image
fcl@fcl-ThinkPad-T480:~/software/d455calib/imu_stereo_data$
```

10. 开始标定

相应参数需要相应更改，target.yaml对应april_6x6_A4.yaml文件

```
source software/kalibr_ws/devel/setup.bash

kalibr_calibrate_imu_camera --bag
/home/fcl/software/d455calib/imu_stereo_data/imu_stereo.bag --cam
/home/fcl/software/d455calib/imu_stereo_data/chain.yaml --imu
/home/fcl/software/d455calib/imu_stereo_data/imu.yaml --target
/home/fcl/software/d455calib/multicalib_yaml_data/april_6x6_A4.yaml --bag-from-to
3 125 --show-extraction
```

最终得到的结果为是得打yaml, txt, 和pdf文件

标定结果的好坏可以看results-imucam-homezjimu_stereo.txt中的重投影误差Reprojection error，两个相机都在0.15以下说明标定的结果比较好