OpenVSLAM

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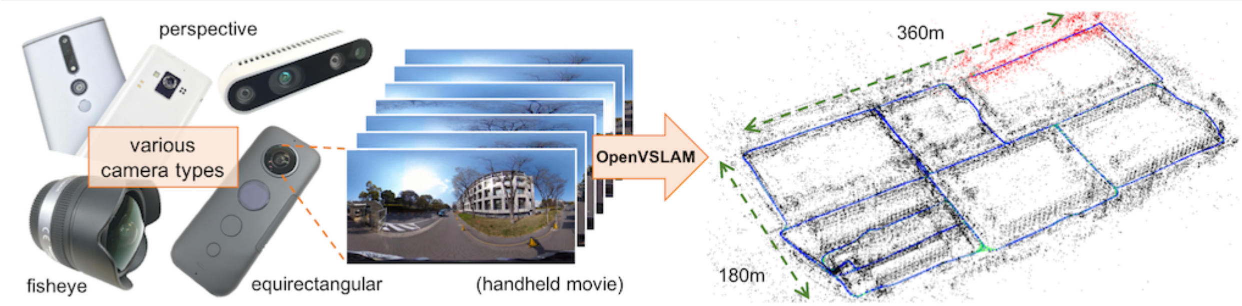
CONTENTS

This is the OpenVSLAM documentation.

CHAPTER

ONE

OVERVIEW



OpenVSLAM is a monocular, stereo, and RGBD visual SLAM system. The notable features are:

- It is compatible with **various type of camera models** and can be easily customized for other camera models.
- Created maps can be **stored and loaded**, then OpenVSLAM can **localize new images** based on the prebuilt maps.
- The system is fully modular. It is designed by encapsulating several functions in separated components with easy-to-understand APIs.
- We provided **some code snippets** to understand the core functionalities of this system.

OpenVSLAM is based on an indirect SLAM algorithm with sparse features, such as ORB-SLAM, ProSLAM, and UcoSLAM. One of the noteworthy features of OpenVSLAM is that the system can deal with various type of camera models, such as perspective, fisheye, and equirectangular. If needed, users can implement extra camera models (e.g. dual fisheye, catadioptric) with ease. For example, visual SLAM algorithm using **equirectangular camera models** (e.g. RICOH THETA series, insta360 series, etc) is shown above.

Some code snippets to understand the core functionalities of the system are provided. You can employ these snippets for in your own programs. Please see the `*.cc` files in `./example` directory or check *Simple Tutorial* and *Example*.

Also, some examples to run OpenVSLAM on ROS framework are provided. Please check *ROS Package*.

Please contact us via GitHub issues if you have any questions or notice any bugs about the software.

1.1 Installation

Please see *Installation* chapter.

The instructions for Docker users are also provided.

1.2 Tutorial

Please see *Simple Tutorial*.

A sample ORB vocabulary file can be downloaded from here.
Sample datasets are also provided at here.

If you would like to run visual SLAM with standard benchmarking datasets (e.g. KITTI Odometry dataset), please see *SLAM with standard datasets*.

1.3 Reference

- Raul Mur-Artal, J. M. M. Montiel, and Juan D. Tardos. 2015. ORB-SLAM: a Versatile and Accurate Monocular SLAM System. IEEE Transactions on Robotics 31, 5 (2015), 1147–1163.
- Raul Mur-Artal and Juan D. Tardos. 2017. ORB-SLAM2: an Open-Source SLAM System for Monocular, Stereo and RGB-D Cameras. IEEE Transactions on Robotics 33, 5 (2017), 1255–1262.
- Dominik Schlegel, Mirco Colosi, and Giorgio Grisetti. 2018. ProSLAM: Graph SLAM from a Programmer's Perspective. In Proceedings of IEEE International Conference on Robotics and Automation (ICRA). 1–9.
- Rafael Munoz-Salinas and Rafael Medina Carnicer. 2019. UcoSLAM: Simultaneous Localization and Mapping by Fusion of KeyPoints and Squared Planar Markers. arXiv:1902.03729.
- Mapillary AB. 2019. OpenSfM. https://github.com/mapillary/OpenSfM.
- Giorgio Grisetti, Rainer Kümmerle, Cyrill Stachniss, and Wolfram Burgard. 2010. A Tutorial on Graph-Based SLAM. IEEE Transactions on Intelligent Transportation SystemsMagazine 2, 4 (2010), 31–43.
- Rainer Kummerle, Giorgio Grisetti, Hauke Strasdat, Kurt Konolige, and Wolfram Burgard. 2011. g2o: A general framework for graph optimization. In Proceedings of IEEE International Conference on Robotics and Automation (ICRA). 3607–3613.

CHAPTER

TWO

INSTALLATION

2.1 Source code

The source code can be viewed from this GitHub repository.

Cloning the repository:

```
git clone https://github.com/OpenVSLAM-Community/openvslam.git
cd openvslam
git submodule update -i --recursive
```

If you are Windows 10 user, please install the dependencies and OpenVSLAM with *SocketViewer support* on Windows Subsystem for Linux (WSL). We have checked the correct operation of OpenVSLAM and SocketViewer on Ubuntu 16.04 running on WSL.

Docker systems can be used instead of preparing the dependencies manually.

2.2 Dependencies

OpenVSLAM requires a **C++11-compliant** compiler. It relies on several open-source libraries as shown below.

2.2.1 Requirements for OpenVSLAM

- Eigen : version 3.3.0 or later.
- g2o : Please use the latest release. Tested on commit ID 9b41a4e.
- SuiteSparse : Required by g2o.
- FBoW : **Please use the custom version of FBoW** released in https://github.com/OpenVSLAM-Community/FBoW.
- yaml-cpp : version 0.6.0 or later.
- OpenCV : version 3.3.1 or later.

Note: OpenCV with GUI support is necessary for using the built-in viewer (Pangolin Viewer).

Note: OpenCV with video support is necessary if you plan on using video files (e.g. `.mp4`) as inputs.

2.2.2 Requirements for PangolinViewer

We provided an OpenGL-based simple viewer.
This viewer is implemented with Pangolin. Thus, we call it **PangolinViewer**.
Please install the following dependencies if you plan on using PangolinViewer.

- Pangolin : Please use the latest release. Tested on commit ID ad8b5f8.
- GLEW : Required by Pangolin.

2.2.3 Requirements for SocketViewer

We provided an WebGL-based simple viewer running on web browsers.
The SLAM systems publish the map and the frame to the server implemented with Node.js via WebSocket. Thus, we call it **SocketViewer**.
Please install the following dependencies if you plan on using SocketViewer.

- socket.io-client-cpp : **Please use the custom version of socket.io-client-cpp** released in https://github.com/shinsumicco/socket.io-client-cpp.
- Protobuf : version 3 or later.

The following libraries are the dependencies for the server.

- Node.js : version 6 or later.
- npm : Tested on version 3.5.2.

2.2.4 Recommended

- google-glog : Used for stack-trace logger.

2.3 Prerequisites for Unix

Note: In the following instruction, we assume that `CMAKE_INSTALL_PREFIX` is `/usr/local`. If you want to install the libraries to the different location, set `CMAKE_INSTALL_PREFIX` to your environment and **set the environment variables accordingly**.

Note: If your PC is frozen during the build, please reduce the number of parallel compile jobs when executing `make` (e.g. `make -j2`).

2.3.1 Installing for Linux

Tested for **Ubuntu 18.04**.

Install the dependencies via apt.

```
apt update -y
apt upgrade -y --no-install-recommends
# basic dependencies
apt install -y build-essential pkg-config cmake git wget curl unzip
# g2o dependencies
apt install -y libatlas-base-dev libsuitesparse-dev
# OpenCV dependencies
apt install -y libgtk-3-dev
apt install -y ffmpeg
apt install -y libavcodec-dev libavformat-dev libavutil-dev libswscale-dev libavresample-
↪dev
# eigen dependencies
apt install -y gfortran
# other dependencies
apt install -y libyaml-cpp-dev libgoogle-glog-dev libgflags-dev

# (if you plan on using PangolinViewer)
# Pangolin dependencies
apt install -y libglew-dev

# (if you plan on using SocketViewer)
# Protobuf dependencies
apt install -y autogen autoconf libtool
# Node.js
curl -sL https://deb.nodesource.com/setup_12.x | sudo -E bash -
apt install -y nodejs
```

Download and install Eigen from source.

```
cd /path/to/working/dir
wget -q https://gitlab.com/libeigen/eigen/-/archive/3.3.7/eigen-3.3.7.tar.bz2
tar xf eigen-3.3.7.tar.bz2
rm -rf eigen-3.3.7.tar.bz2
cd eigen-3.3.7
mkdir -p build && cd build
cmake \
    -DCMAKE_BUILD_TYPE=Release \
    -DCMAKE_INSTALL_PREFIX=/usr/local \
    ..
make -j4
make install
```

Download, build and install OpenCV from source.

```
cd /path/to/working/dir
wget -q https://github.com/opencv/opencv/archive/3.4.0.zip
unzip -q 3.4.0.zip
rm -rf 3.4.0.zip
```

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```
cd opencv-3.4.0
mkdir -p build && cd build
cmake \
    -DCMAKE_BUILD_TYPE=Release \
    -DCMAKE_INSTALL_PREFIX=/usr/local \
    -DENABLE_CXX11=ON \
    -DBUILD_DOCS=OFF \
    -DBUILD_EXAMPLES=OFF \
    -DBUILD_JASPER=OFF \
    -DBUILD_OPENEXR=OFF \
    -DBUILD_PERF_TESTS=OFF \
    -DBUILD_TESTS=OFF \
    -DWITH_EIGEN=ON \
    -DWITH_FFMPEG=ON \
    -DWITH_OPENMP=ON \
    ..
make -j4
make install
```

Jump to *Common Installation Instructions* for the next step.

2.3.2 Installing for macOS

Tested for **macOS High Sierra**.

Install the dependencies via `brew`.

```
brew update
# basic dependencies
brew install pkg-config cmake git
# g2o dependencies
brew install suite-sparse
# OpenCV dependencies and OpenCV
brew install eigen
brew install ffmpeg
brew install opencv
# other dependencies
brew install yaml-cpp glog gflags

# (if you plan on using PangolinViewer)
# Pangolin dependencies
brew install glew

# (if you plan on using SocketViewer)
# Protobuf dependencies
brew install automake autoconf libtool
# Node.js
brew install node
```

Jump to *Common Installation Instructions* for the next step.

2.3.3 Common Installation Instructions

Download, build and install **the custom FBoW** from source.

```
cd /path/to/working/dir
git clone https://github.com/OpenVSLAM-Community/FBoW.git
cd FBoW
mkdir build && cd build
cmake \
    -DCMAKE_BUILD_TYPE=Release \
    -DCMAKE_INSTALL_PREFIX=/usr/local \
    ..
make -j4
make install
```

Download, build and install g2o.

```
cd /path/to/working/dir
git clone https://github.com/RainerKuemmerle/g2o.git
cd g2o
git checkout 9b41a4ea5ade8e1250b9c1b279f3a9c098811b5a
mkdir build && cd build
cmake \
    -DCMAKE_BUILD_TYPE=Release \
    -DCMAKE_INSTALL_PREFIX=/usr/local \
    -DCMAKE_CXX_FLAGS=-std=c++11 \
    -DBUILD_SHARED_LIBS=ON \
    -DBUILD_UNITTESTS=OFF \
    -DG2O_USE_CHOLMOD=OFF \
    -DG2O_USE_CSPARSE=ON \
    -DG2O_USE_OPENGL=OFF \
    -DG2O_USE_OPENMP=ON \
    ..
make -j4
make install
```

(**if you plan on using PangolinViewer**)
Download, build and install Pangolin from source.

```
cd /path/to/working/dir
git clone https://github.com/stevenlovegrove/Pangolin.git
cd Pangolin
git checkout ad8b5f83222291c51b4800d5a5873b0e90a0cf81
mkdir build && cd build
cmake \
    -DCMAKE_BUILD_TYPE=Release \
    -DCMAKE_INSTALL_PREFIX=/usr/local \
    ..
make -j4
make install
```

(**if you plan on using SocketViewer**)
Download, build and install socket.io-client-cpp from source.

```
cd /path/to/working/dir
git clone https://github.com/shinsumicco/socket.io-client-cpp.git
cd socket.io-client-cpp
git submodule init
git submodule update
mkdir build && cd build
cmake \
    -DCMAKE_BUILD_TYPE=Release \
    -DCMAKE_INSTALL_PREFIX=/usr/local \
    -DBUILD_UNIT_TESTS=OFF \
    ..
make -j4
make install
```

(**if you plan on using SocketViewer**)
Install Protobuf.

If you use Ubuntu 18.04 or macOS, Protobuf 3.x can be installed via `apt` or `brew`.

```
# for Ubuntu 18.04 (or later)
apt install -y libprotobuf-dev protobuf-compiler
# for macOS
brew install protobuf
```

Otherwise, please download, build and install Protobuf from source.

```
wget -q https://github.com/google/protobuf/archive/v3.6.1.tar.gz
tar xf v3.6.1.tar.gz
cd protobuf-3.6.1
./autogen.sh
./configure \
    --prefix=/usr/local \
    --enable-static=no
make -j4
make install
```

2.4 Build Instructions

When building with support for PangolinViewer, please specify the following cmake options: `-DUSE_PANGOLIN_VIEWER=ON` and `-DUSE_SOCKET_PUBLISHER=OFF`.

```
cd /path/to/openvslam
mkdir build && cd build
cmake \
```

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```
    -DUSE_PANGOLIN_VIEWER=ON \
    -DINSTALL_PANGOLIN_VIEWER=ON \
    -DUSE_SOCKET_PUBLISHER=OFF \
    -DUSE_STACK_TRACE_LOGGER=ON \
    -DBUILD_TESTS=ON \
    -DBUILD_EXAMPLES=ON \
    ..
make -j4
```

When building with support for SocketViewer, please specify the following cmake options: `-DUSE_PANGOLIN_VIEWER=OFF` and `-DUSE_SOCKET_PUBLISHER=ON`.

```
cd /path/to/openvslam
mkdir build && cd build
cmake \
    -DUSE_PANGOLIN_VIEWER=OFF \
    -DUSE_SOCKET_PUBLISHER=ON \
    -DUSE_STACK_TRACE_LOGGER=ON \
    -DBUILD_TESTS=ON \
    -DBUILD_EXAMPLES=ON \
    ..
make -j4
```

After building, check to see if it was successfully built by executing `./run_kitti_slam -h`.

```
$ ./run_kitti_slam -h
Allowed options:
-h, --help              produce help message
-v, --vocab arg         vocabulary file path
-d, --data-dir arg      directory path which contains dataset
-c, --config arg        config file path
--frame-skip arg (=1)   interval of frame skip
--no-sleep              not wait for next frame in real time
--auto-term             automatically terminate the viewer
--debug                 debug mode
--eval-log              store trajectory and tracking times for evaluation
-p, --map-db arg        store a map database at this path after SLAM
```

2.5 Server Setup for SocketViewer

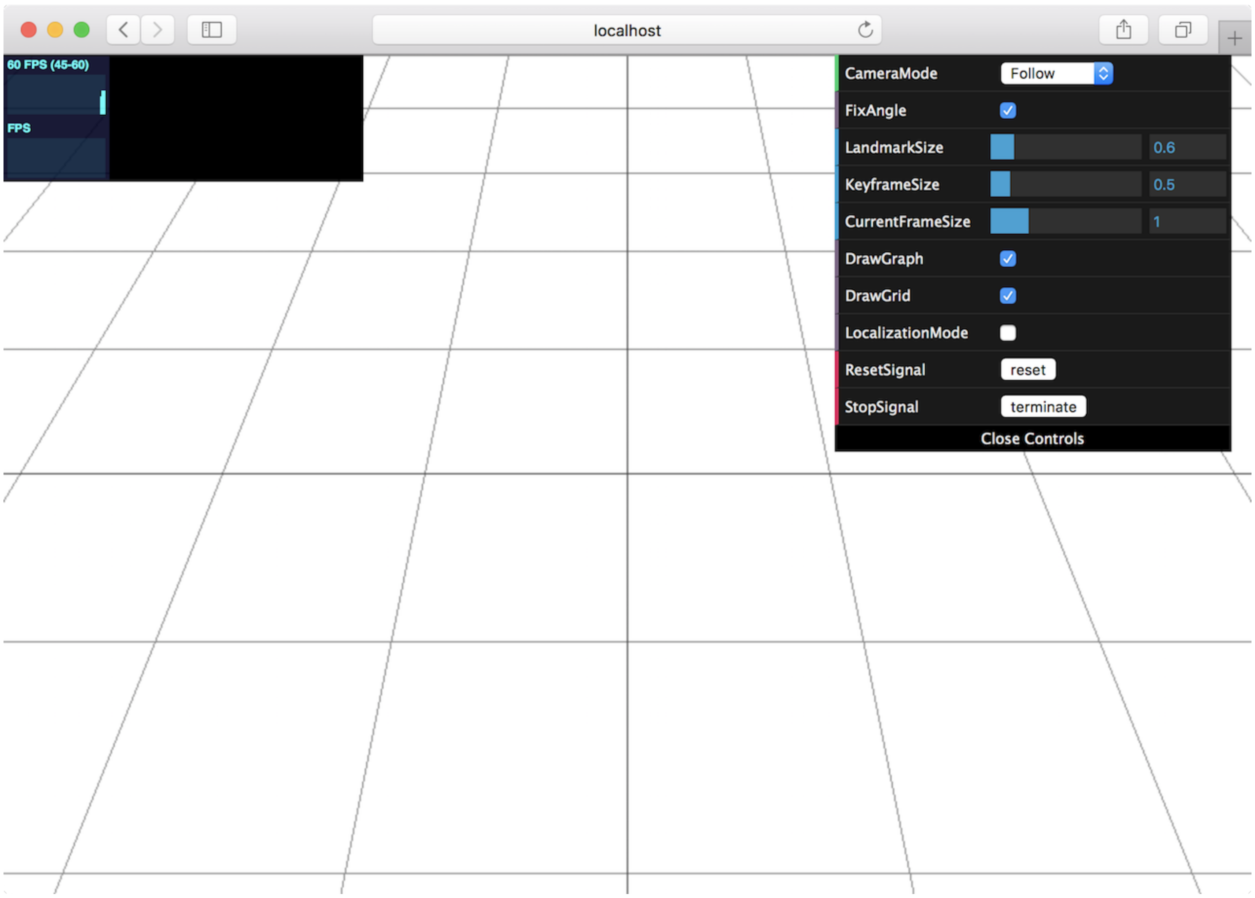
If you plan on using SocketViewer, please setup the environment for the server with `npm`.

```
$ cd /path/to/openvslam/viewer
$ ls
Dockerfile  app.js  package.json  public  views
$ npm install
added 88 packages from 60 contributors and audited 204 packages in 2.105s
found 0 vulnerabilities
$ ls
Dockerfile  app.js  node_modules  package-lock.json  package.json  public  views
```

Then, launch the server with `node app.js`.

```
$ cd /path/to/openvslam/viewer
$ ls
Dockerfile  app.js  node_modules  package-lock.json  package.json  public  views
$ node app.js
WebSocket: listening on *:3000
HTTP server: listening on *:3001
```

After launching, please access to `http://localhost:3001/` to check whether the server is correctly launched.



Note: When you try *the tutotial* and *the examples* with SocketViewer, please launch the server in the other terminal and access to it with the web browser **in advance**.

CHAPTER

THREE

SIMPLE TUTORIAL

3.1 TL; DR

Note: If you use *SocketViewer*, please launch the server in the other terminal and access to it with the web browser **in advance**.

Running the following commands will give a feel for what OpenVSLAM can do. The later parts of this chapter explains what each of the commands do in more detail.

```
# at the build directory of openvslam ...
$ pwd
/path/to/openvslam/build/
$ ls
run_video_slam   run_video_localization   lib/   ...

# download an ORB vocabulary from GitHub
curl -sL "https://github.com/OpenVSLAM-Community/FBoW_orb_vocab/raw/main/orb_vocab.fbow" ␣
↪-o orb_vocab.fbow

# download a sample dataset from Google Drive
FILE_ID="1d8kADKWBptEqTF7jEVhKatBEdN7g0ikY"
curl -sc /tmp/cookie "https://drive.google.com/uc?export=download&id=${FILE_ID}" > /dev/
↪null
CODE="$(awk '/_warning_/ {print $NF}' /tmp/cookie)"
curl -sLb /tmp/cookie "https://drive.google.com/uc?export=download&confirm=${CODE}&id=$
↪{FILE_ID}" -o aist_living_lab_1.zip
unzip aist_living_lab_1.zip

# download a sample dataset from Google Drive
FILE_ID="1TVf2D2QvMZPHsFoTb7HNxbXclPoFMGLX"
curl -sc /tmp/cookie "https://drive.google.com/uc?export=download&id=${FILE_ID}" > /dev/
↪null
CODE="$(awk '/_warning_/ {print $NF}' /tmp/cookie)"
curl -sLb /tmp/cookie "https://drive.google.com/uc?export=download&confirm=${CODE}&id=$
↪{FILE_ID}" -o aist_living_lab_2.zip
unzip aist_living_lab_2.zip

# run tracking and mapping
./run_video_slam -v ./orb_vocab.fbow -m ./aist_living_lab_1/video.mp4 -c ../example/aist/
↪equirectangular.yaml --frame-skip 3 --no-sleep --map-db map.msg
```

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```
# click the [Terminate] button to close the viewer
# you can find map.msg in the current directory

# run localization
./run_video_localization -v ./orb_vocab.fbow -m ./aist_living_lab_2/video.mp4 -c ../
↪example/aist/equirectangular.yaml --frame-skip 3 --no-sleep --map-db map.msg
```

3.2 Sample Datasets

You can use OpenVSLAM with various video datasets. If you want to run OpenVSLAM with standard benchmarking detasets, please see *this section*.

Start by downloading some datasets you like.

3.2.1 Equirectangular Datasets

name	camera model	length	Google Drive	Baidu Wangpan
aist_entrance_hall_1	equirectangular (mono)	0:54	link	link (Pass: r7r4)
aist_entrance_hall_2	equirectangular (mono)	0:54	link	link (Pass: 4qma)
aist_factory_A_1	equirectangular (mono)	1:55	link	link (Pass: yy2u)
aist_factory_A_2	equirectangular (mono)	1:54	link	link (Pass: 9vey)
aist_factory_B_1	equirectangular (mono)	1:04	link	link (Pass: gpec)
aist_factory_B_2	equirectangular (mono)	1:34	link	link (Pass: ugrx)
aist_living_lab_1	equirectangular (mono)	2:16	link	link (Pass: 434m)
aist_living_lab_2	equirectangular (mono)	1:47	link	link (Pass: 549f)
aist_living_lab_3	equirectangular (mono)	2:06	link	link (Pass: cc2p)
aist_stairs_A_1	equirectangular (mono)	2:27	link	link (Pass: ncdr)
aist_stairs_B_1	equirectangular (mono)	2:55	link	link (Pass: xr5t)
aist_store_1	equirectangular (mono)	1:12	link	link (Pass: 47vq)
aist_store_2	equirectangular (mono)	1:44	link	link (Pass: xt8u)
aist_store_3	equirectangular (mono)	1:18	link	link (Pass: kghc)
ALL	equirectangular (mono)		link	link (Pass: vsv7)

3.2.2 Fisheye Datasets

name	camera model	length	Google Drive	Baidu Wangpan
aist_entrance_hall_1	fisheye (mono)	1:05	link	link (Pass: u86e)
aist_entrance_hall_2	fisheye (mono)	1:06	link	link (Pass: 9iyc)
aist_entrance_hall_3	fisheye (mono)	1:23	link	link (Pass: qaqc)
aist_entrance_hall_4	fisheye (mono)	1:27	link	link (Pass: em43)
aist_living_lab_1	fisheye (mono)	1:20	link	link (Pass: wcw4)
aist_living_lab_2	fisheye (mono)	2:26	link	link (Pass: dxns)
aist_living_lab_3	fisheye (mono)	3:43	link	link (Pass: 7n4q)
nu_eng2_corridor_1	fisheye (mono)	2:56	link	link (Pass: 71ws)
nu_eng2_corridor_2	fisheye (mono)	2:45	link	link (Pass: yrtj)
nu_eng2_corridor_3	fisheye (mono)	2:04	link	link (Pass: btpj)
ALL	fisheye (mono)		link	link (Pass: gumj)

After downloading and uncompressing a zip file, you will find a video file and a config file (old format) under the uncompressed directory.

```
$ ls dataset_name_X/
config.yaml  video.mp4
```

You can put the dataset in any directory where you have access to.

Additionally, please download a vocabulary file for FBoW from here.

For the rest of this chapter, we will use `aist_living_lab_1` and `aist_living_lab_2` datasets for our example.

3.3 Tracking and Mapping

Here we should know how to run SLAM and create a map database file with `aist_living_lab_1` dataset. You can use `./run_video_slam` to run SLAM with the video file.

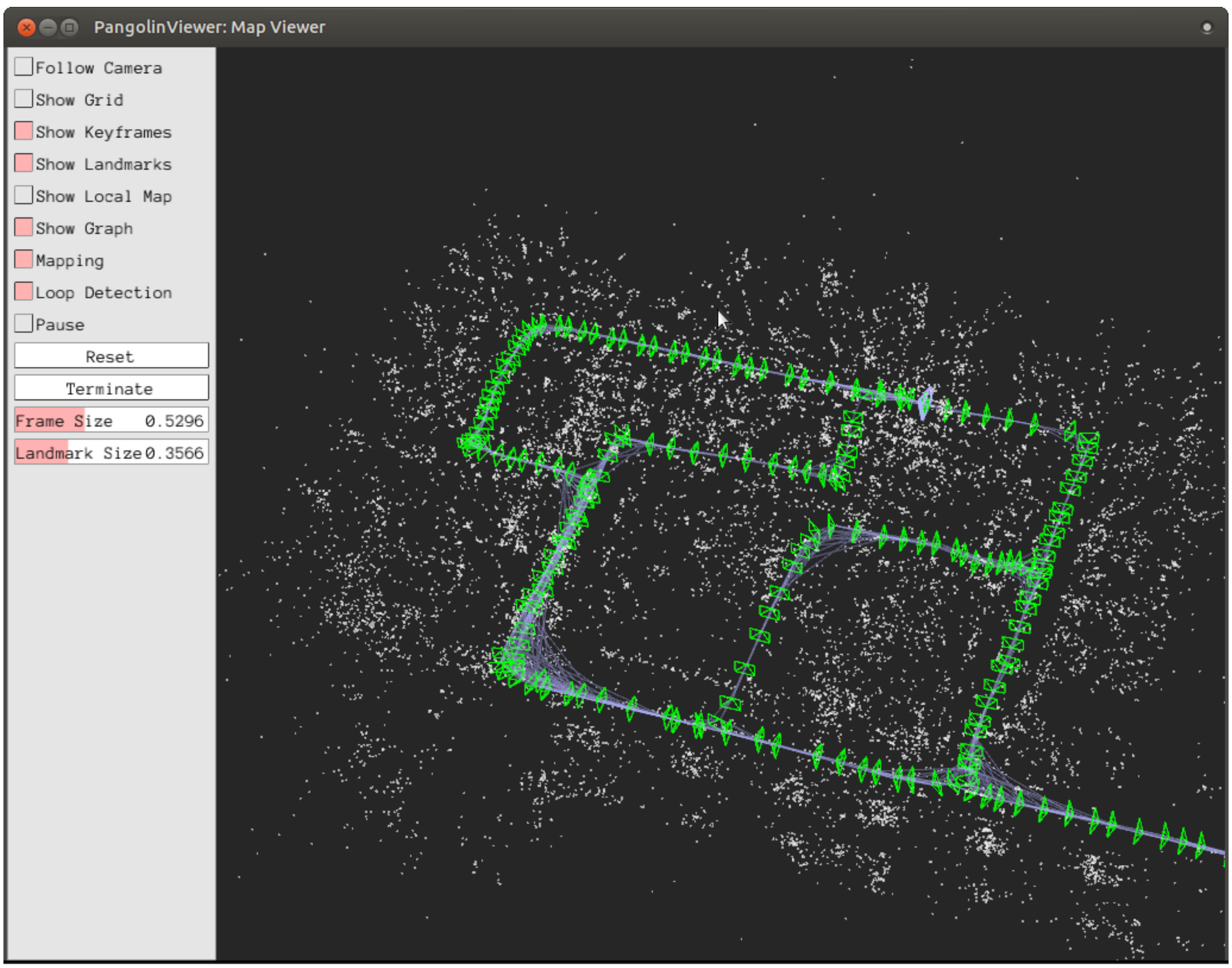
```
# at the build directory of OpenVSLAM
$ ls
...
run_video_slam
...
$ ./run_video_slam -h
Allowed options:
  -h, --help              produce help message
  -v, --vocab arg         vocabulary file path
  -m, --video arg         video file path
  -c, --config arg        config file path
  --mask arg              mask image path
  --frame-skip arg (=1)   interval of frame skip
  --no-sleep              not wait for next frame in real time
  --auto-term             automatically terminate the viewer
  --debug                 debug mode
  --eval-log              store trajectory and tracking times for evaluation
  -p, --map-db arg        store a map database at this path after SLAM
```

Execute the following command to run SLAM. The paths should be changed accordingly.

```
$ ./run_video_slam \
    -v /path/to/orb_vocab/orb_vocab.fbow \
    -c /path/to/openvslam/example/aist/equirectangular.yaml \
    -m /path/to/aist_living_lab_1/video.mp4 \
    --frame-skip 3 \
    --map-db aist_living_lab_1_map.msg
```

The frame viewer and map viewer should launch as well. If the two viewers are not launching correctly, check if you launched the command with the appropriate paths.


PangolinViewer: Frame Viewer
MAPPING | KF: 45, LM: 4491, KP: 149, track time: 81ms


PangolinViewer: Map Viewer
Follow Camera
Show Grid
Show Keyframes
Show Landmarks
Show Local Map
Show Graph
Mapping
Loop Detection
Pause
Reset
Terminate
Frame Size 0.5296
Landmark Size 0.3566

```
[2019-05-20 17:52:41.677] [I] config file loaded: /path/to/openvslam/example/aist/
↪equirectangular.yaml
  ___                 __   _____ _      _   __  __
 / _ \ _ __  ___ _ _\ \ / / __| |    /_\ |  \/  |
| (_) | '_ \/ -_) ' \\ V /\__ \ |__ / _ \| |\/| |
 \___/| .__/\___|_||_|\_/ |___/____/_/ \_\_|  |_|
      |_|

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and you are welcome to redistribute it under certain conditions.
See the LICENSE file.

Camera Configuration:
- name: RICOH THETA S 960
- setup: Monocular
- fps: 30
- cols: 1920
- rows: 960
- color: RGB
- model: Equirectangular
ORB Configuration:
- number of keypoints: 2000
- scale factor: 1.2
- number of levels: 8
- initial fast threshold: 20
- minimum fast threshold: 7
- edge threshold: 19
- patch size: 31
- half patch size: 15
- mask rectangles:
  - [0, 1, 0, 0.1]
  - [0, 1, 0.84, 1]
  - [0, 0.2, 0.7, 1]
  - [0.8, 1, 0.7, 1]
Tracking Configuration:

[2019-05-20 17:52:41.678] [I] loading ORB vocabulary: /path/to/orb_vocab/orb_vocab.fbow
[2019-05-20 17:52:42.037] [I] startup SLAM system
[2019-05-20 17:52:42.038] [I] start local mapper
[2019-05-20 17:52:42.038] [I] start loop closer
[2019-05-20 17:52:42.395] [I] initialization succeeded with E
[2019-05-20 17:52:42.424] [I] new map created with 191 points: frame 0 - frame 2
[2019-05-20 17:53:39.092] [I] detect loop: keyframe 36 - keyframe 139
[2019-05-20 17:53:39.094] [I] pause local mapper
[2019-05-20 17:53:39.303] [I] resume local mapper
[2019-05-20 17:53:39.303] [I] start loop bundle adjustment
[2019-05-20 17:53:40.186] [I] finish loop bundle adjustment
[2019-05-20 17:53:40.186] [I] updating map with pose propagation
[2019-05-20 17:53:40.194] [I] pause local mapper
```

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```
[2019-05-20 17:53:40.199] [I] resume local mapper
[2019-05-20 17:53:40.199] [I] updated map
[2019-05-20 17:55:36.218] [I] shutdown SLAM system
[2019-05-20 17:55:36.218] [I] encoding 1 camera(s) to store
[2019-05-20 17:55:36.218] [I] encoding 301 keyframes to store
[2019-05-20 17:55:37.906] [I] encoding 19900 landmarks to store
[2019-05-20 17:55:38.819] [I] save the MessagePack file of database to aist_living_lab_1_
↪map.msg
median tracking time: 0.045391[s]
mean tracking time: 0.0472221[s]
[2019-05-20 17:55:40.087] [I] clear BoW database
[2019-05-20 17:55:40.284] [I] clear map database
```

Please click the **Terminate** button to close the viewer.

After terminating, you will find a map database file `aist_living_lab_1_map.msg`.

```
$ ls
...
aist_living_lab_1_map.msg
...
```

The format of map database files is MessagePack, so you can reuse created maps for any third-party applications other than OpenVSLAM.

3.4 Localization

In this section, we will localize the frames in `aist_living_lab_2` dataset using the created map file `aist_living_lab_1_map.msg`. You can use `./run_video_localization` to run localization.

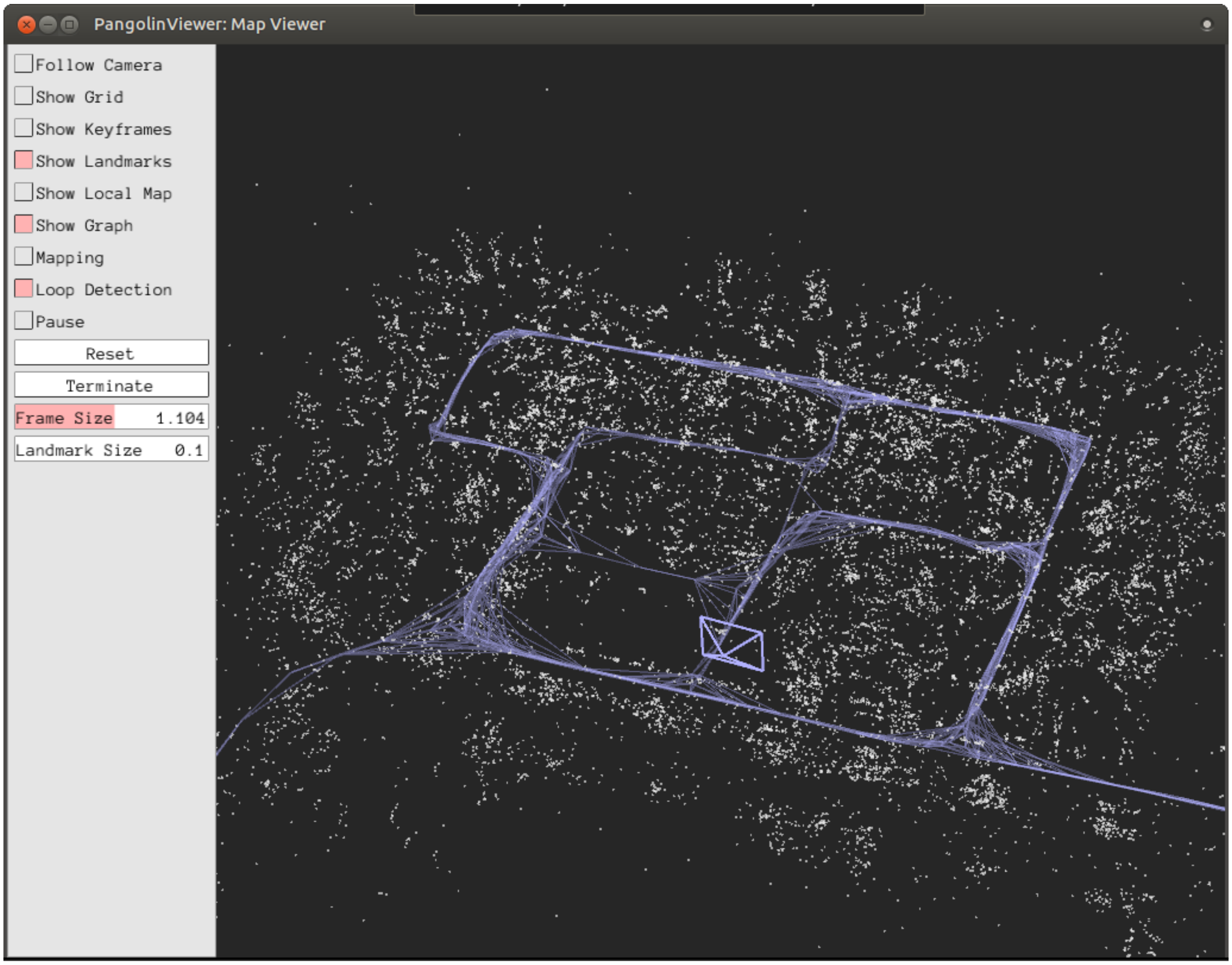
```
$ ./run_video_localization -h
Allowed options:
  -h, --help             produce help message
  -v, --vocab arg        vocabulary file path
  -m, --video arg        video file path
  -c, --config arg       config file path
  -p, --map-db arg       path to a prebuilt map database
  --mapping              perform mapping as well as localization
  --mask arg             mask image path
  --frame-skip arg (=1)  interval of frame skip
  --no-sleep             not wait for next frame in real time
  --auto-term            automatically terminate the viewer
  --debug                debug mode
```

Execute the following command to start localization. The paths should be changed accordingly.

```
$ ./run_video_localization \
    -v /path/to/orb_vocab/orb_vocab.fbow \
    -c /path/to/openvslam/example/aist/equirectangular.yaml \
    -m /path/to/aist_living_lab_2/video.mp4 \
    --frame-skip 3 \
    --map-db aist_living_lab_1_map.msg
```

The frame viewer and map viewer should launch as well. If the two viewers are not launching correctly, check if you launched the command with the appropriate paths.

You can see if the current frame is being localized, based on the prebuild map.




```
[2019-05-20 17:58:54.728] [I] config file loaded: /path/to/openvslam/example/aist/
↪equirectangular.yaml
  ___                __   _____ _      _   __  __
 / _ \ _ __  ___ _ _\ \ / / __| |    /_\ |  \/  |
| (_) | '_ \/ -_) ' \\ V /\__ \ |__ / _ \| |\/| |
 \___/| .__/\___|_||_|\_/ |___/____/_/ \_\_|  |_|
      |_|

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and you are welcome to redistribute it under certain conditions.
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Camera Configuration:
```

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```
- name: RICOH THETA S 960
- setup: Monocular
- fps: 30
- cols: 1920
- rows: 960
- color: RGB
- model: Equirectangular
ORB Configuration:
- number of keypoints: 2000
- scale factor: 1.2
- number of levels: 8
- initial fast threshold: 20
- minimum fast threshold: 7
- edge threshold: 19
- patch size: 31
- half patch size: 15
- mask rectangles:
  - [0, 1, 0, 0.1]
  - [0, 1, 0.84, 1]
  - [0, 0.2, 0.7, 1]
  - [0.8, 1, 0.7, 1]
Tracking Configuration:

[2019-05-20 17:58:54.729] [I] loading ORB vocabulary: /path/to/orb_vocab/orb_vocab.fbow
[2019-05-20 17:58:55.083] [I] clear map database
[2019-05-20 17:58:55.083] [I] clear BoW database
[2019-05-20 17:58:55.083] [I] load the MessagePack file of database from aist_living_lab_
↪1_map.msg
[2019-05-20 17:58:57.832] [I] decoding 1 camera(s) to load
[2019-05-20 17:58:57.832] [I] load the tracking camera "RICOH THETA S 960" from JSON
[2019-05-20 17:58:58.204] [I] decoding 301 keyframes to load
[2019-05-20 17:59:02.013] [I] decoding 19900 landmarks to load
[2019-05-20 17:59:02.036] [I] registering essential graph
[2019-05-20 17:59:02.564] [I] registering keyframe-landmark association
[2019-05-20 17:59:03.161] [I] updating covisibility graph
[2019-05-20 17:59:03.341] [I] updating landmark geometry
[2019-05-20 17:59:04.189] [I] startup SLAM system
[2019-05-20 17:59:04.190] [I] start local mapper
[2019-05-20 17:59:04.191] [I] start loop closer
[2019-05-20 17:59:04.195] [I] pause local mapper
[2019-05-20 17:59:04.424] [I] relocalization succeeded
[2019-05-20 18:01:12.387] [I] shutdown SLAM system
median tracking time: 0.0370831[s]
mean tracking time: 0.0384683[s]
[2019-05-20 18:01:12.390] [I] clear BoW database
[2019-05-20 18:01:12.574] [I] clear map database
```

If you set the `--mapping` option, the mapping module is enabled to extend the prebuild map.

CHAPTER FOUR

EXAMPLE

We provided example code snippets for running OpenVSLAM with variety of datasets.

4.1 SLAM with Video Files

4.1.1 Tracking and Mapping

We provide an example snippet for using video files (e.g. .mp4) for visual SLAM. The source code is placed at ./example/run_video_slam.cc. The following options are allowed:

```
$ ./run_video_slam -h
Allowed options:
-h, --help              produce help message
-v, --vocab arg         vocabulary file path
-m, --video arg         video file path
-c, --config arg        config file path
--mask arg              mask image path
--frame-skip arg (=1)   interval of frame skip
--no-sleep              not wait for next frame in real time
--auto-term             automatically terminate the viewer
--debug                 debug mode
--eval-log              store trajectory and tracking times for evaluation
-p, --map-db arg        store a map database at this path after SLAM
```

The camera that captures the video file must be calibrated. Create a config file (.yaml) according to the camera parameters.

We provided a vocabulary file for FBoW at here.

4.1.2 Localization

We provide an example snippet for using video files (e.g. `.mp4`) for localization based on a prebuilt map. The source code is placed at `./example/run_video_localization.cc`. The following options are allowed:

```
$ ./run_video_localization -h
Allowed options:
-h, --help              produce help message
-v, --vocab arg         vocabulary file path
-m, --video arg         video file path
-c, --config arg        config file path
-p, --map-db arg        path to a prebuilt map database
--mapping               perform mapping as well as localization
--mask arg              mask image path
--frame-skip arg (=1)   interval of frame skip
--no-sleep              not wait for next frame in real time
--auto-term             automatically terminate the viewer
--debug                 debug mode
```

The camera that captures the video file must be calibrated. Create a config file (`.yaml`) according to the camera parameters.
We provided a vocabulary file for FBoW at here.

You can create a map database file by running one of the `run_****_slam` executables with `--map-db map_file_name.msg` option.

4.2 SLAM with Image Sequences

4.2.1 Tracking and Mapping

We provided an example snippet for using image sequences for visual SLAM. The source code is placed at `./example/run_image_slam.cc`. The following options are allowed:

```
$ ./run_image_slam -h
Allowed options:
-h, --help              produce help message
-v, --vocab arg         vocabulary file path
-i, --img-dir arg       directory path which contains images
-c, --config arg        config file path
--mask arg              mask image path
--frame-skip arg (=1)   interval of frame skip
--no-sleep              not wait for next frame in real time
--auto-term             automatically terminate the viewer
--debug                 debug mode
--eval-log              store trajectory and tracking times for evaluation
-p, --map-db arg        store a map database at this path after SLAM
```

The camera that captures the video file must be calibrated. Create a config file (`.yaml`) according to the camera parameters.

We provided a vocabulary file for FBoW at here.

4.2.2 Localization

We provided an example snippet for using image sequences for localization based on a prebuilt map. The source code is placed at `./example/run_image_localization.cc`. The following options are allowed:

```
$ ./run_image_localization -h
Allowed options:
-h, --help               produce help message
-v, --vocab arg          vocabulary file path
-i, --img-dir arg        directory path which contains images
-c, --config arg         config file path
-p, --map-db arg         path to a prebuilt map database
--mapping                perform mapping as well as localization
--mask arg               mask image path
--frame-skip arg (=1)    interval of frame skip
--no-sleep               not wait for next frame in real time
--auto-term              automatically terminate the viewer
--debug                  debug mode
```

The camera that captures the video file must be calibrated. Create a config file (`.yaml`) according to the camera parameters.

We provided a vocabulary file for FBoW at here.

You can create a map database file by running one of the `run_****_slam` executables with `--map-db map_file_name.msg` option.

4.3 SLAM with Standard Datasets

4.3.1 KITTI Odometry dataset

KITTI Odometry dataset is a benchmarking dataset for monocular and stereo visual odometry and lidar odometry that is captured from car-mounted devices. We provided an example source code for running monocular and stereo visual SLAM with this dataset. The source code is placed at `./example/run_kitti_slam.cc`.

Start by downloading the dataset from here. Download the grayscale set (`data_odometry_gray.zip`).

After downloading and uncompressing it, you will find several sequences under the `sequences/` directory.

```
$ ls sequences/
00  01  02  03  04  05  06  07  08  09  10  11  12  13  14  15  16  17  18  19  20  21
```

In addition, download a vocabulary file for FBoW from here.

A configuration file for each sequence is contained under `./example/kitti/`.

If you built examples with Pangolin Viewer support, a map viewer and frame viewer will be launced right after executing the following command.

```
# at the build directory of OpenVSLAM
$ ls
...
run_kitti_slam
...
# monocular SLAM with sequence 00
$ ./run_kitti_slam \
    -v /path/to/orb_vocab/orb_vocab.fbow \
    -d /path/to/KITTI/Odometry/sequences/00/ \
    -c ../example/kitti/KITTI_mono_00-02.yaml
# stereo SLAM with sequence 05
$ ./run_kitti_slam \
    -v /path/to/orb_vocab/orb_vocab.fbow \
    -d /path/to/KITTI/Odometry/sequences/05/ \
    -c ../example/kitti/KITTI_stereo_04-12.yaml
```

The following options are allowed:

```
$ ./run_kitti_slam -h
Allowed options:
-h, --help              produce help message
-v, --vocab arg         vocabulary file path
-d, --data-dir arg      directory path which contains dataset
-c, --config arg        config file path
--frame-skip arg (=1)   interval of frame skip
--no-sleep              not wait for next frame in real time
--auto-term             automatically terminate the viewer
--debug                 debug mode
--eval-log              store trajectory and tracking times for evaluation
-p, --map-db arg        store a map database at this path after SLAM
```

4.3.2 EuRoC MAV dataset

EuRoC MAV dataset is a benchmarking dataset for monocular and stereo visual odometry that is captured from drone-mounted devices. We provide an example source code for running monocular and stereo visual SLAM with this dataset. The source code is placed at `./example/run_euroc_slam.cc`.

Start by downloading the dataset from here. Download the `.zip` file of a dataset you plan on using.

After downloading and uncompressing it, you will find several directories under the `mav0/` directory.

```
$ ls mav0/
body.yaml  cam0  cam1  imu0  leica0  state_groundtruth_estimate0
```

In addition, download a vocabulary file for FBoW from here.

We provided the two config files for EuRoC, `./example/euroc/EuRoC_mono.yaml` for monocular and `./example/euroc/EuRoC_stereo.yaml` for stereo.

If you have built examples with Pangolin Viewer support, a map viewer and frame viewer will be launched right after executing the following command.

```
# at the build directory of OpenVSLAM
$ ls
```

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```
...
run_euroc_slam
...
# monocular SLAM with any EuRoC sequence
$ ./run_euroc_slam \
    -v /path/to/orb_vocab/orb_vocab.fbow \
    -d /path/to/EuRoC/MAV/mav0/ \
    -c ../example/euroc/EuRoC_mono.yaml
# stereo SLAM with any EuRoC sequence
$ ./run_euroc_slam \
    -v /path/to/orb_vocab/orb_vocab.fbow \
    -d /path/to/EuRoC/MAV/mav0/ \
    -c ../example/euroc/EuRoC_stereo.yaml
```

The following options are allowed:

```
$ ./run_euroc_slam -h
Allowed options:
-h, --help              produce help message
-v, --vocab arg         vocabulary file path
-d, --data-dir arg      directory path which contains dataset
-c, --config arg        config file path
--frame-skip arg (=1)   interval of frame skip
--no-sleep              not wait for next frame in real time
--auto-term             automatically terminate the viewer
--debug                 debug mode
--eval-log              store trajectory and tracking times for evaluation
-p, --map-db arg        store a map database at this path after SLAM
```

4.3.3 TUM RGBD dataset

Will be written soon.

The following options are allowed:

```
$ ./run_tum_slam -h
Allowed options:
-h, --help              produce help message
-v, --vocab arg         vocabulary file path
-d, --data-dir arg      directory path which contains dataset
-a, --assoc arg         association file path
-c, --config arg        config file path
--frame-skip arg (=1)   interval of frame skip
--no-sleep              not wait for next frame in real time
--auto-term             automatically terminate the viewer
--debug                 debug mode
--eval-log              store trajectory and tracking times for evaluation
-p, --map-db arg        store a map database at this path after SLAM
```

4.4 SLAM with UVC camera

4.4.1 Tracking and Mapping

We provided an example snippet for using a UVC camera, which is often called a webcam, for visual SLAM. The source code is placed at `./example/run_camera_slam.cc`. The following options are allowed:

```
$ ./run_camera_slam  -h
Allowed options:
-h, --help              produce help message
-v, --vocab arg         vocabulary file path
-n, --number arg        camera number
-c, --config arg        config file path
--mask arg              mask image path
-s, --scale arg (=1)    scaling ratio of images
-p, --map-db arg        store a map database at this path after SLAM
--debug                 debug mode
```

Please specify the camera number you want to use by `-n` option.
The camera must be calibrated. Create a config file (`.yaml`) according to the camera parameters.
You can scale input images to the performance of your machine by `-s` option. Please modify the config accordingly.
We provided a vocabulary file for FBoW at here.

4.4.2 Localization

We provided an example snippet for using a UVC camera for localization based on a prebuilt map. The source code is placed at `./example/run_camera_localization.cc`. The following options are allowed:

```
$ ./run_camera_localization -h
Allowed options:
-h, --help              produce help message
-v, --vocab arg         vocabulary file path
-n, --number arg        camera number
-c, --config arg        config file path
--mask arg              mask image path
-s, --scale arg (=1)    scaling ratio of images
-p, --map-db arg        path to a prebuilt map database
--mapping               perform mapping as well as localization
--debug                 debug mode
```

Please specify the camera number you want to use by `-n` option.
The camera must be calibrated. Create a config file (`.yaml`) according to the camera parameters.
You can scale input images to the performance of your machine by `-s` option. Please modify the config accordingly.
We provided a vocabulary file for FBoW at here.

CHAPTER

FIVE

PARAMETERS

5.1 Camera

Name	Description
name	It is used by the camera database to identify the camera.
setup	monocular, stereo, RGBD
model	perspective, fisheye, equirectangular, radial_division
fx, fy	Focal length (pixel)
cx, cy	Principal point (pixel)
k1, k2, p1, p2, k3	Distortion parameters for perspective camera. When using StereoRectifier, there is no distortion after stereo rectification.
k1, k2, k3, k4	Distortion parameters for fisheye camera
distortion	Distortion parameters for radial_division camera
fps	Framerate of input images
cols, rows	Resolution (pixel)
color_order	Gray, RGB, RGBA, BGR, BGRA
focal_x_baseline	For stereo cameras, it is the value of the baseline between the left and right cameras multiplied by the focal length fx. For RGBD cameras, if the measurement method is stereo, set it based on its baseline. If the measurement method is other than that, set the appropriate value based on the relationship between depth accuracy and baseline.

5.2 Feature

Name	Description
scale_factor	Scale of the image pyramid
num_levels	Number of levels of in the image pyramid
ini_fast_threshold	FAST threshold for try first
min_fast_threshold	FAST threshold for try second time

Name	Description
max_num_keypoints	Maximum number of feature points per frame to be used for SLAM.
ini_max_num_keypoints	Maximum number of feature points per frame to be used for Initialization. It is only used for monocular camera models.
depth_threshold	The ratio used to determine the depth threshold.
depthmap_factor	The ratio used to convert depth image pixel values to distance.
re-loc_distance_threshold	Maximum distance threshold (in meters) where close keyframes could be found when doing a relocalization by pose.
reloc_angle_threshold	Maximum angle threshold (in radians) between given pose and close keyframes when doing a relocalization by pose.

5.3 Mapping

Name	Description
baseline_dist_thr_ratio	For two frames of baseline below the threshold, no triangulation will be performed. In the monocular case, the scale is indefinite, so relative values are recommended. Either baseline_dist_thr or this one should be specified. If not specified, baseline_dist_thr_ratio will be used.
baseline_dist_thr	For two frames of baseline below the threshold, no triangulation will be performed.

5.4 StereoRectifier

Name	Description
K_left, K_right	Intrinsic parameters. The 3x3 matrix are written in row-major order.
D_left, D_right	Distortion parameters. The 5 parameters are k1, k2, p1, p2, k3.
R_left, R_right	Stereo-recitification parameters. The 3x3 matrix are written in row-major order.

5.5 Initializer

Name	Description
num_min_triangulated_pts	Minimum number of triangulated points

5.6 PangolinViewer

Name	Description
keyframe_size	
keyframe_line_width	
graph_line_width	
point_size	
camera_size	
camera_line_width	
viewpoint_x, viewpoint_y, viewpoint_z, viewpoint_f	

5.7 SocketPublisher

Name	Description
emitting_interval	
image_quality	
server_uri	
publish_points	If true, pointcloud transfer is enabled. The default is true. Pointcloud transfer is slow, so disabling pointcloud transfer may be useful to improve performance of SocketViewer.

CHAPTER

SIX

RUNNING ON DOCKER

6.1 Instructions for PangolinViewer

`Dockerfile.desktop` can be used for easy installation. This chapter provides instructions on building and running examples with PangolinViewer support using Docker.

The instructions are tested on Ubuntu 16.04 and 18.04 and 20.04. Docker for Mac are NOT supported due to OpenGL forwarding.

Note that **docker host machines with NVIDIA graphics cards are NOT officially supported yet.**

Note: If you're using Ubuntu, there are easy setup scripts in scripts/ubuntu. see scripts/ubuntu/README.md

If you plan on using a machine with NVIDIA graphics card(s), please use nvidia-docker2 and the version 390 or later of NVIDIA driver. These examples depend on X11 forwarding with OpenGL for visualization. Note that our `Dockerfile.desktop` is **NOT** compatible with nvidia-docker1.

If the viewer cannot be lanched at all or you are using macOS, please *install the dependencies manually* or use *the docker images for SocketViewer*.

6.1.1 Building Docker Image

Execute the following commands:

```
cd /path/to/openvslam
docker build -t openvslam-desktop -f Dockerfile.desktop .
```

You can accelerate the build of the docker image with `--build-arg NUM_THREADS=<number of parallel builds>` option. For example:

```
# building the docker image with four threads
docker build -t openvslam-desktop -f Dockerfile.desktop . --build-arg NUM_THREADS=`expr
↪$(nproc) - 1`
```

6.1.2 Starting Docker Container

In order to enable X11 forwarding, supplemental options (`-e DISPLAY=$DISPLAY` and `-v /tmp/.X11-unix/:/tmp/.X11-unix:ro`) are needed for `docker run`.

```
# before launching the container, allow display access from local users
xhost +local:
# launch the container
docker run -it --rm -e DISPLAY=$DISPLAY -v /tmp/.X11-unix/:/tmp/.X11-unix:ro openvslam-
↪desktop
```

Note: Additional option `--runtime=nvidia` is needed if you use NVIDIA graphics card(s). If you're using Docker with **Native GPU Support** then the options are `--gpus all`. Please see here for more details.

After launching the container, the shell interface will be launched in the docker container.

```
root@ddad048b5fff:/openvslam/build# ls
lib                    run_image_slam         run_video_slam
run_euroc_slam         run_kitti_slam         run_tum_slam
run_image_localization  run_video_localization
```

See *Tutorial* to run SLAM examples in the container.

Note: If the viewer does not work, please *install the dependencies manually* on your host machine or use *the docker images for SocketViewer* instead.

If you need to access to any files and directories on a host machine from the container, *bind directories* between the host and the container.

6.2 Instructions for SocketViewer

`Dockerfile.socket` and `viewer/Dockerfile` can be used for easy installation. This chapter provides instructions on building and running examples with SocketViewer support using Docker.

6.2.1 Building Docker Images

Docker Image of OpenVSLAM

Execute the following commands:

```
cd /path/to/openvslam
docker build -t openvslam-socket -f Dockerfile.socket .
```

You can accelerate the build of the docker image with `--build-arg NUM_THREADS=<number of parallel builds>` option. For example:

```
# building the docker image with four threads
docker build -t openvslam-socket -f Dockerfile.socket . --build-arg NUM_THREADS=`expr
↪$(nproc) - 1`
```

Docker Image of Server

Execute the following commands:

```
cd /path/to/openvslam
cd viewer
docker build -t openvslam-server .
```

6.2.2 Starting Docker Containers

On Linux

Launch the server container and access to it with the web browser in advance. Please specify `--net=host` in order to share the network with the host machine.

```
$ docker run --rm -it --name openvslam-server --net=host openvslam-server
WebSocket: listening on *:3000
HTTP server: listening on *:3001
```

After launching, access to `http://localhost:3001/` with the web browser.

Next, launch the container of OpenVSLAM. The shell interface will be launched in the docker container.

```
$ docker run --rm -it --name openvslam-socket --net=host openvslam-socket
root@hostname:/openvslam/build#
```

See *Tutorial* to run SLAM examples in the container.

If you need to access to any files and directories on a host machine from the container, *bind directories* between the host and the container.

On macOS

Launch the server container and access to it with the web browser in advance. Please specify `-p 3001:3001` for port-forwarding.

```
$ docker run --rm -it --name openvslam-server -p 3001:3001 openvslam-server
WebSocket: listening on *:3000
HTTP server: listening on *:3001
```

After launching, access to `http://localhost:3001/` with the web browser.

Then, inspect the container's IP address and append the `SocketPublisher.server_uri` entry to the YAML config file of OpenVSLAM.

```
# inspect the server's IP address
$ docker inspect openvslam-server | grep -m 1 \"IPAddress\" | sed 's/ //g' | sed 's/,//g'
"IPAddress": "172.17.0.2"
```

```
# config file of OpenVSLAM

...
```

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```
#============================#
# SocketPublisher Parameters #
#============================#

# append this entry
SocketPublisher.server_uri: "http://172.17.0.2:3000"
```

Next, launch the container of OpenVSLAM. The shell interface will be launched in the docker container.

```
$ docker run --rm -it --name openvslam-socket openvslam-socket
root@hostname:/openvslam/build#
```

See *Tutorial* to run SLAM examples in the container.

Please don't forget to append `SocketPublisher.server_uri` entry to the `config.yaml` if you use the downloaded datasets in the tutorial.

If you need to access to any files and directories on a host machine from the container, *bind directories* between the host and the container.

6.3 Bind of Directories

If you need to access to any files and directories on a host machine from the container, bind directories between the host and the container using `--volume` or `--mount` option. (See the docker documentataion.)

For example:

```
# launch a container of openvslam-desktop with --volume option
$ docker run -it --rm --runtime=nvidia -e DISPLAY=$DISPLAY -v /tmp/.X11-unix/:/tmp/.X11-
↪unix:ro \
    --volume /path/to/dataset/dir/:/dataset:ro \
    --volume /path/to/vocab/dir:/vocab:ro \
    openvslam-desktop
# dataset/ and vocab/ are found at the root directory in the container
root@0c0c9f115d74:/# ls /
...   dataset/   vocab/   ...
```

```
# launch a container of openvslam-socket with --volume option
$ docker run --rm -it --name openvslam-socket --net=host \
    --volume /path/to/dataset/dir/:/dataset:ro \
    --volume /path/to/vocab/dir:/vocab:ro \
    openvslam-socket
# dataset/ and vocab/ are found at the root directory in the container
root@0c0c9f115d74:/# ls /
...   dataset/   vocab/   ...
```

CHAPTER

SEVEN

RUNNING ON ROS

We provide ROS and ROS2 package examples to help you run OpenVSLAM on ROS framework.

7.1 ROS Package

7.1.1 Installation

Requirements

- ROS : `noetic` is recommended. (If you have built OpenCV (3.3.1 or later) manually, you can use `melodic` or later.)
- *OpenVSLAM*
- image_transport : Required by this ROS package examples.
- cv_bridge : Please build it with the same version of OpenCV used in OpenVSLAM.

Prerequisites

Tested for **Ubuntu 18.04**.

Please install the following dependencies.

- ROS : Please follow Installation of ROS.
- OpenVSLAM : Please follow *Installation of OpenVSLAM*.

Note: Please build OpenVSLAM with PangolinViewer or SocketViewer if you plan on using it for the examples.

Install the dependencies via `apt`.

```
apt update -y
apt install ros-${ROS_DISTRO}-image-transport
```

Download the source of `cv_bridge`.

```
mkdir -p ~/catkin_ws/src
git clone --branch ${ROS_DISTRO} --depth 1 https://github.com/ros-perception/vision_
↪opencv.git
```

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```
cp -r vision_opencv/cv_bridge ~/catkin_ws/src
rm -rf vision_opencv
```

Build Instructions

When building with support for PangolinViewer, please specify the following cmake options: `-DUSE_PANGOLIN_VIEWER=ON` and `-DUSE_SOCKET_PUBLISHER=OFF` as described in *build of OpenVSLAM*. openvslam and openvslam_ros need to be built with the same options.

```
cd ~/catkin_ws/src
git clone --branch ros --depth 1 https://github.com/OpenVSLAM-Community/openvslam_ros.git
cd ~/catkin_ws
catkin_make -DUSE_PANGOLIN_VIEWER=ON -DUSE_SOCKET_PUBLISHER=OFF
```

7.1.2 Examples

Run the core program required for ROS-based system in advance.

```
roscore
```

Note: Please leave the **roscore** run.

Publisher

If you want to input image sequences or videos into openvslam_ros, please use ROS2.

Publish Images of a USB Camera

For using a standard USB camera for visual SLAM or localization.

```
apt install ros-${ROS_DISTRO}-usb-cam
```

```
rosparam set usb_cam/pixel_format yuyv
rosrun usb_cam usb_cam_node
```

Republish the ROS topic to `/camera/image_raw`.

```
rosrun image_transport republish \
    raw in:=/usb_cam/image_raw raw out:=/camera/image_raw
```

Subscriber

Subscribers continually receive images. Please execute one of the following command snippets in the new terminal.

Note: Option arguments are the same as *the examples of OpenVSLAM*.

Tracking and Mapping

We provide an example snippet for visual SLAM. The source code is placed at `openvslam_ros/src/run_slam.cc`.

```
source ~/catkin_ws/devel/setup.bash
rosrun openvslam_ros run_slam \
    -v /path/to/orb_vocab.fbow \
    -c /path/to/config.yaml
```

Localization

We provide an example snippet for localization based on a prebuilt map. The source code is placed at `openvslam_ros/src/run_localization.cc`.

```
source ~/catkin_ws/devel/setup.bash
rosrun openvslam_ros run_localization \
    -v /path/to/orb_vocab.fbow \
    -c /path/to/config.yaml \
    --map-db /path/to/map.msg
```

7.2 ROS2 Package

7.2.1 Installation

Requirements

- ROS2 : `foxy` or later.
- *OpenVSLAM*
- image_common : Required by this ROS package examples.
- vision_opencv : Please build it with the same version of OpenCV used in OpenVSLAM.
- image_tools : An optional requirement to use USB cameras.

Prerequisites

Tested for **Ubuntu 18.04**.

Please install the following dependencies.

- ROS2 : Please follow Installation of ROS2.
- OpenVSLAM : Please follow *Installation of OpenVSLAM*.

Note: Please build OpenVSLAM with PangolinViewer or SocketViewer if you plan on using it for the examples.

Download repositories of `image_common` and `vision_opencv`.

```
midir -p ~/ros2_ws/src
cd ~/ros2_ws/src
git clone -b ${ROS_DISTRO} --single-branch https://github.com/ros-perception/image_
↪common.git
git clone -b ros2 --single-branch https://github.com/ros-perception/vision_opencv.git
```

For using USB cam as a image source, donload a repository of `demos` and pick `image_tools` module.

```
cd ~/ros2_ws
git clone https://github.com/ros2/demos.git
cp -r demos/image_tools src/
rm -rf demos
```

Build Instructions

When building with support for PangolinViewer, please specify the following cmake options: `-DUSE_PANGOLIN_VIEWER=ON` and `-DUSE_SOCKET_PUBLISHER=OFF` as described in *build of OpenVSLAM*. openvslam and openvslam_ros need to be built with the same options.

```
cd ~/catkin_ws/src
git clone --branch ros2 --depth 1 https://github.com/OpenVSLAM-Community/openvslam_ros.
↪git
cd ~/ros2_ws
colcon build --symlink-install --cmake-args -DUSE_PANGOLIN_VIEWER=ON -DUSE_SOCKET_
↪PUBLISHER=OFF
```

7.2.2 Examples

Publisher

If you want to input image sequences or videos into openvslam_ros, please refer to dataset_publisher_ros2.

Publish Images Captured by a USB Camera

For using a standard USB camera for visual SLAM or localization.

```
ros2 run image_tools cam2image
```

Republish the ROS topic to `/camera/image_raw`.

```
ros2 run image_transport republish \
    raw in:=image raw out:=/camera/image_raw
```

Subscriber

Subscribers continually receive images. Please execute one of the following command snippets in the new terminal.

Note: Option arguments are the same as *the examples of OpenVSLAM*.

Tracking and Mapping

We provide an example snippet for visual SLAM. The source code is placed at `openvslam_ros/src/run_slam.cc`.

```
source ~/ros2_ws/install/setup.bash
ros2 run openvslam_ros run_slam \
    -v /path/to/orb_vocab.fbow \
    -c /path/to/config.yaml
```

Localization

We provide an example snippet for localization based on a prebuilt map. The source code is placed at `openvslam_ros/src/run_localization.cc`.

```
source ~/ros2_ws/install/setup.bash
ros2 run openvslam_ros run_localization \
    -v /path/to/orb_vocab.fbow \
    -c /path/to/config.yaml \
    --map-db /path/to/map.msg
```

CHAPTER

EIGHT

TROUBLE SHOOTING

8.1 For building

1. OpenVSLAM terminates abnormaly soon after **launching** or **optimization with g2o**.

   Please configure and rebuild g2o and OpenVSLAM with `-DBUILD_WITH_MARCH_NATIVE=OFF` option for `cmake`.

8.2 For SLAM

CHAPTER NINE

CITE US

If you use OpenVSLAM for a publication, please cite it as:

```
@inproceedings{openvslam2019,
  author = {Sumikura, Shinya and Shibuya, Mikiya and Sakurada, Ken},
  title = {{OpenVSLAM: A Versatile Visual SLAM Framework}},
  booktitle = {Proceedings of the 27th ACM International Conference on Multimedia},
  series = {MM '19},
  year = {2019},
  isbn = {978-1-4503-6889-6},
  location = {Nice, France},
  pages = {2292--2295},
  numpages = {4},
  url = {http://doi.acm.org/10.1145/3343031.3350539},
  doi = {10.1145/3343031.3350539},
  acmid = {3350539},
  publisher = {ACM},
  address = {New York, NY, USA}
}
```