Magicbot-Z1 SDK Development Documentation

Release 1.2.4-doc1

MagicLab

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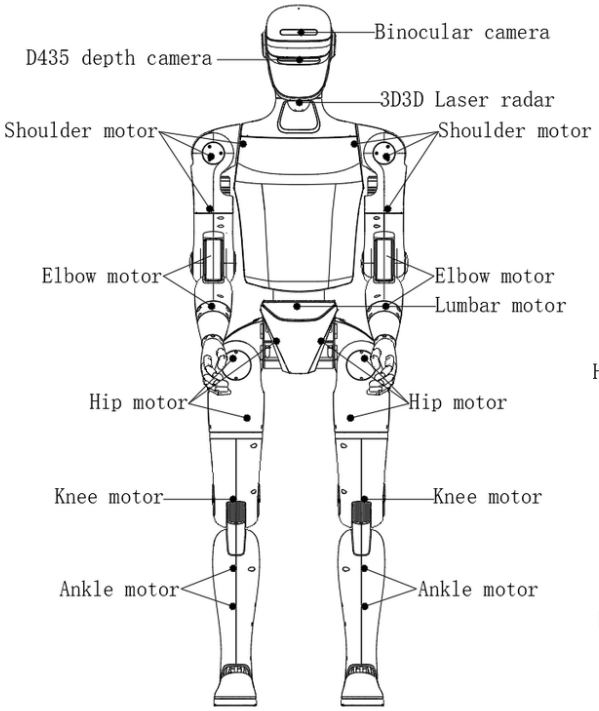
Contents

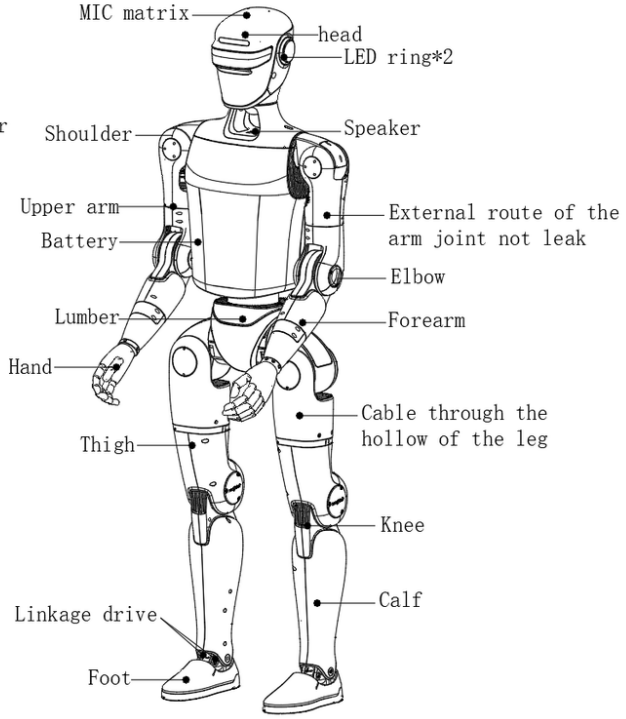
CHAPTER 1

About MagicBot Z1

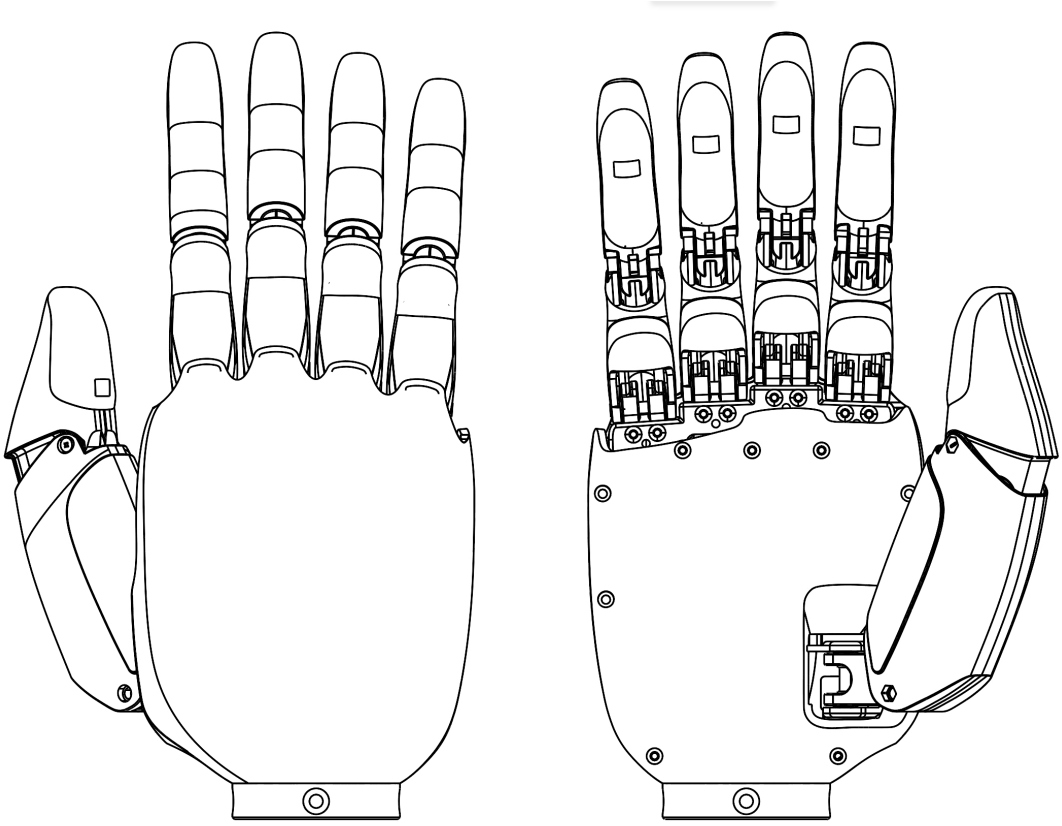
1.1 Part Name

The MagicBot Z1 whole body is divided into upper and , with multiple degrees of freedom. The head has 1 degree of freedom (Yaw). A single arm has 5+ degrees of freedom, including shoulder-body joint, upper arm joint, elbow joint, and wrist joint (optional). A single leg has 6 degrees of freedom, including hip joint, leg joint, hip joint, knee joint, and ankle joint. The waist has 1 degree of freedom (Yaw). Depending on the version, the whole body can be divided into the Z1 basic version with 24 degrees of freedom, and the Z1 development version with an optional 24-50 degrees of freedom. Having multiple joint motor degrees of freedom enables the robot to achieve precise motion and posture control. The MagicBot Z1_24 degrees of freedom humanoid robot body is shown in the figure below, and please refer to the physical product for details.


Binocular camera
D435 depth camera
3D3D Laser radar
Shoulder motor
Shoulder motor
Elbow motor
Elbow motor
Lumbar motor
Hip motor
Hip motor
Knee motor
Knee motor
Ankle motor
Ankle motor


MIC matrix
head
LED ring*2
Shoulder
Speaker
Upper arm
External route of the arm joint not leak
Battery
Elbow
Lumber
Forearm
Hand
Cable through the hollow of the leg
Thigh
Knee
Calf
Linkage drive
Foot

1.2 Dexterous Hand MagicHand S01



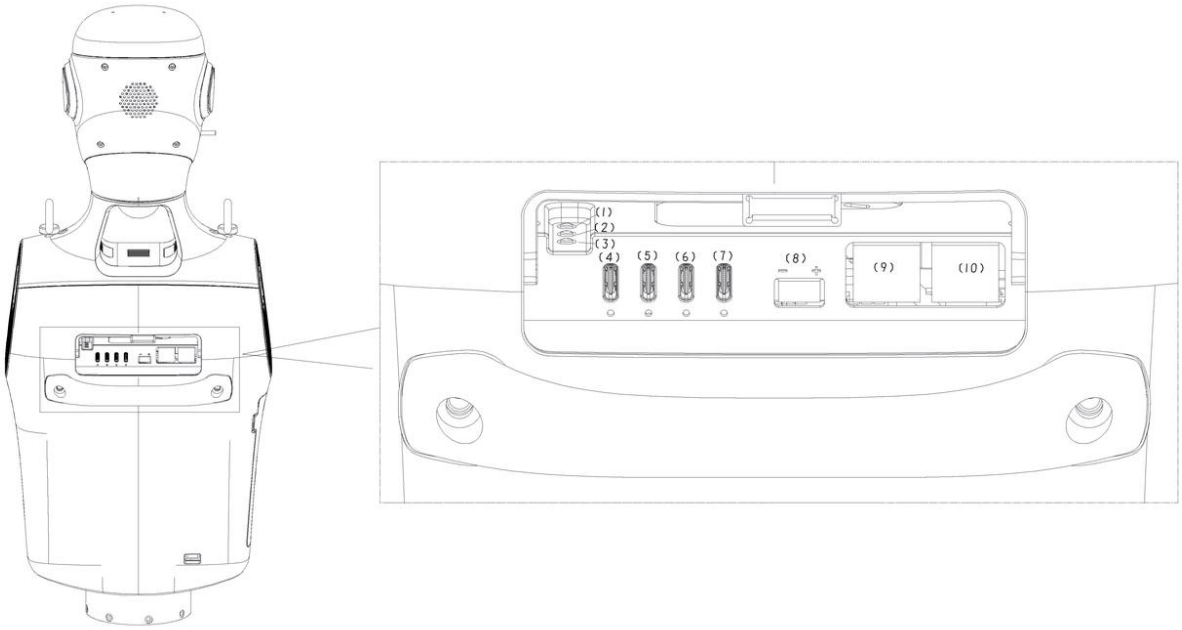
MagicHand S01 Specifications	
Length, Width, and Depth	200mm x 87mm x 55mm
Weight	≤650g
Rating	5
Total Degrees of Freedom (Number of Joints)	11
Active Degrees of Freedom (Number of Motors)	61, Active Degrees of Freedom for Common Fingers: 22, Active Degrees of Freedom for Thumb: 1
Joint Angles	Common Fingers Flexion: 13° to 203°; Thumb Flexion: -9° to 66.6°; Thumb Lateral Pendulum: 71° to 180°.
Drive mode	Coreless motor + reduction gearbox + T-type screw
Transmission mode	Connecting rod transmission
Actuation options	Pinching, grasping, pressing, lifting, pushing, and other anthropomorphic actions
Operating voltage	DC12V
Quiescent current	0.1A @12V
Maximum current	3A@12V
Proximity Sensing Solution	ToF
Number of Tactile Sensors	5
Tactile Sensor Dimensions	Normal Force, Tangential Force
Tactile Sensor Resolution*	0.1N
Tactile Sensor Range	0.1-10N
Single-Finger Grip Strength*	2.5kg
Four-Finger Grip Strength*	9.1kg
Total Hand Load*	5kg
End-of-Hand Repeatability*	0.1mm
Opening and Closing Time*	1.2s
Thumb Lateral Swing Speed*	112°/s
Thumb Flexion Speed*	106°/s
Four-Finger Flexion Speed*	150°/s
Communication Interface	RS485, EtherCAT
SDK Language	C++
Durability Lifespan*	More than 100,000 times

*Parameters such as single-finger grip strength, four-finger grip strength, and whole-hand load were measured in a laboratory environment.

*The above parameters may vary under different business scenarios and device configurations. Please refer to the actual usage experience.

1.3 Electrical Interface

The back of MagicBot Z1 is equipped with electrical interfaces, which are used to connect various body joint motors, sensor peripherals, network ports, etc. This design allows you to conveniently perform debugging, troubleshooting, and secondary development.



Serial Number	Interface Type	Interface Name	Instructions for Use
1	button	Remote control matching	Press and hold this button, the remote control will turn on and start pairing. The buzzer of the remote control will beep to complete the configuration, then release the button. For details, please refer to the user manual of the remote control.
2	button	Wireless Emergency Stop Matching	Press briefly 3 times to enter pairing mode. Press any key on the remote control to successfully complete the pairing.
3	button	Bluetooth Network Pairing Button	Press briefly once to enter Bluetooth pairing mode
4	Type-C	Type-C USB3.0	Supports USB3.0 Host, with a maximum output of 5V/1.5A
5	Type-C	Type-C USB3.0	Supports USB3.0 Host, with a maximum output of 5V/1.5A
6	Type-C	Type-C USB3.0	Supports USB3.0 Host, with a maximum output of 5V/1.5A
7	Type-C	Type-C USB3.0	Supports USB3.0 Host, with a maximum output of 5V/1.5A
8	XT30PV M30.G.	VBAT	Directly connected battery output, voltage 54V, current recommended not to exceed 5A. Pay attention to the positive and negative poles
9	RJ45	1000Base-T	Supports 10/100/1000Mbps, supports debugging
10	RJ45	1000Base-T	Supports 10/100/1000Mbps, supports debugging

1.4 Airborne Computer

MagicBot Z1 comes standard with 1 [Motion Control Computing Unit] and 1 [Development Computing Unit] on board.

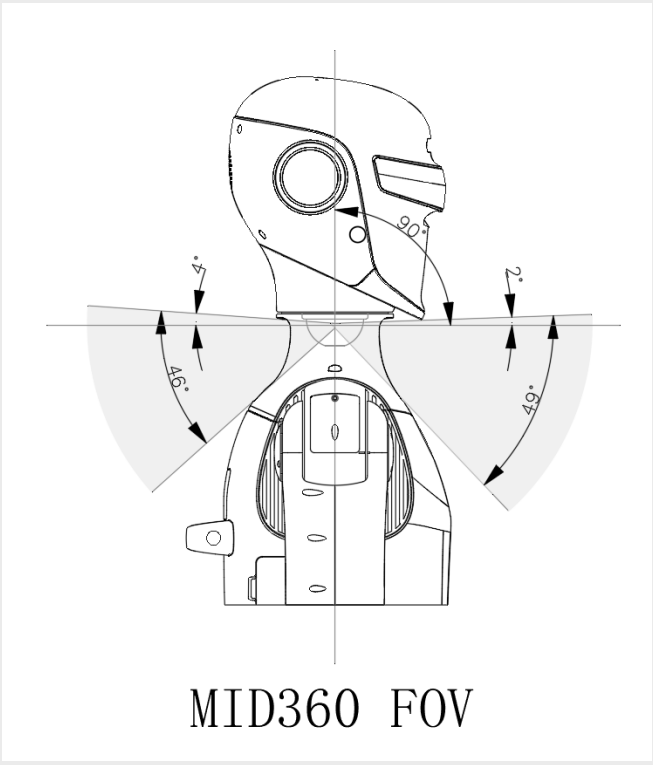
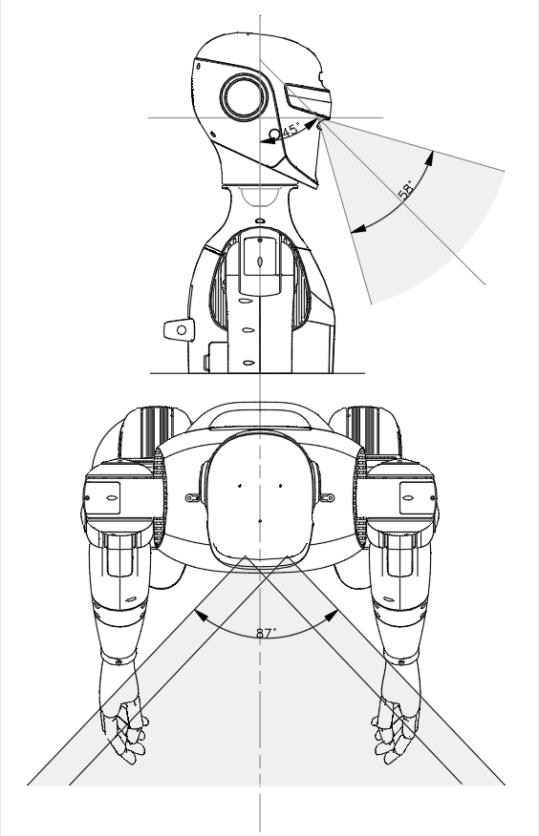
Parameter	Develop computing unit
Model	Jetson Orin NX
CPU	Arm® Cortex®-A78AE
Number of Cores	8
Number of Threads	8
Max Turbo Frequency	2GHz
Video Memory	16G
Memory	16G
Cache	2MB L2 + 4MB L3
Storage	512G
GPU	1024-core NVIDIA Ampere architecture GPU with 32 Tensor Cores
Maximum Dynamic Frequency of Graphics Card	918MHz
Gaussian and Neural Accelerator	3
Instruction Set Architecture	64bit
OpenGL	4.6
OpenGL ES	3.2
Vulkan™	1.1
CUDA	11.4

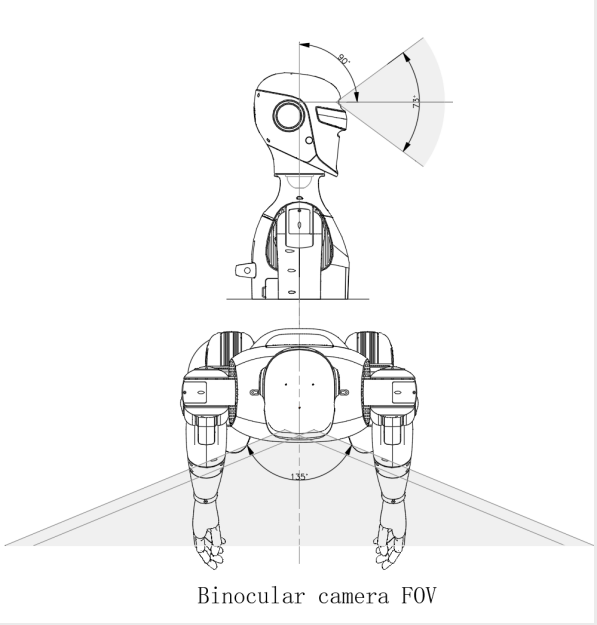
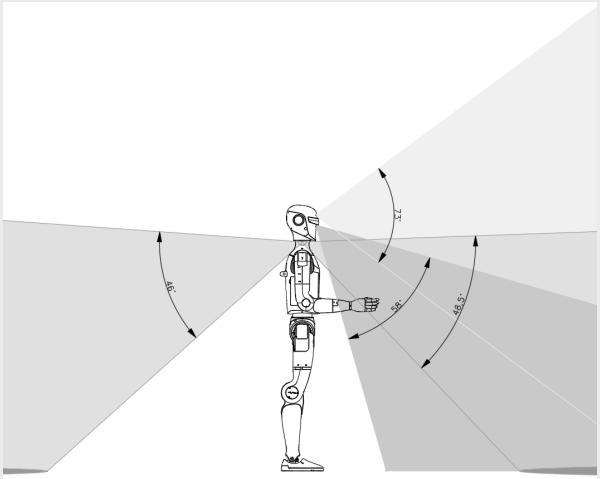
【Motion Control Computing Unit】is dedicated to the magic atom motion control program and is not open to the public. Developers can only use the 【Development Computing Unit】for secondary development.

1.5 Field of View of Radar and Camera

The MagicBot Z1 is equipped with a LIVOX-MID360 lidar on its head, providing the robot with excellent environmental perception capabilities. The lidar uses an all-round, full-angle scanning technology, with a horizontal FOV of up to 360° and a maximum vertical FOV of 49°, enabling it to obtain accurate environmental data in real time. It can quickly identify and measure surrounding objects, providing high-resolution point cloud data.

The Z1 head is equipped with a D435i depth camera (FOV horizontal 87°, vertical 58°) and a binocular fisheye camera (FOV horizontal 135°, vertical 75°). This provides the robot with excellent visual perception capabilities, enabling it to more accurately perceive and understand the surrounding environment, achieve precise spatial perception and obstacle detection, and allowing the robot to interact with the environment more intelligently and flexibly and handle various scenarios.

Field of View Image 1	Field of View Image 2
 MID360 FOV	 D435 depth camera FOV

Field of View Image 3	Field of View Image 4
 Binocular camera FOV	 MID360 and D435 depth camera and Binocular camera merged FOV

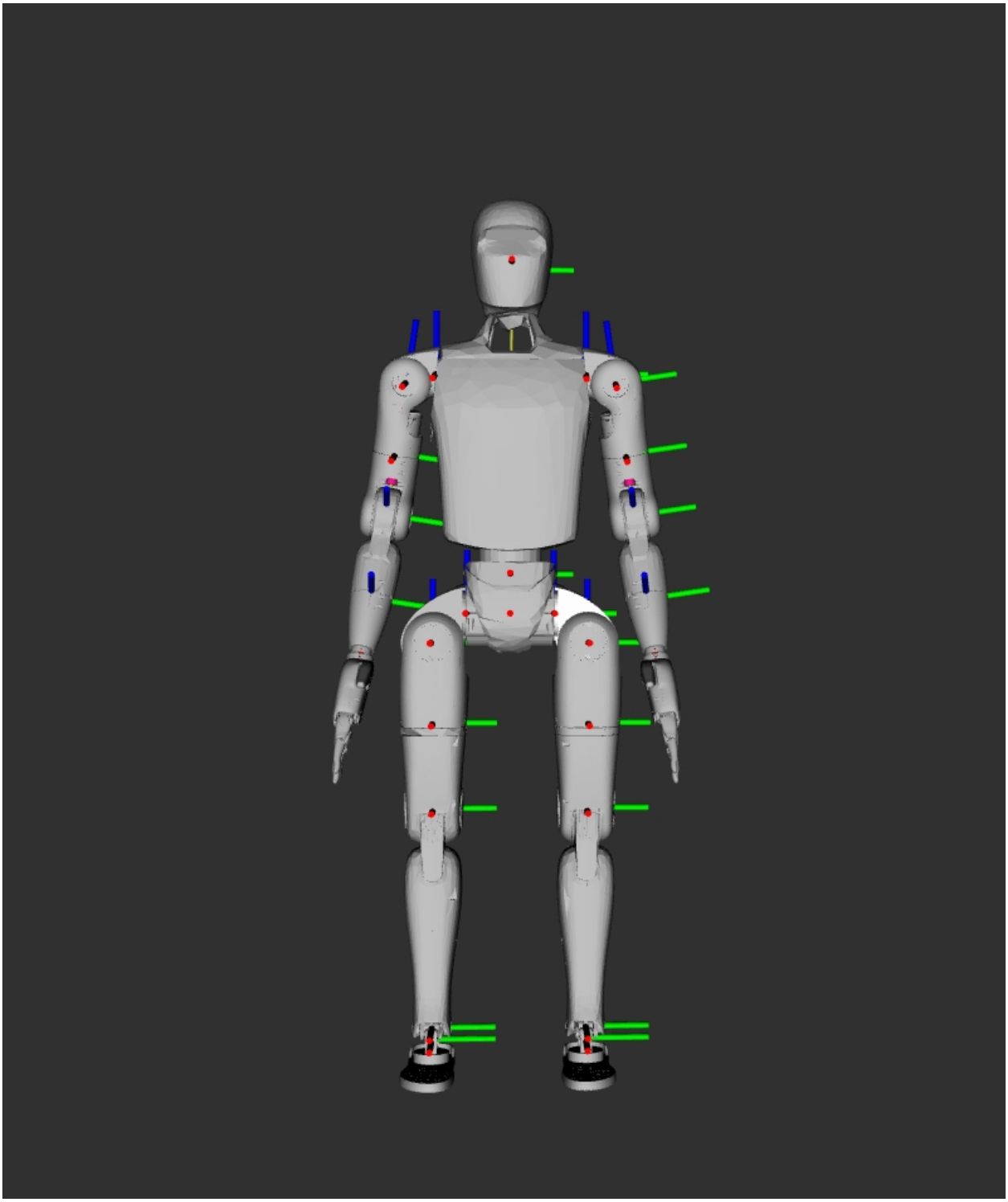
1.6 Joint Motor

The joints of MagicBot Z1 are equipped with Magic Atom’ s full stack self-developed motors, which have excellent performance and features. The maximum torque of the motor is 130 N.m, and the motor structure is lightweight and compact. The motor is also equipped with dual encoders, providing more accurate position and speed feedback to meet the requirements of high-precision control. Joint sequence names and joint limits

Joint number	Joint name	Limit (radians)
1	left_hip_pitch_joint	-2.7925~2.7925
2	left_hip_roll_joint	-0.524~2.967
3	left_hip_yaw_joint	-2.7925~2.7925
4	left_knee_joint	0~2.653
5	left_ankle_pitch_joint	-0.83~0.524
6	left_ankle_roll_joint	-0.262~0.262
7	right_hip_pitch_joint	-2.7925~2.7925
8	right_hip_roll_joint	-2.967~0.524
9	right_hip_yaw_joint	-2.7925~2.7925
10	right_knee_joint	0~2.653
11	right_ankle_pitch_joint	-0.83~0.524
12	right_ankle_roll_joint	-0.262~0.262
13	left_shoulder_pitch_joint	-2.88~2.88
14	left_shoulder_roll_joint	-0.175~2.2515
15	left_shoulder_yaw_joint	-2.618~2.618
16	left_elbow_joint	-0.96~1.70
17	left_wrist_yaw_joint	-2.618~2.618
18	right_shoulder_pitch_joint	-2.88~2.88
19	right_shoulder_roll_joint	-2.2515~0.175
20	right_shoulder_yaw_joint	-2.618~2.618
21	right_elbow_joint	-0.96~1.70
22	right_wrist_yaw_joint	-2.618~2.618

1.7 Degree of Freedom Configuration, Coordinate System, Joint Rotation Axis, and Joint Zero Point

When all joints are at zero degrees, the coordinate systems are as shown in the figure below. Red represents the x-axis, green represents the y-axis, and blue represents the z-axis.



1.8 Specification Parameters

1.8.1 Mechanical Parameters

Category	Z1	Z1 Development Edition
Height, Width, and Depth (Standing)	1369*422*200mm	1369*422*200mm
Height, Width, and Depth (Folded)	730*422*395mm	730*422*395mm
Weight with battery	Approximately 40kg	Approximately 40kg+
Total degrees of freedom (number of joints)	24	24 - 50
Single-leg degrees of freedom	6	6
Head degrees of freedom	1	1
Waist degrees of freedom	1	1
Single Arm DOF	5	5+ (2 wrist DOF optional)
Dexterous Hand DOF	/	Optional 11-DOF Haptic Dexterous Hand
Joint Output Bearing	Industrial-grade high-rigidity roller bearing (can withstand 8.7 kN impact force)	Industrial-grade high-rigidity roller bearing (can withstand 8.7 kN impact force)
Joint Motor	Low-inertia, high-speed, high-overload permanent magnet synchronous motor (control frequency 25kHz, high burst force, improved heat dissipation)>	Low inertia, high speed, high overload permanent magnet synchronous motor (control frequency 25kHz, high burst force, improved heat dissipation)
Maximum knee torque*	100N.m	130N.m
Maximum arm load*	2kg	3kg

Category	Z1	Z1 Development Edition
Calf + thigh length	0.6m	0.6m
Arm span	Approximately 0.5m	Approximately 0.5m
Head Z-axis joint range of motion	±40°	±40°
Waist Z-axis joint range of motion	±160°	±160°>
Knee joint range of motion	0-152°,	0-152°,
Hip joint range of motion	P ±160°, R -30-+110°, Y ±160°	P ±160°, R -30~+110°, Y ±160°

1.8.2 Electrical Characteristics

Category	Z1	Z1 Development Edition
Joint Encoder	Dual Encoder	Dual Encoder
Cooling System	Intelligent Air Cooling	Intelligent Air Cooling
Power Supply	15-cell Battery	15-cell Battery
Basic Computing Power	8-core High-Performance CPU	8-core High-Performance CPU
Perception Sensors:	3D LiDAR + Depth Camera + Binocular Fisheye Camera + Head Tactile Sensor	3D LiDAR + Depth Camera + Binocular Fisheye Camera + Head Tactile Sensor
WiFi6, Bluetooth 5.2	Yes	Yes
Microphone Array	Yes	Yes
5W Speaker	Yes	Yes

1.8.3 Supporting Equipment

Category	Z1	Z1 Development Edition
High Computing Power Module	No	Optional
Smart Battery (Quick Release)	10000mAh	10000mAh
Charger	62V 5A	62V 5A
Handheld Remote Control	Yes	Yes

1.8.4 Other

Category	Z1	Z1 Development Edition
Battery Life	Approximately 2 hours	Approximately 2 hours
OTA Upgrade	Supported	Supported
Secondary Development	No	Yes

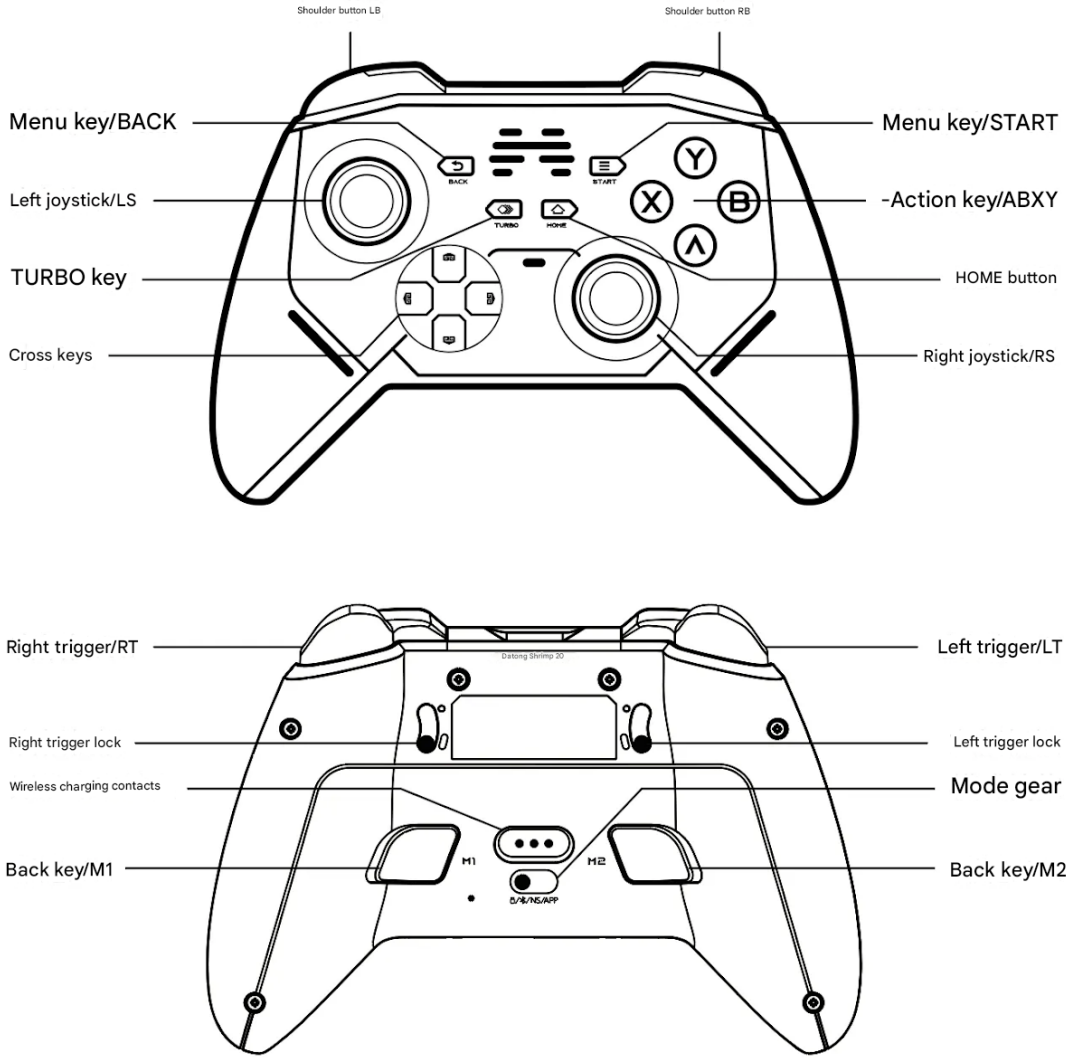
*Maximum torque, maximum arm load, endurance time, etc. are measured under laboratory conditions.

*The above parameters may vary under different business scenarios and device configurations. Please refer to the actual usage experience.

CHAPTER 2

remote-control

2.1 Button Diagram



2.2 Remote Control Settings

Remote Control Settings	Buttons/Operations
Remote Control Power On	Press Home Button
Remote Control Power Off	Back + B, press and hold for 3 seconds; it will automatically shut down (lights off) after a period of inactivity.
Pairing the Remote Control with the Robot	Approaching the robot will automatically pair it. The remote control will vibrate once upon successful pairing; if pairing fails, the indicator light will flash red rapidly.
Gaining Control of the Robot	Press Home + Start buttons
Releasing Control of the Robot	Press Home + Back buttons

Note: The remote control communicates with the robot via 2.4G. The corresponding indicator light is red. If yellow, blue, green, or other colors appear, the remote control's mode is incorrect. The mode switch needs to be moved to the far left on the back, as shown in the button diagram.

2.3 Functional Modes

Functional Modes	Buttons
Standing in Place 1	LT+RT + A
Posture Display 2	LT+RT + B
Human Walking 3	LT+RT + X
Human Running 4	LT+RT + Y

Hanger power on: Power on -> 1 -> Demo -> 1 -> Power off. The demonstration is divided into posture display and anthropomorphic walking/running.

2.4 Posture Display

Posture Display	Buttons
Welcome	LT+A
Shake head	LT+B
Greeting (Left hand)	LT+X
Greeting (Right hand)	LT+Y
Shake hands - Left hand - Extend hand	LB+A
Shake hands - Left hand - Withdraw hand	LB+B
Shake hands - Right hand - Extend hand	LB+X
Shake hands - Right hand - Withdraw hand	LB+Y
Left turn introduction - High	RB+A
Left turn introduction - Low	RB+B
Right Turn Introduction - High	RB+X
Right Turn Introduction - Low	RB+Y

Note: When displaying the postures in the table above, you must first enter posture 2 display mode.

2.5 Charging Instructions

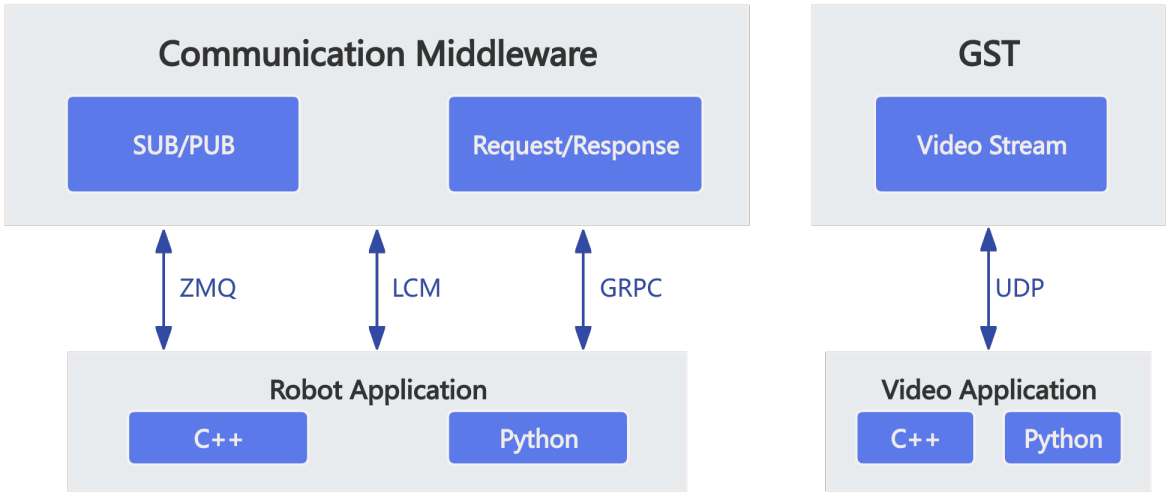
Battery Status	**Indicator Light Effects**
Battery less than 20%	Red flashing indicator
Charging in progress	Red breathing (slow flashing)
Charging complete with power on	Solid red light
Charging complete with power off	Red solid light will turn off after 7 seconds

Note: Remote control via Type-C Charge using the charging cable.

CHAPTER 3

SDK Overview

3.1 SDK Communication Interface Introduction



- Current software version does not support GST video stream transmission

Z1 uses LCM/GRPC/UDP/ZMQ as message middleware, with main data interaction modes: topics (subscribe/publish) and RPC (request/response)

- **Topics (Subscribe/Publish)**: Receivers subscribe to specific messages, senders send messages to receivers based on subscription lists, mainly used for medium-high frequency or continuous data interaction.
- **RPC (Request/Response)**: Question-answer mode, implementing data acquisition or operations through requests. Used for low-frequency or data interaction during function switching.

Main calling methods for topics and RPC interfaces: functional interfaces

- **Functional Interface**: Encapsulates API calls into function calls for user convenience.

3.2 Getting the SDK

magicbot-z1_sdk is Magic Lab ' s next-generation robot Z1 development SDK. The SDK encapsulates high-level motion control, low-level motor control, voice control and other interfaces, and provides related functional interfaces. You can refer to our provided SDK tutorials to learn robot control and complete Z1 secondary development;

3.2.1 SDK Download Address:

magicbot-z1_sdk

- The SDK version must be aligned with the robot firmware version. Please refer to ChangeLog
- For downloading the SDK PDF documentation, please refer to: PDF

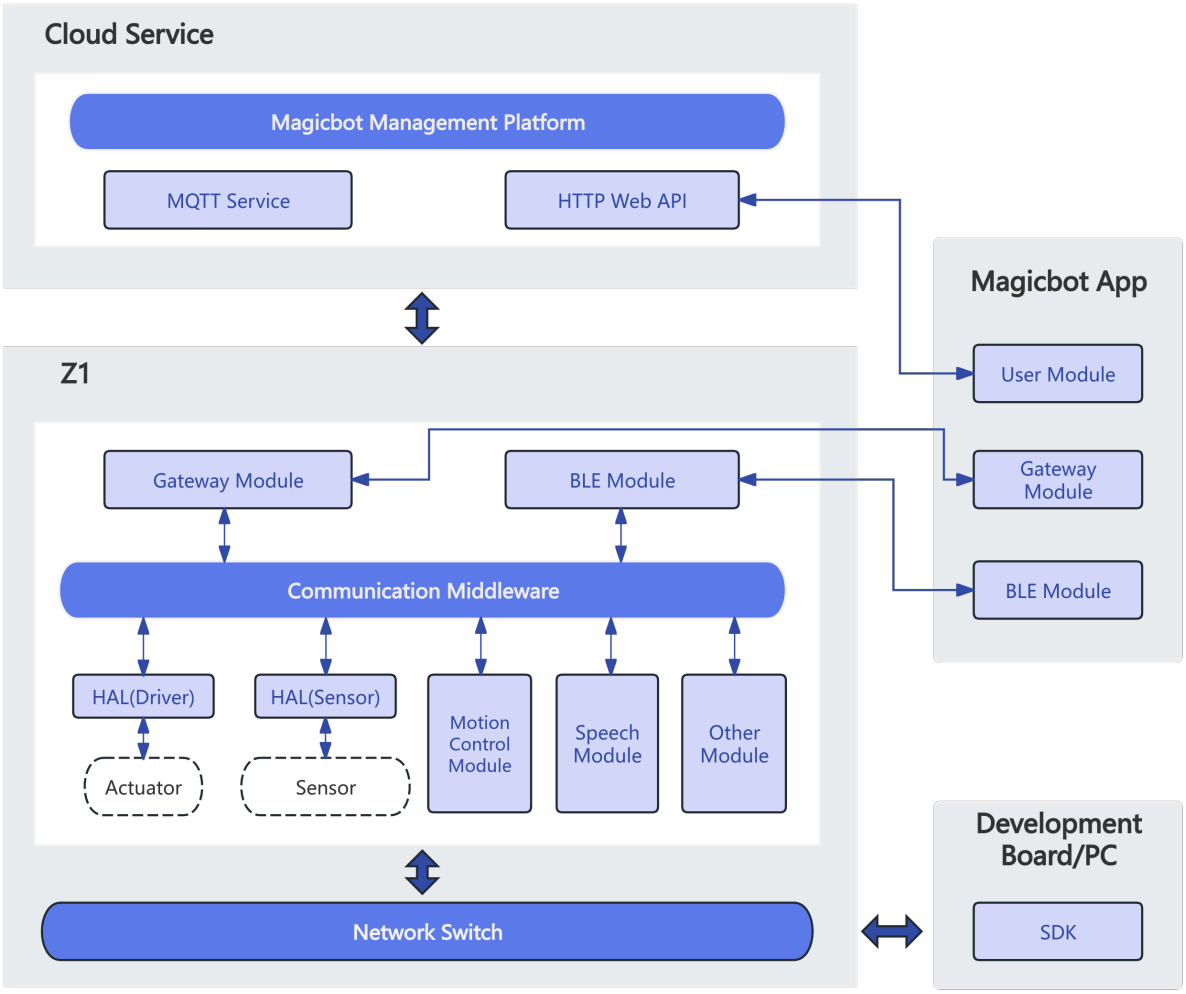
3.2.2 URDF/MJCF Download Address:

URDF/MJCF

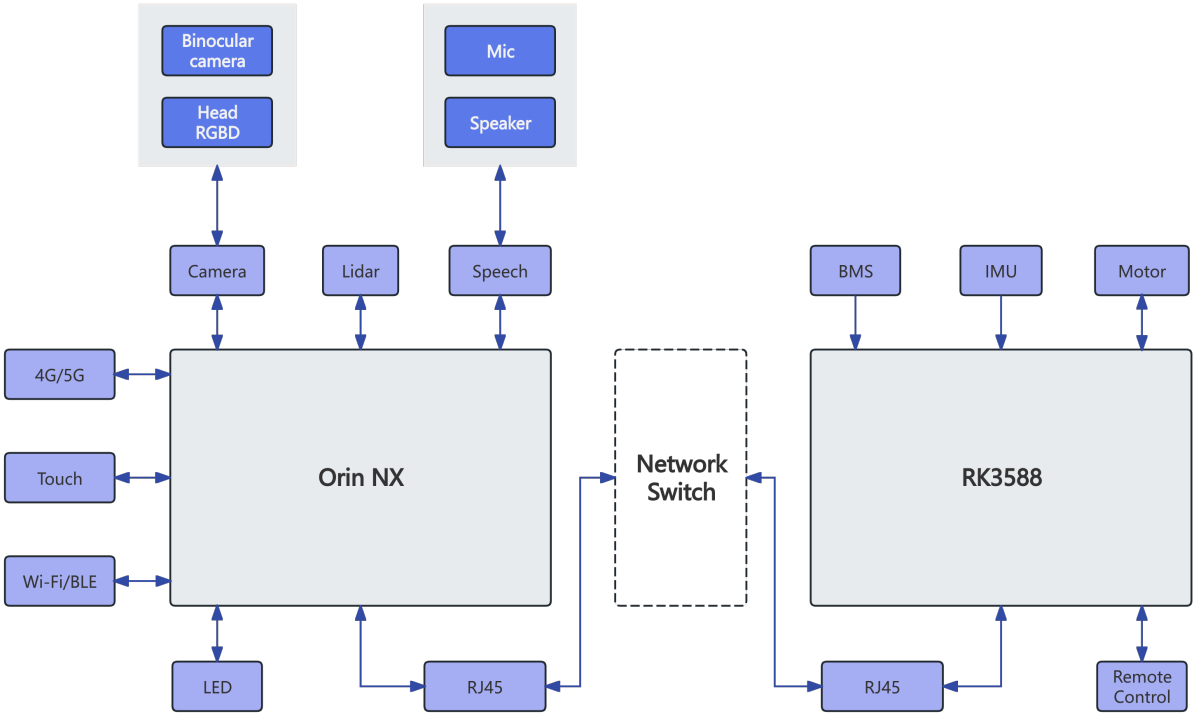
CHAPTER 4

Software and Hardware Architecture

4.1 Software System Architecture Diagram

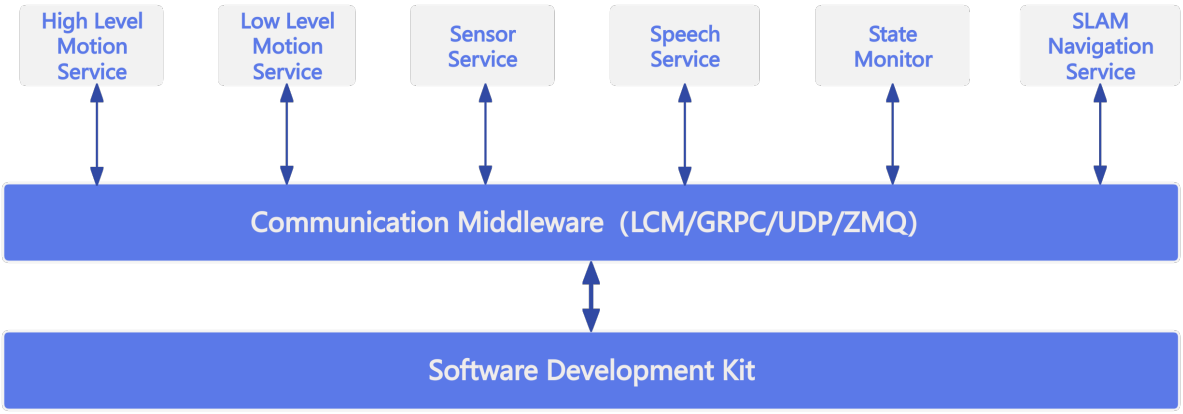


4.2 Hardware System Architecture Diagram



CHAPTER 5

Service Introduction



Magicbot Z1 provides the following services through message middleware (LCM/GRPC/UDP/ZMQ):

- **High-Level Motion Control Service**

Based on Z1’s built-in gait controller, it can perform gait switching, trick execution, attitude and velocity control (equivalent to remote control) and other functions. High-level motion control service uses GRPC for communication.

- **Low-Level Motion Control Service**

Through service interfaces, joint and IMU data can be obtained in real-time, and joint commands can be sent in real-time to control motors. Low-level motion control service uses LCM for communication.

- **Audio Service**

Through service interfaces, volume and voice control can be managed. Audio service uses GRPC/LCM for communication.

- **Sensor Service**

Supports data subscription for lidar, RGBD, binocular camera and other sensors. Sensor service uses GRPC/UDP/LCM/ZMQ for communication.

> Notice: Current version only supports lidar data subscription, RGBD/binocular camera data is not yet supported

- **Status Monitoring Service**

Through service interfaces, robot body software/hardware faults and BMS status can be subscribed to. Status monitoring service uses LCM for communication.

- **SLAM Navigation Service**

Robot SLAM mapping and navigation control can be performed through service interfaces. SLAM navigation service uses GRPC/LCM for communication.

CHAPTER 6

Quick Start

6.1 System Environment

Development is recommended on Ubuntu 22.04 system. Mac/Windows systems are not currently supported for development. The robot’ s onboard PC runs official services and does not support development;

APP and SDK cannot suppport control the robot simultaneously

6.1.1 Development Environment Requirements

- GCC ≥ 11.4 (for Linux)
- CMake ≥ 3.16
- Make build system
- C++20 (minimum)
- Eigen3
- python3.10

6.1.2 System Configuration

First, to achieve real-time communication under regular users, add the following configuration to the `/etc/security/limits.conf` file:

```
*    -   rtprio   98
```

Second, to increase the receive buffer for each socket connection, add the following configuration to the `/etc/sysctl.conf` file. Use `sudo sysctl -p` to take effect immediately or restart to take effect:

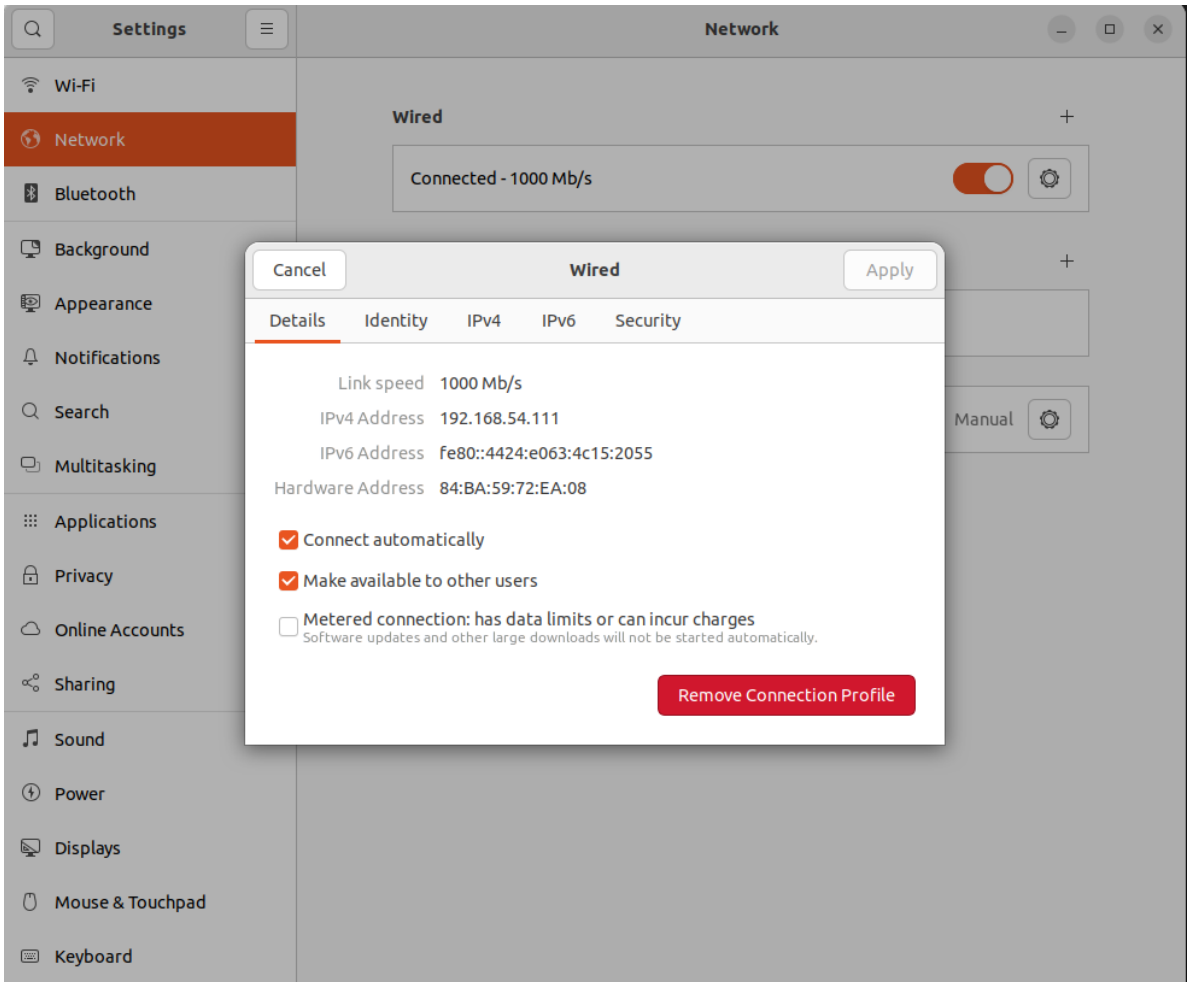
```
net.core.rmem_max=20971520
net.core.rmem_default=20971520
net.core.wmem_max=20971520
net.core.wmem_default=20971520
```

6.2 Network Environment

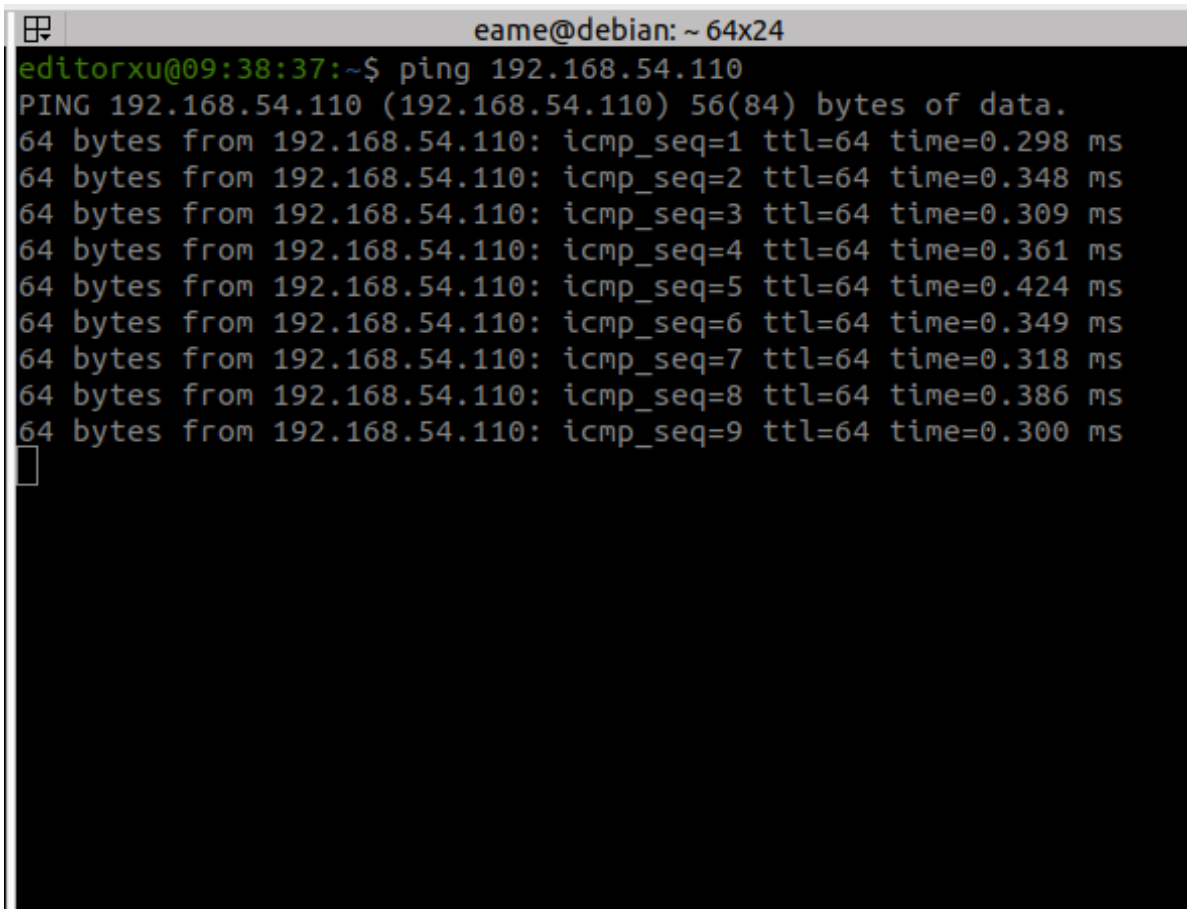
Connect the user computer and robot switch to a unified network. It is recommended that new users use an Ethernet cable to connect the user computer to the robot switch, and set the network card communicating with the robot to the 192.168.54.X network segment, recommended 192.168.54.111. Experienced users can configure the network environment themselves.

6.2.1 Configuration Steps

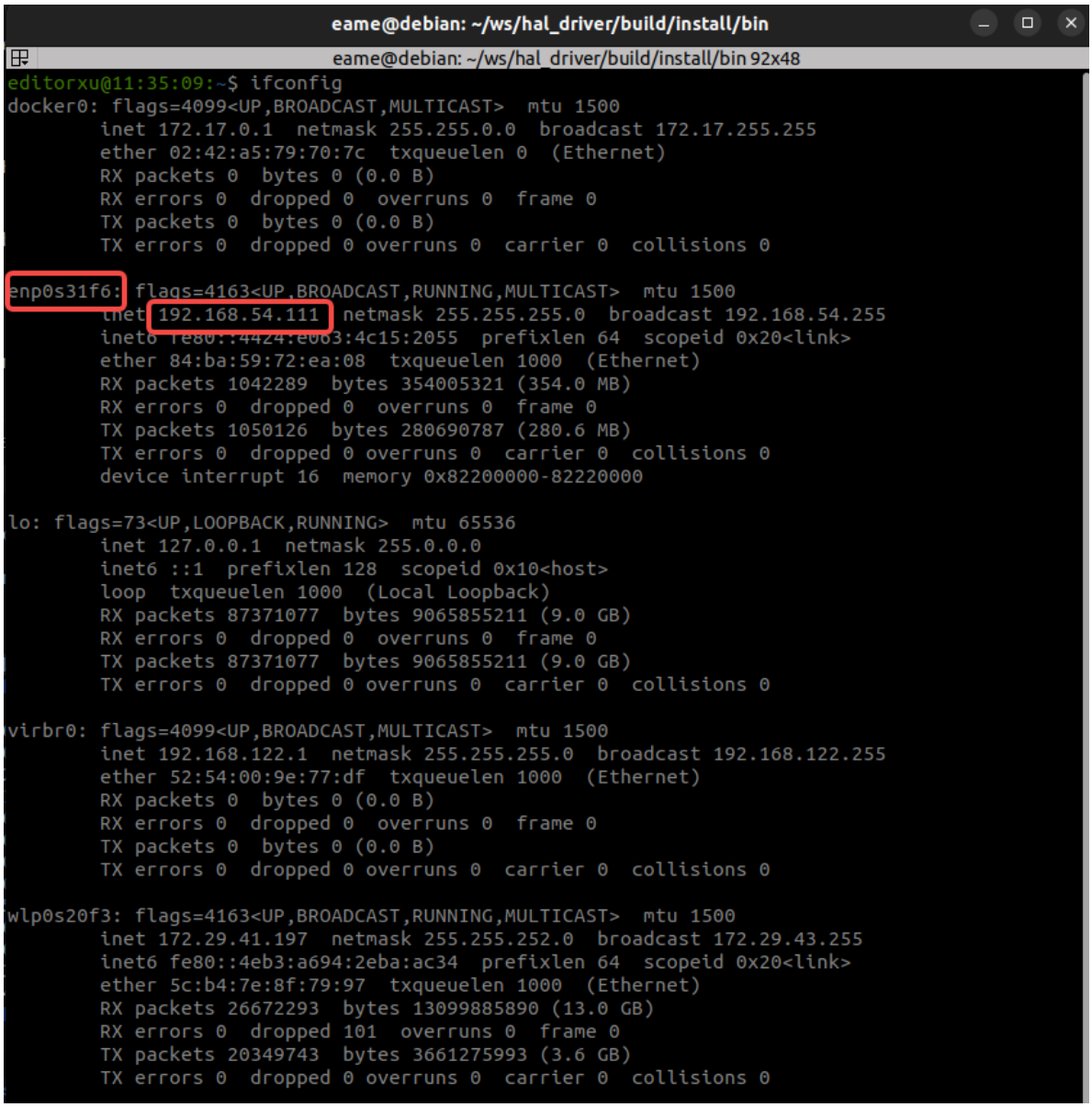
1. Connect one end of the Ethernet cable to the robot and the other end to the user computer. The robot's onboard computer IP addresses are 192.168.54.110 (cerebellum computing board) and 192.168.54.119 (brain computing board), so the computer IP needs to be set to the same network segment, recommended 192.168.54.111.



2. To test if the communication connection is normal, you can test with ping:



3. Check the network card name corresponding to the 192.168.54.111 address by using the `ifconfig` command to view the network card name, as shown in the figure:



Assuming the network port connecting the SDK secondary development PC to the robot is `enp0s31f6`, the following configuration is needed for SDK to communicate with the robot at the low level:

```
sudo ifconfig enp0s31f6 multicast
sudo route add -net 224.0.0.0 netmask 240.0.0.0 dev enp0s31f6
```

To avoid having to manually reconfigure the network interface multicast route every time you unplug and replug the network cable, you can automate this process on your development PC by following the steps below (system requirements: Ubuntu 22.04, and NetworkManager as the network configuration tool):

- Check the service status:

```
$ systemctl is-active NetworkManager
active
```

If the output shows `active`, proceed with the next steps; otherwise, skip the following steps.

- Edit the configuration file with the command: `sudo vim /etc/NetworkManager/dispatcher.d/90-add-mcast-route`:

```
#!/bin/bash

IFACE="$1"
STATUS="$2"

# Target network interface
TARGET_IF="enp0s31f6"

# Only execute when the specified interface is 'carrier on' or 'up'
if [ "$IFACE" = "$TARGET_IF" ] && [[ "$STATUS" = "up" || "$STATUS" = "carrier" ]];
↪ then
    # Delete any possible old route
    ip route del 224.0.0.0/4 dev "$TARGET_IF" 2>/dev/null

    # Add the required route (with scope link)
    ip route add 224.0.0.0/4 dev "$TARGET_IF" scope link
fi
```

- Add execute permission:

```
sudo chmod +x /etc/NetworkManager/dispatcher.d/90-add-mcast-route
```

- Restart the service to take effect:

```
sudo systemctl restart NetworkManager
```

Check if the network interface route is configured correctly:

```
$ ip route | grep 224.0.0.0
224.0.0.0/4 dev enp0s31f6 scope link
```

6.3 Installation and Compilation

The following steps assume the working directory is `/home/magicbot/workspace`

6.3.1 Install magicbot-z1_sdk:

Installation steps: Enter the magicbot-z1_sdk directory and execute the following commands step by step to install the SDK to the /opt/magic_robotics/magicbot_z1_sdk directory for easy find_package retrieval for secondary development program compilation and linking:

```
cd /home/magicbot/workspace/magicbot-z1_sdk/
mkdir build
cd build
cmake .. -DCMAKE_INSTALL_PREFIX=/opt/magic_robotics/magicbot_z1_sdk
sudo make install
```

6.3.2 Example Compilation

Compilation steps: Enter the magicbot-z1_sdk directory and execute the following commands step by step to generate example executable programs in the build directory:

```
cd /home/magicbot/workspace/magicbot-z1_sdk/
mkdir build
cd build
cmake .. -DBUILD_EXAMPLES=ON
make -j8
```

6.4 Example Programs

In the magicbot-z1_sdk/build directory:

- **Audio Example**:
  - audio_example
- **Sensor Example**:
  - sensor_example
- **Status Monitoring Example**:
  - monitor_example
- **Low-Level Motion Control Example**:
  - low_level_motion_example

- **High-Level Motion Control Example**:
  - high_level_motion_example
- **SLAM Example**:
  - slam_example
- **Navigation Example**:
  - navigation_example

  Notice: Among these, the high-level motion control examples have sequential dependencies (recovery stand -> balance stand -> execute trick actions/remote control)

6.4.1 Enter Debug Mode:

Follow the operation procedures to ensure the robot enters debug mode

6.4.2 Run Examples

Enter the magicbot-z1_sdk/build directory and execute the following commands:

```
cd /home/magicbot/workspace/magicbot-z1_sdk/build
# Environment configuration
sudo ifconfig enp0s31f6 multicast
sudo route add -net 224.0.0.0 netmask 240.0.0.0 dev enp0s31f6
export LD_LIBRARY_PATH=/opt/magic_robotics/magicbot_z1_sdk/lib:$LD_LIBRARY_PATH

# execute audio control example
./audio_example
```

6.5 Python Example Programs

In the magicbot-z1_sdk/example/python directory:

- **Audio Example**:
  - audio_example.py
- **Sensor Example**:
  - sensor_example.py
- **Status Monitoring Example**:
  - monitor_example.py
- **Low-Level Motion Control Example**:
  - low_level_motion_example.py

- **High-Level Motion Control Example**:
  - high_level_motion_example.py
- **SLAM Example**:
  - slam_example.py
- **Navigation Example**:
  - navigation_example.py

  Notice: Among these, the high-level motion control examples have sequential dependencies (recovery stand -> balance stand -> execute trick actions/remote control)

6.5.1 Enter Debug Mode:

Follow the operation procedures to ensure the robot enters debug mode

6.5.2 Run Examples

Enter the magicbot-z1_sdk/example/python directory and execute the following commands:

```
cd /home/magicbot/workspace/magicbot-z1_sdk/example/python
# Environment configuration
sudo ifconfig enp0s31f6 multicast
sudo route add -net 224.0.0.0 netmask 240.0.0.0 dev enp0s31f6
export PYTHONPATH=/opt/magic_robotics/magicbot_z1_sdk/lib:$PYTHONPATH
export LD_LIBRARY_PATH=/opt/magic_robotics/magicbot_z1_sdk/lib:$LD_LIBRARY_PATH

# execute audio control example
python3 audio_example.py
```

Get Python API help information:

```
# Environment configuration
export PYTHONPATH=/opt/magic_robotics/magicbot_z1_sdk/lib:$PYTHONPATH
export LD_LIBRARY_PATH=/opt/magic_robotics/magicbot_z1_sdk/lib:$LD_LIBRARY_PATH

$ python3
Python 3.10.12 (main, Aug 15 2025, 14:32:43) [GCC 11.4.0] on linux
Type "help", "copyright", "credits" or "license" for more information.
# Import Magic Z1 python SDK interface
>>> import magicbot_z1_python
# View all interface information
>>> help(magicbot_z1_python)
```

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```
# View CameraInfo structure information
>>> help(magicbot_z1_python.CameraInfo)
# View HighLevelMotionController object information
>>> help(magicbot_z1_python.HighLevelMotionController)
# View LowLevelMotionController object information
>>> help(magicbot_z1_python.LowLevelMotionController)
# View SensorController object information
>>> help(magicbot_z1_python.SensorController)
# View AudioController object information
>>> help(magicbot_z1_python.AudioController)
# View StateMonitor object information
>>> help(magicbot_z1_python.StateMonitor)
```

For example, if you want to view the TrickAction enumeration values:

```
$ python3
Python 3.10.12 (main, Aug 15 2025, 14:32:43) [GCC 11.4.0] on linux
Type "help", "copyright", "credits" or "license" for more information.
>>> import magicbot_z1_python
>>> help(magicbot_z1_python.TrickAction)
Help on class TrickAction in module magicbot_z1_python:

class TrickAction(pybind11_builtins.pybind11_object)
 |  Method resolution order:
 |      TrickAction
 |      pybind11_builtins.pybind11_object
 |      builtins.object
 |
 |  Methods defined here:
 |
 |  __eq__(...)
 |      __eq__(self: object, other: object, /) -> bool
 |
 |  __getstate__(...)
 |      __getstate__(self: object, /) -> int
 |
 |  __hash__(...)
 |      __hash__(self: object, /) -> int
 |
 |  __index__(...)
```

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```
 |      __index__(self: magicbot_z1_python.TrickAction, /) -> int
 |
 |  __init__(...)
 |      __init__(self: magicbot_z1_python.TrickAction, value: typing.SupportsInt) ->␣
↪None
 |
 |  __int__(...)
 |      __int__(self: magicbot_z1_python.TrickAction, /) -> int
 |
 |  __ne__(...)
 |      __ne__(self: object, other: object, /) -> bool
 |
 |  __repr__(...)
 |      __repr__(self: object, /) -> str
 |
 |  __setstate__(...)
 |      __setstate__(self: magicbot_z1_python.TrickAction, state: typing.SupportsInt,␣
↪/) -> None
 |
 |  __str__(...)
 |      __str__(self: object, /) -> str
 |
 |  ----------------------------------------------------------------------
 |  Readonly properties defined here:
 |
 |  __members__
 |
 |  name
 |      name(self: object, /) -> str
 |
 |  value
 |
 |  ----------------------------------------------------------------------
 |  Data and other attributes defined here:
 |
 |  ACTION_LEFT_GREETING = <TrickAction.ACTION_LEFT_GREETING: 300>
 |
 |  ACTION_NONE = <TrickAction.ACTION_NONE: 0>
 |
 |  ACTION_RIGHT_GREETING = <TrickAction.ACTION_RIGHT_GREETING: 301>
```

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```
|
|  ACTION_SHAKE_HEAD = <TrickAction.ACTION_SHAKE_HEAD: 220>
|
|  ACTION_SHAKE_LEFT_HAND_REACHOUT = <TrickAction.ACTION_SHAKE_LEFT_HAND_...
|
|  ACTION_SHAKE_LEFT_HAND_WITHDRAW = <TrickAction.ACTION_SHAKE_LEFT_HAND_...
|
|  ACTION_SHAKE_RIGHT_HAND_REACHOUT = <TrickAction.ACTION_SHAKE_RIGHT_HAN...
|
|  ACTION_SHAKE_RIGHT_HAND_WITHDRAW = <TrickAction.ACTION_SHAKE_RIGHT_HAN...
|
|  ACTION_TRUN_LEFT_INTRODUCE_HIGH = <TrickAction.ACTION_TRUN_LEFT_INTROD...
|
|  ACTION_TRUN_LEFT_INTRODUCE_LOW = <TrickAction.ACTION_TRUN_LEFT_INTRODU...
|
|  ACTION_TRUN_RIGHT_INTRODUCE_HIGH = <TrickAction.ACTION_TRUN_RIGHT_INTR...
|
|  ACTION_TRUN_RIGHT_INTRODUCE_LOW = <TrickAction.ACTION_TRUN_RIGHT_INTRO...
|
|  ACTION_WELCOME = <TrickAction.ACTION_WELCOME: 340>
|
|  ----------------------------------------------------------------------
|  Static methods inherited from pybind11_builtins.pybind11_object:
|
|  __new__(*args, **kwargs) from pybind11_builtins.pybind11_type
|      Create and return a new object.  See help(type) for accurate signature.
```

6.6 Others

6.6.1 SDK Configuration File

The SDK will generate its default configuration file in the /tmp directory by default during runtime. If the configuration file already exists, it will use the existing configuration:

```
$ ls /tmp/magicbot_z1_mjrrt.yaml
/tmp/magicbot_z1_mjrrt.yaml
```

6.6.2 SDK Logs

The SDK’s internal logs is generated in the /tmp/logs directory by default during runtime:

```
$ ls /tmp/logs/magicbot_z1_sdk.log
/tmp/logs/magicbot_z1_sdk.log
```

CHAPTER 7

Robot Main Control Service (C++)

Provides robot system main controller. Through the `MagicRobot` class, you can perform resource initialization, manage communication connections, and access various sub-controllers such as motion controllers, audio, state monitoring, and sensor controllers.

7.1 Interface Definition

`MagicRobot` is the unified entry class for the robot SDK.

7.1.1 MagicRobot

Item	Content
Function Name	MagicRobot
Function Declaration	`MagicRobot();`
Function Overview	Constructor, creates MagicRobot instance.
Notes	Constructs internal state.

7.1.2 ~MagicRobot

Item	Content
Function Name	~MagicRobot
Function Declaration	`~MagicRobot();`
Function Overview	Destructor, releases MagicRobot instance resources.
Notes	Ensures safe resource release.

7.1.3 Initialize

Item	Content
Function Name	Initialize
Function Declaration	`bool Initialize(const std::string& local_ip);`
Function Overview	Initialize robot system, including controllers and network modules.
Parameter Description	`local_ip`: Local communication IP address.
Return Value	`true` indicates success, `false` indicates failure.
Notes	Must be called before first use.

7.1.4 Shutdown

Item	Content
Function Name	Shutdown
Function Declaration	`void Shutdown();`
Function Overview	Shutdown robot system and release resources.
Notes	Used in conjunction with Initialize.

7.1.5 Release

Item	Content
Function Name	Release
Function Declaration	`void Release();`
Function Overview	Release resources.
Notes	Releases SDK-occupied topic resources.

7.1.6 Connect

Item	Content
Function Name	Connect
Function Declaration	`Status Connect();`
Function Overview	Establish communication connection with robot service.
Return Value	`Status::OK` indicates success.
Notes	Blocking interface, must be called after initialization.

7.1.7 Disconnect

Item	Content
Function Name	Disconnect
Function Declaration	`Status Disconnect();`
Function Overview	Disconnect from robot service.
Return Value	gRPC call status.
Notes	Blocking interface, used in conjunction with Connect.

7.1.8 GetSDKVersion

Item	Content
Function Name	GetSDKVersion
Function Declaration	`std::string GetSDKVersion() const;`
Function Overview	Get current SDK version number.
Return Value	SDK version string (e.g., `0.0.1`).
Notes	Non-blocking interface, convenient for debugging or log marking.

7.1.9 GetMotionControlLevel

Item	Content
Function Name	GetMotionControlLevel
Function Declaration	`ControllerLevel GetMotionControlLevel();`
Function Overview	Get current motion control level (high-level/low-level).
Return Value	`ControllerLevel` enumeration value.
Notes	Non-blocking interface, used to determine current control permissions.

7.1.10 SetMotionControlLevel

Item	Content
Function Name	SetMotionControlLevel
Function Declaration	`Status SetMotionControlLevel(ControllerLevel level);`
Function Overview	Set current motion control level.
Parameter Description	`level`: Control permission enumeration value.
Return Value	`Status::OK` indicates successful setting, others indicate setting failure.
Notes	Blocking interface, used when switching control modes.

7.1.11 GetHighLevelMotionController

Item	Content
Function Name	GetHighLevelMotionController
Function Declaration	`HighLevelMotionController& GetHighLevelMotionController();`
Function Overview	Get high-level motion controller object.
Return Value	Reference type, used to call high-level control interfaces.
Notes	Non-blocking interface, encapsulates gait, tricks, remote control, etc.

7.1.12 GetLowLevelMotionController

Item	Content
Function Name	GetLowLevelMotionController
Function Declaration	`LowLevelMotionController& GetLowLevelMotionController();`
Function Overview	Get low-level motion controller object.
Return Value	Reference type, used to control joints or motors.
Notes	Non-blocking interface, directly controls joint motors, gets IMU data, etc.

7.1.13 GetAudioController

Item	Content
Function Name	GetAudioController
Function Declaration	`AudioController& GetAudioController();`
Function Overview	Get audio controller object.
Return Value	Reference type, used for audio control.
Notes	Non-blocking interface, plays audio and controls volume.

7.1.14 GetSensorController

Item	Content
Function Name	GetSensorController
Function Declaration	`SensorController& GetSensorController();`
Function Overview	Get sensor controller object.
Return Value	Reference type, used to access sensor data.
Notes	Non-blocking interface, encapsulates LiDAR, RGBD, etc. reading.

7.1.15 GetStateMonitor

Item	Content
Function Name	GetStateMonitor
Function Declaration	`StateMonitor& GetStateMonitor();`
Function Overview	Get state monitor object.
Return Value	Reference type, used to get current robot state information.
Notes	Non-blocking interface, encapsulates reading of BMS, faults, and other state information.

7.1.16 GetSlamNavController

Item	Content
Function Name	GetSlamNavController
Function Declaration	`SlamNavController& GetSlamNavController();`
Function Overview	Get SLAM and navigation controller object.
Return Value	Reference type, used for mapping and localization.
Notes	Non-blocking interface, used for robot SLAM mapping and autonomous navigation functions.

CHAPTER 8

High-Level Motion Control Service (C++)

Provides robot system high-level motion control service. Through the `HighLevelMotionController`, you can control robot gait, tricks, and remote control via RPC communication.

8.1 Interface Definition

`HighLevelMotionController` is a high-level motion controller for semantic control, supporting control operations such as walking, tricks, head movement, etc., encapsulating low-level details for upper system calls.

8.1.1 HighLevelMotionController

Item	Content
Function Name	HighLevelMotionController
Function Declaration	`HighLevelMotionController();`
Function Overview	Constructor, initializes high-level controller state
Notes	Constructs internal control resources

8.1.2 ~HighLevelMotionController

Item	Content
Function Name	~HighLevelMotionController
Function Declaration	`virtual ~HighLevelMotionController();`
Function Overview	Destructor, releases controller resources
Notes	Used in conjunction with constructor

8.1.3 Initialize

Item	Content
Function Name	Initialize
Function Declaration	`virtual bool Initialize() override;`
Function Overview	Initialize controller, prepare high-level control functions
Return Value	`true` indicates success, `false` indicates failure
Notes	Must be called before first use

8.1.4 Shutdown

Item	Content
Function Name	Shutdown
Function Declaration	`virtual void Shutdown() override;`
Function Overview	Shutdown controller and release resources
Notes	Used in conjunction with Initialize, safely disconnect

8.1.5 SetGait

Item	Content
Function Name	SetGait
Function Declaration	`Status SetGait(const GaitMode gait_mode, int timeout_ms);`
Function Overview	Set robot gait mode (such as recovery stand, balance stand, humanoid walk, etc.)
Parameter Description	`gait_mode`: Gait control enumeration
Return Value	`Status::OK` indicates success, others indicate failure
Notes	Blocking interface, can switch between multiple gait modes

8.1.6 GetGait

Item	Content
Function Name	GetGait
Function Declaration	`Status GetGait(GaitMode&amp; gait_mode);`
Function Overview	Get robot gait mode (such as recovery stand, balance stand, humanoid walk, etc.)
Parameter Description	`gait_mode`: Gait control enumeration
Return Value	`Status::OK` indicates success, others indicate failure
Notes	Blocking interface, gets current gait mode

8.1.7 ExecuteTrick

Item	Content
Function Name	ExecuteTrick
Function Declaration	`Status ExecuteTrick(const TrickAction trick_action, int timeout_ms);`
Function Overview	Execute trick actions (such as welcome, etc.)
Parameter Description	`trick_action`: Trick action identifier
Return Value	`Status::OK` indicates success, others indicate failure
Notes	Blocking interface, ensure robot can currently execute tricksNote: Trick actions must be performed in GaitMode::GAIT_BALANCE_STAND(46) gait

- Note: Trick actions must be performed in GaitMode::GAIT_BALANCE_STAND(46) gait to execute trick demonstrations

8.1.8 SendJoyStickCommand

Item	Content
Function Name	SendJoyStickCommand
Function Declaration	`Status SendJoyStickCommand(const JoystickCommand&amp; joy_command);`
Function Overview	Send real-time joystick control commands
Parameter Description	`joy_command`: Control data containing joystick coordinates
Return Value	`Status::OK` indicates success, others indicate failure
Notes	Non-blocking interface, recommended sending frequency is 20Hz

8.1.9 HeadMove

Item	Content
Function Name	HeadMove
Function Declaration	`Status HeadMove(float shake_angle, int timeout_ms);`
Function Overview	Control robot head swinging motion
Parameter Description	`shake_angle`: Head swing angle, unit: rad, range: [-0.698, 0.698]`timeout_ms`: Timeout duration, default 5000 milliseconds
Return Value	`Status::OK` indicates success, others indicate failure
Notes	Blocking interface, controls robot head left-right swinging motion

8.2 Type Definitions

8.2.1 `JoystickCommand` —High-Level Motion Control Joystick Command Structure

Field Name	Type	Description
`left_x_axis`	`float`	Left joystick X-axis direction value (-1.0: left, 1.0: right)
`left_y_axis`	`float`	Left joystick Y-axis direction value (-1.0: down, 1.0: up)
`right_x_axis`	`float`	Right joystick X-axis direction value (rotation -1.0: left, 1.0: right)
`right_y_axis`	`float`	Right joystick Y-axis direction value (purpose not yet defined)

8.3 Enumeration Type Definitions

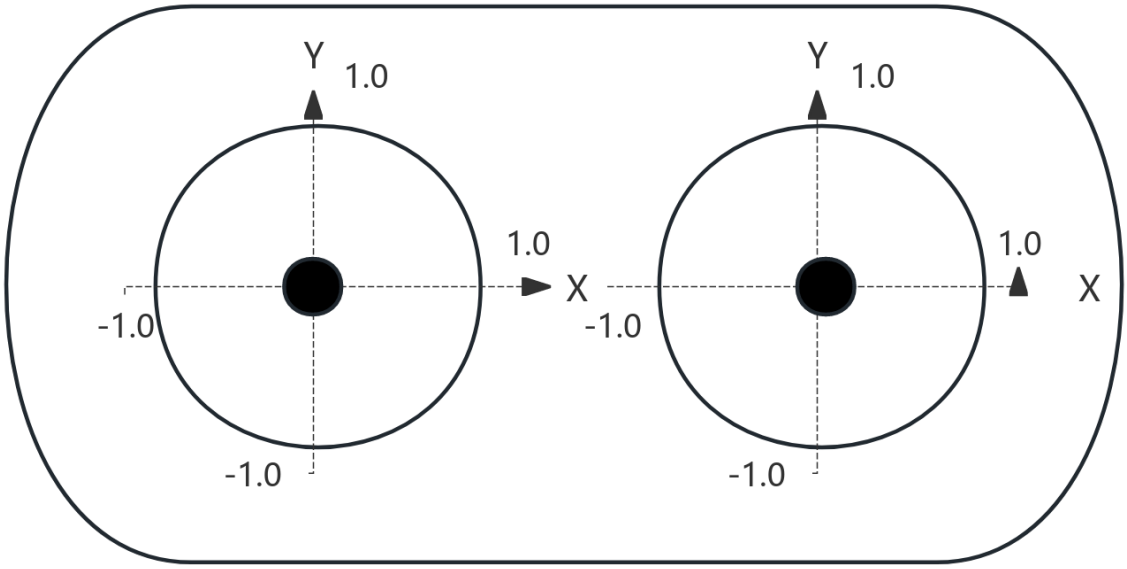
8.3.1 `GaitMode` —Robot Gait Mode Enumeration

Enumeration Value	Value	Description
`GAIT_PASSIVE`	0	Passive
`GAIT_RECOVERY_STAND`	1	Recovery Stand
`GAIT_BALANCE_STAND`	46	Balance Stand (supports movement)
`GAIT_HUMANOID_WALK`	79	Humanoid Walk
`GAIT_LOWLEVL_SDK`	200	Low-Level Control SDK Mode

8.3.2 `TrickAction` —Trick Action Command Enumeration

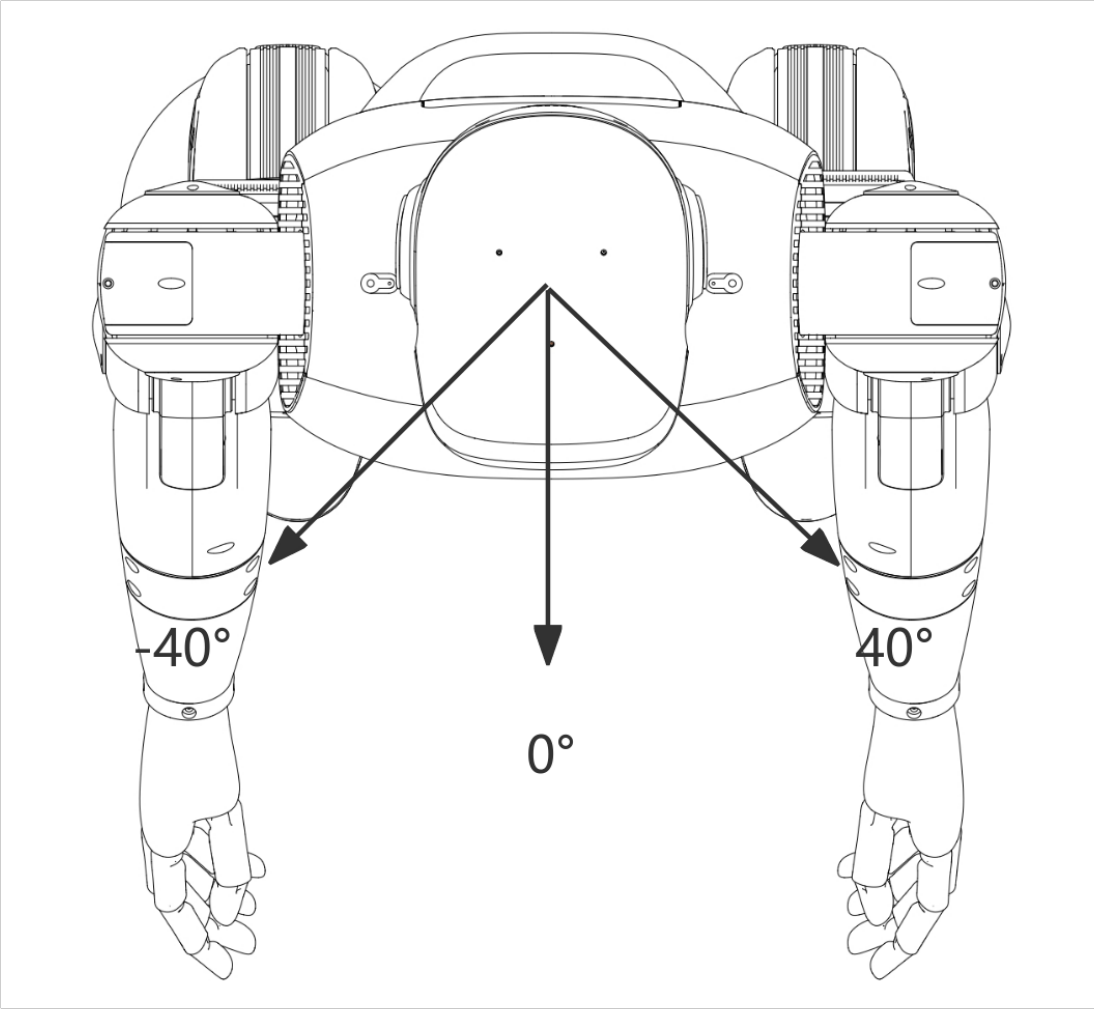
Enumeration Value	Value	Description
ACTION_SHAKE_LEFT_HAND_REACHOUT	215	Handshake (Left Hand) - Reach Out
ACTION_SHAKE_LEFT_HAND_WITHDRAW	216	Handshake (Left Hand) - Withdraw
ACTION_SHAKE_RIGHT_HAND_REACHOUT	217	Handshake (Right Hand) - Reach Out
ACTION_SHAKE_RIGHT_HAND_WITHDRAW	218	Handshake (Right Hand) - Withdraw
ACTION_SHAKE_HEAD	220	Shake Head
ACTION_LEFT_GREETING	300	Greeting (Left Hand)
ACTION_RIGHT_GREETING	301	Greeting (Right Hand)
ACTION_TRUN_LEFT_INTRODUCE_HIGH	304	Turn Left Introduce - High
ACTION_TRUN_LEFT_INTRODUCE_LOW	305	Turn Left Introduce - Low
ACTION_TRUN_RIGHT_INTRODUCE_HIGH	306	Turn Right Introduce - High
ACTION_TRUN_RIGHT_INTRODUCE_LOW	307	Turn Right Introduce - Low
ACTION_WELCOME	340	Welcome
FLY_KISS_LEFT	408	Air Kiss - Left Hand
FLY_KISS_RIGHT	409	Air Kiss - Right Hand
SUPERMAN_WAVE	410	Superman Wave
CLAP_HAND	411	Clap Hands
HOLD_CERT_REACHOUT	412	Hold Certificate - Reach Out
HOLD_CERT_WITHDRAW	413	Hold Certificate - Withdraw
HUG_REACHOUT	414	Hug with Both Hands - Reach Out
HUG_WITHDRAW	415	Hug with Both Hands - Withdraw
TRUN_WAVE_LEFT	417	Turn and Wave - Left Hand
TRUN_WAVE_RIGHT	418	Turn and Wave - Right Hand
RIGHT_HAND_SALUTE	419	Right Hand Salute

8.4 Joystick Diagram



1. The X-axis and Y-axis value ranges for left and right joysticks are [-1.0, 1.0];
2. The up/right direction of the left and right joystick X-axis and Y-axis is positive, as shown in the diagram;

8.5 Head Movement Range Diagram



- Movement Range [-40°, 40°] ([-0.698rad, 0.698rad])

8.6 High-Level Motion Control Robot State Introduction

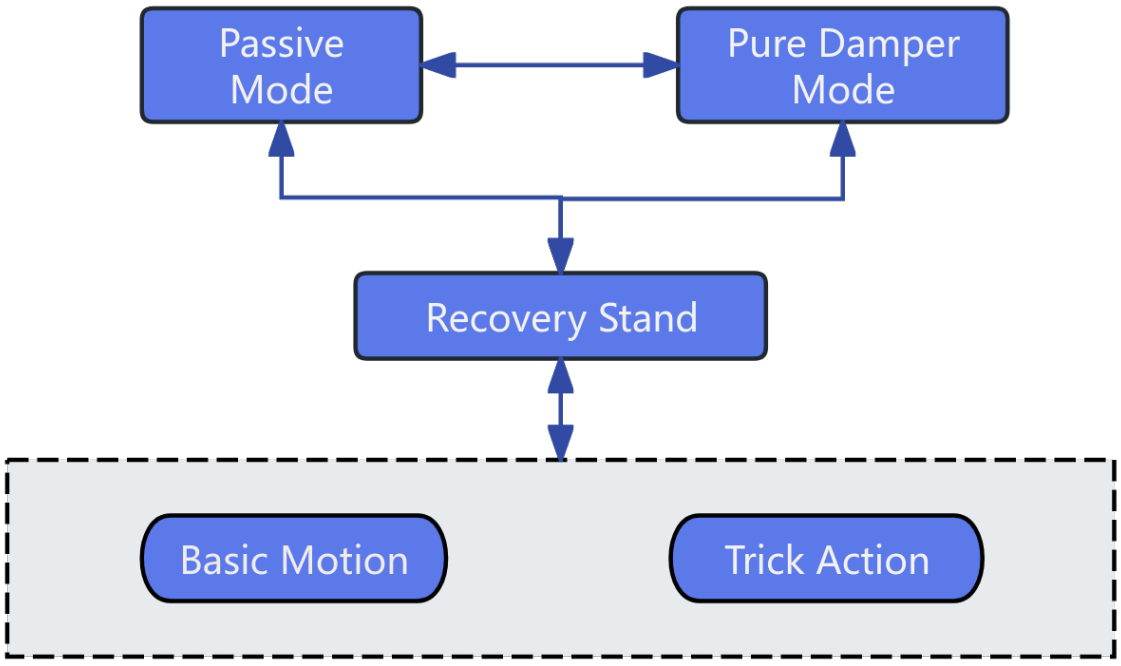
Robot motion includes recovery stand, balance stand, basic motion, and trick action states. During operation, the robot switches between different states through a state machine to achieve different control tasks. The explanations for each state are as follows:

- **Recovery Stand**: Recovery stand is the state connecting robot suspension landing and balance stand. The robot needs to enter the balance stand state before calling corresponding motion services to achieve robot control.
- **Balance Stand**: In the balance stand state, you can call various SDK interfaces to achieve robot trick actions and

basic motion control.

- **Basic Motion**: During motion execution, you can call SDK interfaces to make the robot enter different gaits.
- **Trick Actions**: When entering the special action execution state, other motion control services will be suspended first, waiting for the current action to complete and enter the balance stand state before taking effect again.

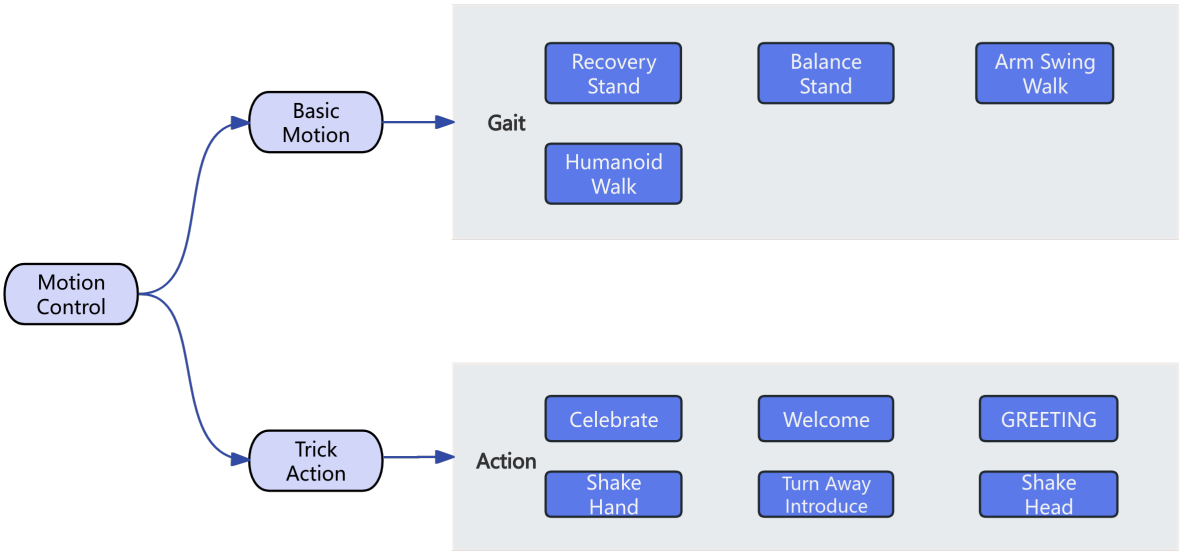
Robot state switching mechanism;



8.7 High-Level Motion Control Interface

Robot high-level motion control services can be divided into basic motion control and trick action control.

- In basic motion control services, you can call corresponding interfaces to switch robot walking gaits according to different terrain scenarios and task requirements.
- In trick action control services, you can call corresponding interfaces to achieve robot built-in special tricks, such as celebrate, handshake, greeting, etc.



8.7.1 Gait Switching

Current Gait	Gait Switching Process	Diagram
Recovery Stand		
Balance Stand		
Arm Swing Walk		
Humanoid Walk		

8.7.2 Trick Execution

Trick	Trick Execution Process	Diagram
Welcome		
Shake Head		
Greeting (Left Hand)		
Greeting (Right Hand)		
Handshake (Left Hand)		
Handshake (Right Hand)		
Turn Left Introduction		
Turn Right Introduction		

CHAPTER 9

Low-Level Motion Control Service (C++)

Provides robot system low-level motion control service. Through the `LowLevelMotionController`, you can control robot joints and obtain status via topic communication.

9.1 Interface Definition

`LowLevelMotionController` is a motion controller for low-level development, supporting direct control and state subscription of motion components such as arms, legs, head, waist, hands, etc., as well as body IMU data acquisition.

9.1.1 LowLevelMotionController

Item	Content
Function Name	LowLevelMotionController
Function Declaration	`LowLevelMotionController();`
Function Overview	Constructor, initializes low-level controller object.
Notes	Constructs internal resources.

9.1.2 ~LowLevelMotionController

Item	Content
Function Name	~LowLevelMotionController
Function Declaration	`virtual ~LowLevelMotionController();`
Function Overview	Destructor, releases resources.
Notes	Cleans up low-level resources.

9.1.3 Initialize

Item	Content
Function Name	Initialize
Function Declaration	`virtual bool Initialize() override;`
Function Overview	Initialize controller, establish low-level connections.
Return Value	`true` indicates success, `false` indicates failure.
Notes	Must be initialized on first call.

9.1.4 Shutdown

Item	Content
Function Name	Shutdown
Function Declaration	`virtual void Shutdown() override;`
Function Overview	Shutdown controller, release low-level resources.
Notes	Used in conjunction with Initialize.

9.1.5 SubscribeArmState

Item	Content
Function Name	SubscribeArmState
Function Declaration	`void SubscribeArmState(ArmJointStateCallback callback);`
Function Overview	Subscribe to arm joint state data
Parameter Description	callback: Data processing function
Notes	Non-blocking interface.

9.1.6 PublishArmCommand

Item	Content
Function Name	PublishArmCommand
Function Declaration	`Status PublishArmCommand(const JointCommand& command);`
Function Overview	Publish arm control commands
Parameter Description	command: Target position/velocity etc.
Return Value	`true` indicates success, `false` indicates failure.
Notes	Non-blocking interface.

9.1.7 SubscribeLegState

Item	Content
Function Name	SubscribeLegState
Function Declaration	`void SubscribeLegState(LegJointStateCallback callback);`
Function Overview	Subscribe to leg joint state data
Parameter Description	callback: Data processing function
Notes	Non-blocking interface.

9.1.8 PublishLegCommand

Item	Content
Function Name	PublishLegCommand
Function Declaration	`Status PublishLegCommand(const JointCommand& command);`
Function Overview	Publish leg control commands
Parameter Description	command: Target position/velocity etc.
Return Value	`true` indicates success, `false` indicates failure.
Notes	Non-blocking interface, called when publishing or subscribing.

9.1.9 SubscribeHeadState

Item	Content
Function Name	SubscribeHeadState
Function Declaration	`void SubscribeHeadState(HeadJointStateCallback callback);`
Function Overview	Subscribe to head joint state data
Parameter Description	callback: Data processing function
Notes	Non-blocking interface.

9.1.10 PublishHeadCommand

Item	Content
Function Name	PublishHeadCommand
Function Declaration	`Status PublishHeadCommand(const JointCommand& command);`
Function Overview	Publish head control commands
Parameter Description	command: Target position/velocity etc.
Return Value	`true` indicates success, `false` indicates failure.
Notes	Non-blocking interface.

9.1.11 SubscribeWaistState

Item	Content
Function Name	SubscribeWaistState
Function Declaration	`void SubscribeWaistState(WaistJointStateCallback callback);`
Function Overview	Subscribe to waist joint state data
Parameter Description	callback: Data processing function
Notes	Non-blocking interface.

9.1.12 PublishWaistCommand

Item	Content
Function Name	PublishWaistCommand
Function Declaration	`Status PublishWaistCommand(const JointCommand& command);`
Function Overview	Publish waist control commands
Parameter Description	command: Target position/velocity etc.
Return Value	`true` indicates success, `false` indicates failure.
Notes	Non-blocking interface.

9.1.13 SubscribeHandState

Item	Content
Function Name	SubscribeHandState
Function Declaration	`void SubscribeHandState(HandStateCallback callback);`
Function Overview	Subscribe to hand state data
Parameter Description	callback: Data processing function
Notes	Non-blocking interface.

9.1.14 PublishHandCommand

Item	Content
Function Name	PublishHandCommand
Function Declaration	`Status PublishHandCommand(const HandCommand& command);`
Function Overview	Publish hand control commands
Parameter Description	command: Hand joint target position etc.
Return Value	`true` indicates success, `false` indicates failure.
Notes	Non-blocking interface.

9.1.15 SubscribeBodyImu

Item	Content
Function Name	SubscribeBodyImu
Function Declaration	`void SubscribeBodyImu(const BodyImuCallback& callback);`
Function Overview	Subscribe to body IMU data
Parameter Description	callback: IMU data processing function
Notes	Non-blocking interface.

9.1.16 SubscribeEstimatorState

Item	Content
Function Name	SubscribeEstimatorState
Function Declaration	`void SubscribeEstimatorState(const EstimatorStateCallback& callback);`
Function Overview	Subscribe to estimator state data
Parameter Description	callback: estimator state data processing function
Notes	Non-blocking interface.

9.1.17 UnsubscribeArmState

Item	Content
Function Name	UnsubscribeArmState
Function Declaration	`void UnsubscribeArmState();`
Function Overview	Unsubscribe from arm joint state data
Notes	Non-blocking interface, used in conjunction with SubscribeArmState.

9.1.18 UnsubscribeLegState

Item	Content
Function Name	UnsubscribeLegState
Function Declaration	`void UnsubscribeLegState();`
Function Overview	Unsubscribe from leg joint state data
Notes	Non-blocking interface, used in conjunction with SubscribeLegState.

9.1.19 UnsubscribeHeadState

Item	Content
Function Name	UnsubscribeHeadState
Function Declaration	`void UnsubscribeHeadState();`
Function Overview	Unsubscribe from head joint state data
Notes	Non-blocking interface, used in conjunction with SubscribeHeadState.

9.1.20 UnsubscribeWaistState

Item	Content
Function Name	UnsubscribeWaistState
Function Declaration	`void UnsubscribeWaistState();`
Function Overview	Unsubscribe from waist joint state data
Notes	Non-blocking interface, used in conjunction with SubscribeWaistState.

9.1.21 UnsubscribeHandState

Item	Content
Function Name	UnsubscribeHandState
Function Declaration	`void UnsubscribeHandState();`
Function Overview	Unsubscribe from hand state data
Notes	Non-blocking interface, used in conjunction with SubscribeHandState.

9.1.22 UnsubscribeBodyImu

Item	Content
Function Name	UnsubscribeBodyImu
Function Declaration	`void UnsubscribeBodyImu();`
Function Overview	Unsubscribe from body IMU data
Notes	Non-blocking interface, used in conjunction with SubscribeBodyImu.

9.1.23 UnsubscribeEstimatorState

Item	Content
Function Name	UnsubscribeEstimatorState
Function Declaration	`void UnsubscribeEstimatorState();`
Function Overview	Unsubscribe from body state estimator data
Notes	Non-blocking interface, used in conjunction with SubscribeEstimatorState.

9.2 Type Definitions

9.2.1 `SingleHandJointCommand` —Single Hand Joint Control Command

Field Name	Type	Description
`operation_mode`	`int16_t`	Control word
`pos`	`vector<float>`	Desired position array (7 DOF, unit: rad)

9.2.2 `HandCommand` —Complete Hand Control Command

Field Name	Type	Description
`timestamp`	`int64_t`	Timestamp (unit: nanoseconds)
`cmd`	`vector<SingleHandJointCommand>`	Control command array, left hand and right hand in order

9.2.3 `SingleHandJointState` —Single Hand Joint State

Field Name	Type	Description
`status_word`	`int16_t`	Status word
`pos`	`vector<float>`	Current position (unit: rad)
`toq`	`vector<float>`	Current torque (unit: Nm)
`cur`	`vector<float>`	Current current (unit: A)
`error_code`	`int16_t`	Error code

9.2.4 `HandState` —Complete Hand State Information

Field Name	Type	Description
`timestamp`	`int64_t`	Timestamp (unit: nanoseconds)
`state`	`vector<SingleHandJointState>`	All hand joint states (left hand, right hand order)

9.2.5 `SingleJointCommand` —Single Joint Control Command

Field Name	Type	Description
`operation_mode`	`int16_`	Control mode identifier: • 200 = Standby mode • 3 = Parallel triple-loop control (MIT mode) • 4 = Serial triple-loop control
`pos`	`float`	Target position (unit: rad)
`vel`	`float`	Velocity limit (unit: rad/s)
`toq`	`float`	Torque limit (unit: Nm)
`kp`	`float`	Position loop proportional gain
`kd`	`float`	Velocity loop derivative gain

- For joints 1-5 of the arm, the `operation_mode` needs to be switched from mode 200 (standby) to mode 3 (parallel triple-loop control, MIT mode) before sending commands.
- For joint 1 of the waist, the `operation_mode` needs to be switched from mode 200 (standby) to mode 3 (parallel triple-loop control, MIT mode) before sending commands.
- For joints 1-6 of the legs, the `operation_mode` needs to be switched from mode 200 (standby) to mode 3 (parallel triple-loop control, MIT mode) before sending commands.
- The head joint uses pure position control and does not require setting `operation_mode`.

9.2.6 `JointCommand` —Joint Control Command

Lower limbs contain 12 joint items, upper limbs 10(14), head 1(2), waist 1:

Field Name	Type	Description
`timestamp`	`int64_t`	Timestamp (unit: nanoseconds)
`joints`	`vector<SingleJointCommand>`	Control commands for all joints

9.2.7 `SingleJointState` —Single Joint State Information

Field Name	Type	Description
`status_word`	`int16_t`	Current joint state (custom state machine encoding)
`posH`	`float`	Actual position (high-precision encoder reading)
`posL`	`float`	Actual position (low-precision encoder reading, for redundancy check)
`vel`	`float`	Current velocity (unit: rad/s or m/s, automatically switches based on joint type)
`toq`	`float`	Current torque (unit: Nm)
`current`	`float`	Current current (unit: A)
`err_code`	`int16_t`	Error code (such as encoder exception, motor overcurrent, etc., see error code reference table)

9.2.8 `JointState` —Joint State Data

Lower limbs contain 12 joint items, upper limbs 10(14), head 1(2), waist 1:

Field Name	Type	Description
`timestamp`	`int64_t`	Timestamp (unit: nanoseconds)
`joints`	`vector<SingleJointState>`	State data for all joints

9.2.9 `EstimatorState` —State Estimation Data

Field Name	Type	Description
w_base_pos	std::array<double, 3>	Robot base position(m) in world coordinates
w_com_pos	std::array<double, 3>	Center of mass position(m) in world coordinates
w_com_vel	std::array<double, 3>	Center of mass velocity(m/s) in world coordinates
w_base_vel	std::array<double, 3>	Robot base velocity(m/s) in world coordinates
b_base_vel	std::array<double, 3>	Robot base velocity(m/s) in body coordinates

9.2.10 Joint Motor Order

Head Joint

Index	Joint Name
0	`head_joint`

Arm Joints

Index	Joint Name
0	`left_shoulder_pitch_joint`
1	`left_shoulder_roll_joint`
2	`left_shoulder_yaw_joint`
3	`left_elbow_joint`
4	`left_wrist_yaw_joint`
5	`left_wrist_roll_joint`
6	`left_wrist_pitch_joint`
7	`right_shoulder_pitch_joint`
8	`right_shoulder_roll_joint`
9	`right_shoulder_yaw_joint`
10	`right_elbow_roll_joint`
11	`right_wrist_yaw_joint`
12	`right_wrist_roll_joint`
13	`right_wrist_pitch_joint`

Waist Joint

Index	Joint Name
0	`waist_yaw_joint`

Leg Joints

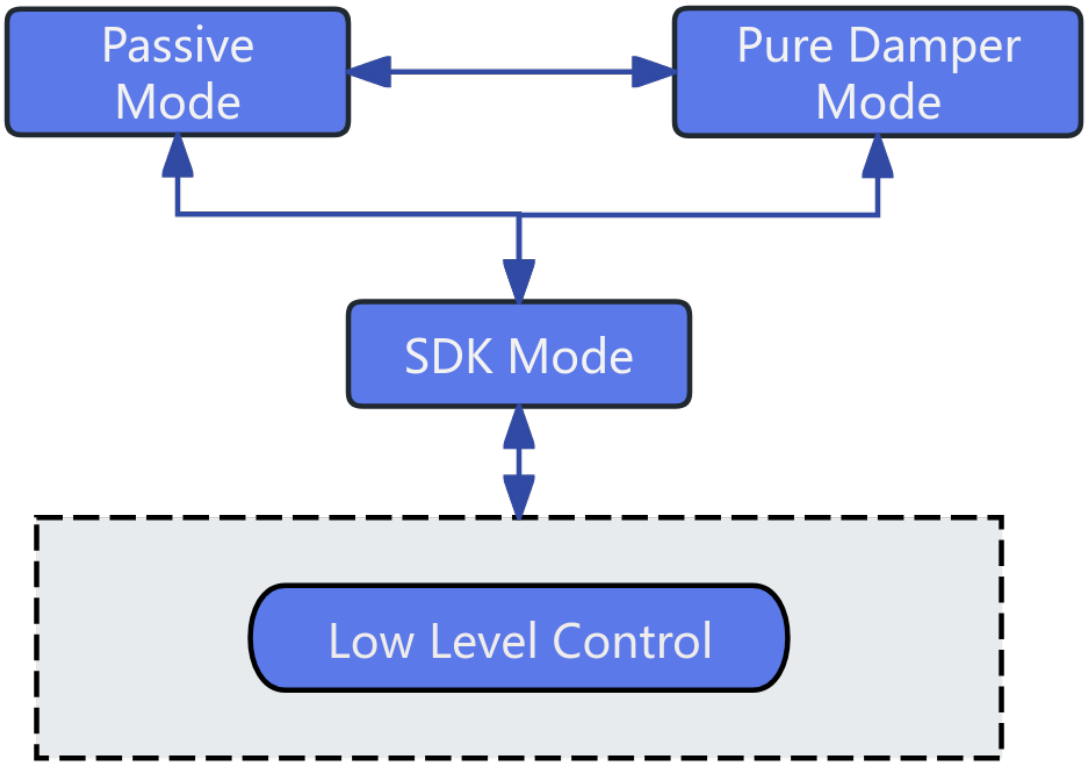
Index	Joint Name
0	left_hip_pitch_joint
1	left_hip_roll_joint
2	left_hip_yaw_joint
3	left_knee_joint
4	left_ankle_pitch_joint
5	left_ankle_roll_joint
6	right_hip_pitch_joint
7	right_hip_roll_joint
8	right_hip_yaw_joint
9	right_knee_joint
10	right_ankle_pitch_joint
11	right_ankle_roll_joint

9.3 URDF Reference

Robot URDF

9.4 Low-Level Motion Control Robot State Introduction

Robot low-level motion mainly develops three-loop control of joints for developers to perform secondary development of robot motion capabilities, basic control state switching mechanism:



9.5 Notice:

- When using subscription-type SDK interfaces such as Subscribe, do not perform blocking operations within the callback function. Doing so may cause message congestion, processing delays, or even unexpected errors.
- The Z1 robot’ s upper arm joints have 5-degree-of-freedom and 7-degree-of-freedom SKU versions. For different versions, the joint motor sequence and names are used in order, and nonexistent joints can be ignored.

CHAPTER 10

Sensor Control Service (C++)

Provides robot system sensor (LiDAR/RGBD camera/binocular camera) services. Through the `SensorController`, you can control robot sensors and obtain status via RPC and topic methods.

10.1 Interface Definition

`SensorController` is a management class that encapsulates various robot sensors, supporting initialization, control, and data subscription of LiDAR, RGBD cameras, and binocular cameras.

10.1.1 SensorController

Item	Content
Function Name	SensorController
Function Declaration	`SensorController();`
Function Overview	Constructor, initializes sensor controller object.
Notes	Constructs internal state.

10.1.2 ~SensorController

Item	Content
Function Name	~SensorController
Function Declaration	`virtual ~SensorController();`
Function Overview	Destructor, releases all sensor resources.
Notes	Sensors should be closed before calling.

10.1.3 Initialize

Item	Content
Function Name	Initialize
Function Declaration	`bool Initialize();`
Function Overview	Initialize controller, including resource allocation and driver loading.
Return Value	`true` indicates success, `false` indicates failure.
Notes	Object must be constructed before calling.

10.1.4 Shutdown

Item	Content
Function Name	Shutdown
Function Declaration	`void Shutdown();`
Function Overview	Close all sensor connections and release resources.
Notes	Used in conjunction with Initialize.

10.1.5 OpenLidar

Item	Content
Function Name	OpenLidar
Function Declaration	`Status OpenLidar();`
Function Overview	Open LiDAR.
Return Value	`Status::OK` indicates success, others indicate failure.
Notes	Blocking interface.

10.1.6 CloseLidar

Item	Content
Function Name	CloseLidar
Function Declaration	`Status CloseLidar();`
Function Overview	Close LiDAR.
Return Value	`Status::OK` indicates success, others indicate failure.
Notes	Blocking interface, used in conjunction with open function.

10.1.7 OpenRgbdCamera

Item	Content
Function Name	OpenRgbdCamera
Function Declaration	`Status OpenRgbdCamera();`
Function Overview	Open RGBD camera (head).
Return Value	`Status::OK` indicates success, others indicate failure.
Notes	Blocking interface.

10.1.8 CloseRgbdCamera

Item	Content
Function Name	CloseRgbdCamera
Function Declaration	`Status CloseRgbdCamera();`
Function Overview	Close RGBD camera.
Return Value	`Status::OK` indicates success, others indicate failure.
Notes	Blocking interface, used in conjunction with open function.

10.1.9 OpenBinocularCamera

Item	Content
Function Name	OpenBinocularCamera
Function Declaration	`Status OpenBinocularCamera();`
Function Overview	Open binocular camera.
Return Value	`Status::OK` indicates success, others indicate failure.
Notes	Blocking interface.

10.1.10 CloseBinocularCamera

Item	Content
Function Name	CloseBinocularCamera
Function Declaration	`Status CloseBinocularCamera();`
Function Overview	Close binocular camera.
Return Value	`Status::OK` indicates success, others indicate failure.
Notes	Blocking interface.

10.1.11 SubscribeLidarImu

Item	Content
Function Name	SubscribeLidarImu
Function Declaration	`void SubscribeLidarImu(const LidarImuCallback& callback);`
Function Overview	Subscribe to LiDAR IMU data
Parameter Description	callback: Data processing function after receiving data
Notes	Non-blocking interface, callback function will be called when data is updated.

10.1.12 SubscribeLidarPointCloud

Item	Content
Function Name	SubscribeLidarPointCloud
Function Declaration	`void SubscribeLidarPointCloud(const LidarPointCloudCallback& callback);`
Function Overview	Subscribe to LiDAR point cloud data
Parameter Description	callback: Point cloud processing function after receiving data
Notes	Non-blocking interface, callback function will be called when data is updated.

10.1.13 SubscribeHeadRgbdColorImage

Item	Content
Function Name	SubscribeHeadRgbdColorImage
Function Declaration	`void SubscribeHeadRgbdColorImage(const RgbdImageCallback& callback);`
Function Overview	Subscribe to head RGBD color image data
Parameter Description	callback: Image processing function after receiving data
Notes	Non-blocking interface, callback function will be called when data is updated.

10.1.14 SubscribeHeadRgbdDepthImage

Item	Content
Function Name	SubscribeHeadRgbdDepthImage
Function Declaration	`void SubscribeHeadRgbdDepthImage(const RgbdImageCallback& callback);`
Function Overview	Subscribe to head RGBD depth image data
Parameter Description	callback: Image processing function after receiving data
Notes	Non-blocking interface, callback function will be called when data is updated.

10.1.15 SubscribeHeadRgbdCameraInfo

Item	Content
Function Name	SubscribeHeadRgbdCameraInfo
Function Declaration	`void SubscribeHeadRgbdCameraInfo(const RgbdCameraInfoCallback& callback);`
Function Overview	Subscribe to head RGBD camera parameters
Parameter Description	callback: Parameter processing function after receiving data
Notes	Non-blocking interface, callback function will be called when data is updated.

10.1.16 SubscribeBinocularImage

Item	Content
Function Name	SubscribeBinocularImage
Function Declaration	`void SubscribeBinocularImage(const BinocularImageCallback& callback);`
Function Overview	Subscribe to binocular camera image frames
Parameter Description	callback: Image frame processing function after receiving data
Notes	Non-blocking interface, callback function will be called when data is updated.

10.1.17 SubscribeBinocularCameraInfo

Item	Content
Function Name	SubscribeBinocularCameraInfo
Function Declaration	`void SubscribeBinocularCameraInfo(const RgbdCameraInfoCallback& callback);`
Function Overview	Subscribe to binocular camera parameters
Parameter Description	callback: Parameter processing function after receiving data
Notes	Non-blocking interface, callback function will be called when data is updated.

10.2 Type Definitions

10.2.1 `Imu` —IMU Data Structure

Field Name	Type	Description
`timestamp`	`int64_t`	Timestamp (unit: nanoseconds)
`orientation[4]`	`std::array<double, 4>`	Attitude quaternion (w, x, y, z)
`angular_velocity[3]`	`std::array<double, 3>`	Angular velocity (unit: rad/s)
`linear_acceleration[3]`	`std::array<double, 3>`	Linear acceleration (unit: m/s^2)
`temperature`	`float`	Temperature (unit: Celsius or other, unit should be specified)

10.2.2 `Header` —Common Message Header Structure

Field Name	Type	Description
`stamp`	`int64_t`	Timestamp (unit: nanoseconds)
`frame_id`	`std::string`	Coordinate frame name

10.2.3 `PointField` —Point Field Description

Field Name	Type	Description
`name`	`std::string`	Field name (such as x, y, z, intensity)
`offset`	`int32_t`	Starting byte offset
`datatype`	`int8_t`	Data type (corresponding constant)
`count`	`int32_t`	Number of elements this field contains per point

10.2.4 `PointCloud2` —Point Cloud Data Structure

Field Name	Type	Description
`header`	`Header`	Message header
`height`	`int32_t`	Number of rows
`width`	`int32_t`	Number of columns
`fields`	`vector&lt;PointField&gt;`	Point field array
`is_bigendian`	`bool`	Byte order
`point_step`	`int32_t`	Number of bytes per point
`row_step`	`int32_t`	Number of bytes per row
`data`	`vector&lt;uint8_t&gt;`	Raw point cloud byte data
`is_dense`	`bool`	Whether dense point cloud

10.2.5 `Image` —Image Data Structure

Field Name	Type	Description
`header`	`Header`	Message header
`height`	`int32_t`	Image height (pixels)
`width`	`int32_t`	Image width (pixels)
`encoding`	`std::string`	Encoding type (such as rgb8, mono8)
`is_bigendian`	`bool`	Whether big-endian mode
`step`	`int32_t`	Number of bytes per image row
`data`	`vector&lt;uint8_t&gt;`	Raw image byte data

10.2.6 `CameraInfo` —Camera Intrinsic Parameters and Distortion Information

Field Name	Type	Description
`header`	`Header`	Message header
`height`	`int32_t`	Image height
`width`	`int32_t`	Image width
`distortion_model`	`std::string`	Distortion model (such as plumb_bob)
`D`	`vector<double>`	Distortion parameter array
`K`	`std::array<double, 9>`	Camera intrinsic parameter matrix
`R`	`std::array<double, 9>`	Rectification matrix
`P`	`std::array<double, 12>`	Projection matrix
`binning_x`	`int32_t`	Horizontal binning coefficient
`binning_y`	`int32_t`	Vertical binning coefficient
`roi_x_offset`	`int32_t`	ROI starting x coordinate
`roi_y_offset`	`int32_t`	ROI starting y coordinate
`roi_height`	`int32_t`	ROI height
`roi_width`	`int32_t`	ROI width
`roi_do_rectify`	`bool`	Whether to perform rectification

10.2.7 `BinocularCameraFrame` —Binocular Camera Frame Data Structure

Field Name	Type	Description
`header`	`Header`	Common message header
`format`	`std::string`	Image format
`data`	`vector<uint8_t>`	Left eye and binocular stitched image data, left half is left eye image, right half is right eye image

10.3 Notice:

When using subscription-type SDK interfaces such as Subscribe, do not perform blocking operations within the callback function. Doing so may cause message congestion, processing delays, or even unexpected errors.

CHAPTER 11

Audio Control Service (C++)

Provides robot system audio service controller. Through the `AudioController`, you can control robot audio and obtain status via RPC methods.

11.1 Interface Definition

`AudioController` is a C++ class that encapsulates audio control functionality, mainly used for audio playback control, TTS playback, volume setting and query, etc.

11.1.1 AudioController

Item	Content
Function Name	AudioController
Function Declaration	`AudioController();`
Function Overview	Initialize audio controller object, construct internal state, allocate resources, etc.
Notes	Constructs internal state.

11.1.2 ~AudioController

Item	Content
Function Name	~AudioController
Function Declaration	`~AudioController();`
Function Overview	Release audio controller resources, ensure playback stops and clean up low-level resources.
Notes	Ensures safe resource release.

11.1.3 Initialize

Item	Content
Function Name	Initialize
Function Declaration	`bool Initialize();`
Function Overview	Initialize audio control module, prepare playback resources and devices.
Return Value	`true` indicates success, `false` indicates failure.
Notes	Used in conjunction with `Shutdown()`.

11.1.4 Shutdown

Item	Content
Function Name	Shutdown
Function Declaration	`void Shutdown();`
Function Overview	Shutdown audio controller and release resources.
Notes	Ensure called before destruction.

11.1.5 Play

Item	Content
Function Name	Play
Function Declaration	`Status Play(const TtsCommand&amp; cmd, int timeout_ms);`
Function Overview	Play TTS (text-to-speech) voice commands.
Parameter Description	`cmd`: TTS command, contains text, speech rate, tone, etc.
Return Value	`Status::OK` indicates success, others indicate failure state.
Notes	Blocking interface, ensure module is initialized before calling.

11.1.6 Stop

Item	Content
Function Name	Stop
Function Declaration	`Status Stop();`
Function Overview	Stop current audio playback.
Return Value	`Status::OK` indicates success, others indicate failure state.
Notes	Blocking interface, usually used to interrupt current voice.

11.1.7 SetVolume

Item	Content
Function Name	SetVolume
Function Declaration	`Status SetVolume(int volume);`
Function Overview	Set audio output volume.
Parameter Description	`volume`: Volume value, typically ranges from 0~100.
Return Value	`Status::OK` indicates success, others indicate failure state.
Notes	Blocking interface, takes effect immediately after setting.

11.1.8 GetVolume

Item	Content
Function Name	GetVolume
Function Declaration	`Status GetVolume(int&amp; volume);`
Function Overview	Get current audio output volume.
Parameter Description	`volume`: Returns current volume value by reference.
Return Value	`Status::OK` indicates success, others indicate failure state.
Notes	Blocking interface, return value should be checked before using `volume`.

11.1.9 OpenAudioStream

Item	Content
Function Name	OpenAudioStream
Function Declaration	`Status OpenAudioStream();`
Function Overview	Open audio stream, prepare for audio playback.
Return Value	Operation status, returns Status::OK on success.

11.1.10 CloseAudioStream

Item	Content
Function Name	CloseAudioStream
Function Declaration	`Status CloseAudioStream();`
Function Overview	Close audio stream.
Return Value	Operation status, returns Status::OK on success.

11.1.11 SubscribeOriginAudioStream

Item	Content
Function Name	SubscribeOriginAudioStream
Function Declaration	`void SubscribeOriginAudioStream(const OriginAudioStreamCallback callback);`
Function Overview	Subscribe to original audio stream data.
Parameter Description	callback: Processing callback function after receiving original audio stream data

11.1.12 UnsubscribeOriginAudioStream

Item	Content
Function Name	UnsubscribeOriginAudioStream
Function Declaration	`void UnsubscribeOriginAudioStream();`
Function Overview	Unsubscribe from original audio stream data.

11.1.13 SubscribeBfAudioStream

Item	Content
Function Name	SubscribeBfAudioStream
Function Declaration	`void SubscribeBfAudioStream(const BfAudioStreamCallback callback);`
Function Overview	Subscribe to BF audio stream data.
Parameter Description	callback: Processing callback function after receiving BF audio stream data

11.1.14 UnsubscribeBfAudioStream

Item	Content
Function Name	UnsubscribeBfAudioStream
Function Declaration	`void UnsubscribeBfAudioStream();`
Function Overview	Unsubscribe from BF audio stream data.

11.1.15 OpenWakeupStatusStream

Item	Content
Function Name	OpenWakeupStatusStream
Function Declaration	`Status OpenWakeupStatusStream();`
Function Overview	Enable voice wakeup status stream.
Return Value	Operation status, returns Status::OK on success.

11.1.16 CloseWakeupStatusStream

Item	Content
Function Name	CloseWakeupStatusStream
Function Declaration	`Status CloseWakeupStatusStream();`
Function Overview	Disable voice wakeup status stream.
Return Value	Operation status, returns Status::OK on success.

11.1.17 SubscribeWakeupStatus

Item	Content
Function Name	SubscribeWakeupStatus
Function Declaration	`void SubscribeWakeupStatus(const WakeupStatusCallback callback);`
Function Overview	Subscribe to voice wakeup status.
Parameter Description	callback: Processing callback function after receiving wakeup status

11.1.18 UnsubscribeWakeupStatus

Item	Content
Function Name	UnsubscribeWakeupStatus
Function Declaration	`void UnsubscribeWakeupStatus();`
Function Overview	Unsubscribe from voice wakeup status.

11.2 Type Definitions

11.2.1 `TtsPriority` —TTS Playback Priority Level

Used to control interrupt behavior between different TTS tasks. Higher priority tasks will interrupt playback of current lower priority tasks.

Enumeration Value	Description
`TtsPriority::HIGH`	Highest priority, e.g.: low battery warning, emergency alerts
`TtsPriority::MIDDLE`	Medium priority, e.g.: system prompts, status announcements
`TtsPriority::LOW`	Lowest priority, e.g.: daily voice conversation, background announcements

11.2.2 `TtsMode` —Task Scheduling Strategy Under Same Priority

Used to fine-tune control of playback order and clearing logic for multiple TTS tasks under the same priority conditions.

Enumeration Value	Description
`TtsMode::CLEARTOP`	Clear all tasks of current priority (including currently playing and waiting queue), immediately play this request
`TtsMode::ADD`	Append this request to the end of current priority queue, play in order (does not interrupt current playback)
`TtsMode::CLEARBUFI`	Clear unplayed requests in queue, keep current playback, then play this request

11.3 Structure Definitions

11.3.1 `TtsCommand` —TTS Playback Command Structure

Describes complete information for a TTS playback request, supporting unique identifier, text content, priority control, and scheduling mode under same priority.

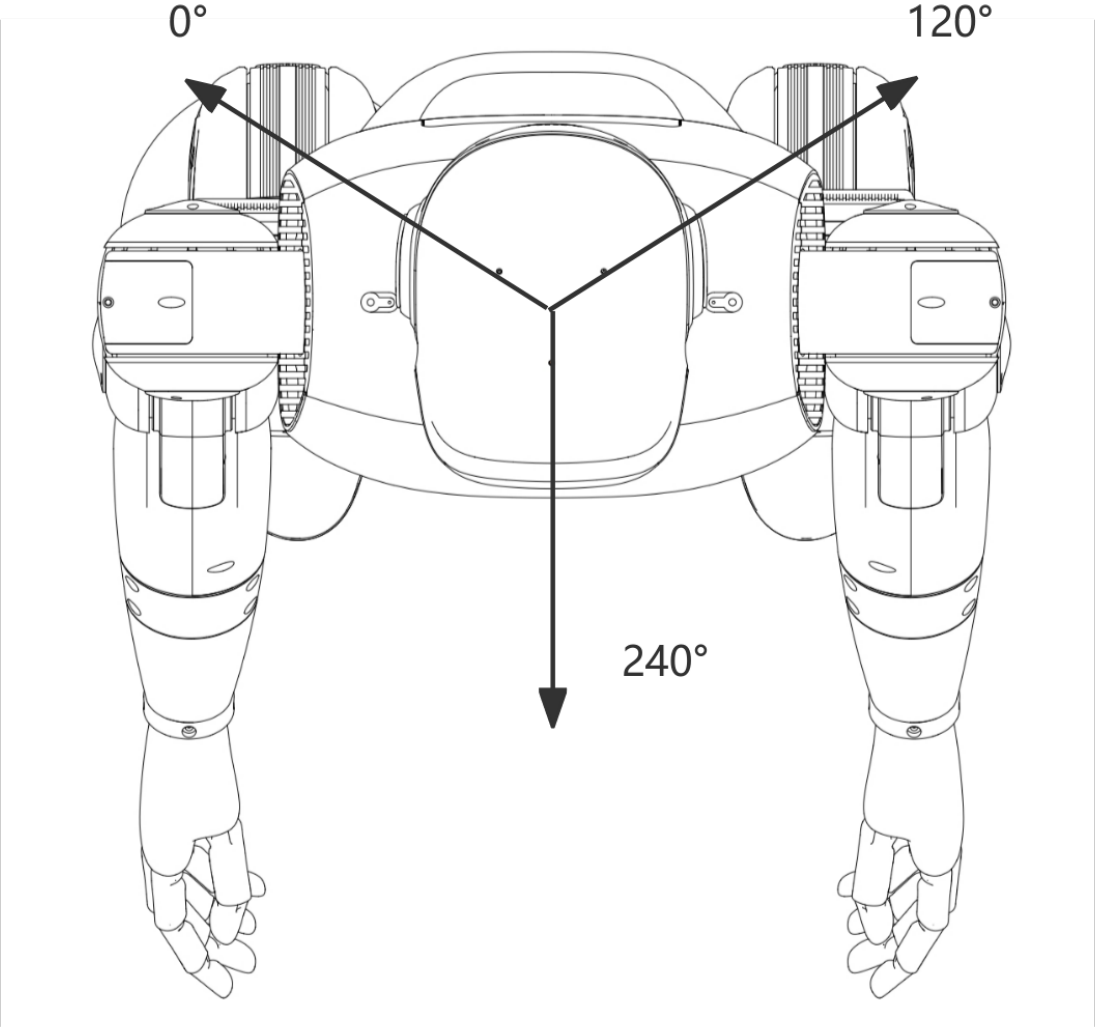
Field Name	Type	Description
`id`	`std::string`	TTS task unique ID, e.g. `"id_01"`, used to track playback status
`content`	`std::string`	Text content to be played, e.g. `"Hello, welcome to the intelligent voice system."`
`priority`	`TtsPriority`	Playback priority, controls whether to interrupt currently playing low-priority voice
`mode`	`TtsMode`	Scheduling strategy under same priority, controls whether tasks are appended, overridden, etc.

11.3.2 `AudioStream` - Audio Stream Structure

Describes raw audio stream or BF audio stream data.

Field Name	Type	Description
`data_length`	`int32_t`	Data length
`raw_data`	`std::vector<uint8_t>`	Audio stream data

11.4 DOA



11.5 Notice:

When using subscription-type SDK interfaces such as Subscribe, do not perform blocking operations within the callback function. Doing so may cause message congestion, processing delays, or even unexpected errors.

CHAPTER 12

State Monitor Service (C++)

Provides robot state monitoring interface class. Through the `StateMonitor`, you can provide state query and other interfaces.

12.1 Interface Definition

`StateMonitor` is a robot system state monitoring management class, typically used to control robot state management, supporting state queries.

12.1.1 StateMonitor

Item	Content
Function Name	StateMonitor
Function Declaration	`StateMonitor();`
Function Overview	Constructor, initializes state monitor object.
Notes	Constructs internal state.

12.1.2 ~StateMonitor

Item	Content
Function Name	~StateMonitor
Function Declaration	`virtual ~StateMonitor();`
Function Overview	Destructor, releases resources.
Notes	Sensors should be closed before calling.

12.1.3 Initialize

Item	Content
Function Name	Initialize
Function Declaration	`bool Initialize();`
Function Overview	Initialize controller, including resource allocation and driver loading.
Return Value	`true` indicates success, `false` indicates failure.
Notes	Object must be constructed before calling.

12.1.4 Shutdown

Item	Content
Function Name	Shutdown
Function Declaration	`void Shutdown();`
Function Overview	Shutdown and release resources.
Notes	Used in conjunction with Initialize.

12.1.5 GetCurrentState

Item	Content
Function Name	`GetCurrentState`
Function Declaration	`RobotState GetCurrentState();`
Function Overview	Get current robot aggregated state
Return Value	`Status::OK` indicates success, others indicate failure.
Notes	Non-blocking interface, gets recently monitored robot state data, including BMS/fault state monitoring, etc., will be iteratively expanded

12.1.6 `RobotState` —Robot State Data Structure

Used to represent overall robot state information:

Field Name	Type	Description
`faults`	`vector<Fault>`	Fault information list
`bms_data`	`BmsData`	Battery management system data

12.1.7 `BmsData` —Battery Management System Data Structure

Represents battery state information:

Field Name	Type	Description
`battery_percentage`	`float`	Current battery remaining power (percentage, 0~100)
`battery_health`	`float`	Battery health status (higher is better)
`battery_state`	`BatteryState`	Battery state (see enumeration below)
`power_supply_status`	`PowerSupplyStatus`	Battery charge/discharge state (see enumeration below)

12.1.8 Enumeration Type Definitions

`BatteryState` —Battery State Enumeration Type

Used to represent current battery state, for battery state judgment and processing in the system:

Enumeration Value	Value	Description
`BatteryState::UNKNOWN`	0	Unknown state
`BatteryState::GOOD`	1	Battery state good
`BatteryState::OVERHEAT`	2	Battery overheating
`BatteryState::DEAD`	3	Battery damaged
`BatteryState::OVERVOLTAGE`	4	Battery overvoltage
`BatteryState::UNSPEC_FAILURE`	5	Unknown fault
`BatteryState::COLD`	6	Battery too cold
`BatteryState::WATCHDOG_TIMER_EXPIRE`	7	Watchdog timer timeout
`BatteryState::SAFETY_TIMER_EXPIRE`	8	Safety timer timeout

`PowerSupplyStatus` —Battery Charge/Discharge State

Used to represent current battery charge/discharge state:

Enumeration Value	Value	Description
`PowerSupplyStatus::UNKNOWN`	0	Unknown state
`PowerSupplyStatus::CHARGING`	1	Battery charging
`PowerSupplyStatus::DISCHARGING`	2	Battery discharging
`PowerSupplyStatus::NOTCHARGING`	3	Battery not charging/discharging
`PowerSupplyStatus::FULL`	4	Battery fully charged

12.2 Error Code Mapping Table

Error Code (Hexadecimal)	Error Description
0x0000	No fault
0x1101	Service invocation failed
0x1301	Central control node lost
0x1302	App node lost
0x1303	Audio node lost
0x1304	Stereo camera node lost
0x1305	LIDAR node lost
0x1306	SLAM node lost
0x1307	Navigation node lost
0x1308	AI node lost
0x1309	Head node lost
0x130A	Point cloud node lost
0x2201	No LIDAR data received
0x2202	No stereo camera data received
0x2203	Stereo camera data error
0x2204	Stereo camera initialization failed
0x220B	No odometry data received
0x220C	No IMU data received
0x2215	Depth camera not detected
0x3101	Failed to connect robot to app
0x3102	Heartbeat lost - assertion failed
0x4201	Failed to open head serial port
0x4202	No head data received
0x5201	No navigation TF data
0x5202	No navigation map data
0x5203	No navigation localization data
0x5204	No navigation LIDAR data

continues on next page

Table 1 – continued from previous page

Error Code (Hexadecimal)	Error Description
0x5205	No navigation depth camera data
0x5206	No navigation multi-line LIDAR data
0x5207	No navigation odometry data
0x6201	SLAM localization error
0x6102	No SLAM LIDAR data
0x6103	No SLAM odometry data
0x6104	SLAM map data error
0x7201	LCM connection timeout
0x8201	Left leg hardware error
0x8202	Right leg hardware error
0x8203	Left arm hardware error
0x8204	Right arm hardware error
0x8205	Waist hardware error
0x8206	Head hardware error
0x8207	Hand hardware error
0x8208	Gripper hardware error
0x8209	IMU hardware error
0x820A	Power system hardware error
0x820B	Leg force sensor hardware error
0x820C	Arm force sensor hardware error
0x9201	ECAT (EtherCAT) hardware error
0xA201	Motion posture error
0xA202	Foot position deviation during movement
0xA203	Joint velocity error during motion

CHAPTER 13

SLAM Navigation Control Service (C++)

Provides SLAM (Simultaneous Localization and Mapping) and navigation control services for robot systems. Through SlamNavController, RPC communication can be used to control robot mapping, localization, navigation and other functions.

13.1 Interface Definition

`SlamNavController` is a controller for SLAM and navigation control, supporting control operations such as mapping, localization, navigation, and map management, encapsulating underlying details for upper-level system calls.

13.1.1 SlamNavController

Item	Content
Function Name	SlamNavController
Function Declaration	`SlamNavController();`
Function Overview	Constructor, initializes SLAM navigation controller state
Remarks	Constructs internal control resources

13.1.2 ~SlamNavController

Item	Content
Function Name	~SlamNavController
Function Declaration	`~SlamNavController();`
Function Overview	Destructor, releases controller resources
Remarks	Used in conjunction with constructor

13.1.3 Initialize

Item	Content
Function Name	Initialize
Function Declaration	`bool Initialize();`
Function Overview	Initializes SLAM navigation controller, prepares SLAM and navigation functions
Return Value	`true` indicates success, `false` indicates failure
Remarks	Must be called before first use

13.1.4 Shutdown

Item	Content
Function Name	Shutdown
Function Declaration	`void Shutdown();`
Function Overview	Closes controller and releases resources
Remarks	Used in conjunction with Initialize, safely disconnects

13.1.5 ActivateSlamMode

Item	Content
Function Name	ActivateSlamMode
Function Declaration	`Status ActivateSlamMode(SlamMode mode, std::string map_path = "", int timeout_ms);`
Function Overview	Activates SLAM mode and starts mapping or localization mode
Parameter Description	`mode`: SLAM mode enumeration`map_path`: Map path (used in localization mode), can be obtained through GetMapPath`timeout_ms`: Timeout time (milliseconds)
Return Value	`Status::OK` indicates success, others indicate failure
Remarks	Blocking interface, supports mapping and localization mode switching

13.1.6 StartMapping

Item	Content
Function Name	StartMapping
Function Declaration	`Status StartMapping(int timeout_ms);`
Function Overview	Starts mapping
Parameter Description	`timeout_ms`: Timeout time (milliseconds)
Return Value	`Status::OK` indicates success, others indicate failure
Remarks	Blocking interface, mapping mode must be activated first

13.1.7 CancelMapping

Item	Content
Function Name	CancelMapping
Function Declaration	`Status CancelMapping(int timeout_ms);`
Function Overview	Cancels mapping
Parameter Description	`timeout_ms`: Timeout time (milliseconds)
Return Value	`Status::OK` indicates success, others indicate failure
Remarks	Blocking interface, cancels current mapping task

13.1.8 SaveMap

Item	Content
Function Name	SaveMap
Function Declaration	`Status SaveMap(const std::string& map_name, int timeout_ms);`
Function Overview	Ends mapping and saves the map
Parameter Description	`map_name`: Map name`timeout_ms`: Timeout time (milliseconds)
Return Value	`Status::OK` indicates success, others indicate failure
Remarks	Blocking interface, must be called in mapping mode

13.1.9 LoadMap

Item	Content
Function Name	LoadMap
Function Declaration	`Status LoadMap(const std::string& map_name, int timeout_ms);`
Function Overview	Loads map and sets it as current map
Parameter Description	`map_name`: Map name`timeout_ms`: Timeout time (milliseconds)
Return Value	`Status::OK` indicates success, others indicate failure
Remarks	Blocking interface, loads map with specified name

13.1.10 DeleteMap

Item	Content
Function Name	DeleteMap
Function Declaration	`Status DeleteMap(const std::string& map_name, int timeout_ms);`
Function Overview	Deletes map
Parameter Description	`map_name`: Name of map to delete`timeout_ms`: Timeout time (milliseconds)
Return Value	`Status::OK` indicates success, others indicate failure
Remarks	Blocking interface, permanently deletes specified map

13.1.11 GetMapPath

Item	Content
Function Name	GetMapPath
Function Declaration	`Status GetMapPath(const std::string& map_name, std::vector& map_path, int timeout_ms);`
Function Overview	Gets map path
Parameter Description	`map_name`: Map name`map_path`: Map path (output parameter)`timeout_ms`: Timeout time (milliseconds)
Return Value	`Status::OK` indicates success, others indicate failure
Remarks	Blocking interface, gets storage path of specified map

13.1.12 GetAllMapInfo

Item	Content
Function Name	GetAllMapInfo
Function Declaration	`Status GetAllMapInfo(AllMapInfo& all_map_info, int timeout_ms);`
Function Overview	Gets all map information
Parameter Description	`all_map_info`: All map information (output parameter)`timeout_ms`: Timeout time (milliseconds)
Return Value	`Status::OK` indicates success, others indicate failure
Remarks	Blocking interface, gets detailed information of all maps in the system

13.1.13 InitPose

Item	Content
Function Name	InitPose
Function Declaration	`Status InitPose(const Pose3DEuler& pose, int timeout_ms);`
Function Overview	Initializes pose
Parameter Description	`pose`: Pose information to publish`timeout_ms`: Timeout time (milliseconds), default value is 15000
Return Value	`Status::OK` indicates success, others indicate failure
Remarks	Blocking interface, sets robot initial pose; when publishing pose, a fixed -1.57rad offset needs to be applied to the Yaw direction because there is a -1.57rad offset between the mechanical installation of the LiDAR and the robot body

13.1.14 GetCurrentLocalizationInfo

Item	Content
Function Name	GetCurrentLocalizationInfo
Function Declaration	`Status GetCurrentLocalizationInfo(LocalizationInfo& pose_info, int timeout_ms);`
Function Overview	Gets current pose information
Parameter Description	`pose_info`: Current position and orientation information (output parameter)`timeout_ms`: Timeout time (milliseconds)
Return Value	`Status::OK` indicates success, others indicate failure
Remarks	Blocking interface, gets robot current pose status

13.1.15 ActivateNavMode

Item	Content
Function Name	ActivateNavMode
Function Declaration	`Status ActivateNavMode(NavMode mode, std::string map_path = "", int timeout_ms);`
Function Overview	Activates navigation mode
Parameter Description	`mode`: Target navigation mode`map_path`: Map path (used in grid map mode), can be obtained through GetMapPath`timeout_ms`: Timeout time (milliseconds)
Return Value	`Status::OK` indicates success, others indicate failure
Remarks	Blocking interface, activates specified navigation mode

13.1.16 SetNavTarget

Item	Content
Function Name	SetNavTarget
Function Declaration	`Status SetNavTarget(const NavTarget& goal, int timeout_ms);`
Function Overview	Sets global navigation target point and starts navigation task
Parameter Description	`goal`: Global coordinates of target point`timeout_ms`: Timeout time (milliseconds)
Return Value	`Status::OK` indicates success, others indicate failure
Remarks	Blocking interface, sets navigation target and starts navigation

13.1.17 PauseNavTask

Item	Content
Function Name	PauseNavTask
Function Declaration	`Status PauseNavTask();`
Function Overview	Pauses current navigation task
Return Value	`Status::OK` indicates success, others indicate failure
Remarks	Non-blocking interface, pauses navigation task

13.1.18 ResumeNavTask

Item	Content
Function Name	ResumeNavTask
Function Declaration	`Status ResumeNavTask();`
Function Overview	Resumes paused navigation task
Return Value	`Status::OK` indicates success, others indicate failure
Remarks	Non-blocking interface, resumes paused navigation task

13.1.19 CancelNavTask

Item	Content
Function Name	CancelNavTask
Function Declaration	`Status CancelNavTask();`
Function Overview	Cancels current navigation task
Return Value	`Status::OK` indicates success, others indicate failure
Remarks	Non-blocking interface, cancels current navigation task

13.1.20 GetNavStatus

Item	Content
Function Name	GetNavStatus
Function Declaration	`Status GetNavStatus(NavStatus& nav_status);`
Function Overview	Gets navigation status
Parameter Description	`nav_status`: Navigation status (output parameter)
Return Value	`Status::OK` indicates success, others indicate failure
Remarks	Non-blocking interface, gets current navigation status information

13.1.21 OpenOdometryStream

Item	Content
Function Name	OpenOdometryStream
Function Declaration	`Status OpenOdometryStream();`
Function Overview	Open odometry stream
Return Value	`Status::OK` indicates success, others indicate failure
Remarks	Blocking interface, check return value to ensure successful execution

13.1.22 CloseOdometryStream

Item	Content
Function Name	CloseOdometryStream
Function Declaration	`Status CloseOdometryStream();`
Function Overview	Close odometry stream
Return Value	`Status::OK` indicates success, others indicate failure
Remarks	Blocking interface, used in conjunction with OpenOdometryStream

13.1.23 SubscribeOdometry

Item	Content
Function Name	SubscribeOdometry
Function Declaration	`void SubscribeOdometry(const OdometryCallback callback);`
Function Overview	Subscribe to odometry data
Parameter Description	`callback`: Processing callback function after receiving odometry data
Remarks	Non-blocking interface, callback function will be called when odometry data is updated

13.1.24 UnsubscribeOdometry

Item	Content
Function Name	UnsubscribeOdometry
Function Declaration	`void UnsubscribeOdometry();`
Function Overview	Unsubscribe from odometry data
Remarks	Non-blocking interface. Used in conjunction with SubscribeOdometry

13.1.25 GetPointCloudMap

Item	Content
Function Name	GetPointCloudMap
Function Declaration	`Status GetPointCloudMap(PointCloud2& point_cloud_map, int timeout_ms);`
Function Overview	Get point cloud map data
Parameter Description	`point_cloud_map`: Point cloud map data (output parameter)`timeout_ms`: Timeout duration (milliseconds)
Return Value	`Status::OK` indicates success, others indicate failure
Remarks	Blocking interface, gets current point cloud map data

13.2 Type Definitions

13.2.1 `Pose3DEuler` —3D Pose Structure

Field Name	Type	Description
`position`	`std::array<double, 3>`	Position coordinates (x, y, z)
`orientation`	`std::array<double, 3>`	Euler angles (roll, pitch, yaw)

13.2.2 `NavTarget` —Navigation Target Point Structure

Field Name	Type	Description
`id`	`int`	Target point ID
`frame_id`	`std::string`	Target point coordinate frame ID
`goal`	`Pose3DEuler`	Target point pose

13.2.3 `LocalizationInfo` —Pose Information Structure

Field Name	Type	Description
`is_localization`	`bool`	Whether localized
`pose`	`Pose3DEuler`	Current pose

13.2.4 `NavStatus` —Navigation Status Structure

Field Name	Type	Description
`id`	`int`	Target point ID, -1 indicates no target point
`status`	`NavStatusType`	Navigation status type
`message`	`std::string`	Navigation status message

13.2.5 `PolyRegion` —Polygon Region Structure

Field Name	Type	Description
`points`	`std::vector<Point2D>`	Polygon vertex list

13.2.6 `Point2D` —2D Point Structure

Field Name	Type	Description
`x`	`double`	X coordinate
`y`	`double`	Y coordinate

13.3 Enumeration Type Definitions

13.3.1 `SlamMode` —SLAM Mode Enumeration

Enum Value	Value	Description
`IDLE`	0	Idle mode
`LOCALIZATION`	1	Localization mode
`MAPPING`	2	Mapping mode

13.3.2 `NavMode` —Navigation Mode Enumeration

Enum Value	Value	Description
`IDLE`	0	Idle mode
`GRID_MAP`	1	Grid map navigation mode

13.3.3 `NavStatusType` —Navigation Status Type Enumeration

Enum Value	Value	Description
`NONE`	0	No status
`RUNNING`	1	Running
`END_SUCCESS`	2	Successfully ended
`END_FAILED`	3	Failed to end
`PAUSE`	4	Paused
`CONTINUE`	5	Continue
`CANCEL`	6	Canceled

13.4 SLAM Navigation Control Introduction

The robot’ s SLAM navigation control service can be divided into SLAM functions and navigation functions.

- In SLAM functions, corresponding interfaces can be called to implement mapping, localization, map management and other functions.
- In navigation functions, corresponding interfaces can be called to implement target navigation, navigation control and other functions.

13.4.1 Applicable Scenarios and Scope

- Static indoor flat areas smaller than 100 m × 100 m with rich features. Do not exceed the recommended range.
- This functionality is applicable to the education and research industry and is not recommended for commercial applications. For commercial use, please contact sales.

13.4.2 SLAM Function Flow

Function	Operation Flow
Mapping	Activate mapping mode → Start mapping → Save map
Map Management	Load map, get map information, delete map, get map path, etc.

13.4.3 Navigation Function Flow

Function	Operation Flow
Localization	Load map → Activate localization mode → Initialize pose → Get localization status
Navigation	Localization success → Activate navigation mode → Set target pose → Get navigation status
Navigation Control	Set target pose → PauseNavTask navigation → ResumeNavTask navigation → CancelNavTask navigation

13.4.4 Localization Mode Initialization

When SLAM is in localization mode, an initial pose can be specified to quickly complete relocalization and initialization. For large-scale maps, specifying the initial pose is mandatory.

Small Map Mode

满足如下条件：

The following conditions must be met:

- Condition 1: The map should not be too large. For example, in a single room, it is best to keep the map area within 10m × 10m.

- Condition 2: Modify the configuration to adapt to this mode:

```
# Log in to the robot
ssh eame@192.168.54.119
# Modify the following configuration
# vim /opt/eame/eamegrapher_3d/share/eamegrapher_3d/config/params.yaml
reloc_options: true

# After modifying the YAML file for the first time, restart the SLAM module for the␣
↪change to take effect:
sudo systemctl restart slam.service
```

Large Map Mode

The following conditions must be met:

- Condition 1: The robot must be located at the mapping origin (the starting position when mapping began), and the robot's orientation must remain consistent.
- Condition 2: Modify the configuration to adapt to this mode:

When using the SDK for SLAM navigation (unlike the app, which allows convenient visual positioning), you must modify the SLAM configuration to fix the map orientation and facilitate localization:

```
# Log in to the robot
ssh eame@192.168.54.119
# Modify the following configuration
# vim /opt/eame/eamegrapher_3d/share/eamegrapher_3d/config/params.yaml
align_map: false

# After modifying the YAML file for the first time, restart the SLAM module for the␣
↪change to take effect:
sudo systemctl restart slam.service
```

- Condition 3: When initializing the pose, apply a 180° (3.14 rad) offset to the yaw angle:

because the LiDAR's mechanical installation differs from the robot body orientation by 180°.

13.4.5 Map Noise Removal and Obstacle Addition

- Software Name: GIMP
- Download Link: https://www.gimp.org/downloads/
- Operating System: Ubuntu

- File to Edit: /home/eame/cust_para/maps/${map_name}/map/map.pgm Log in to the robot (ssh eame@192.168.54.119), open the .pgm map file with GIMP for editing, and replace the original file after modifications are complete.
- Editing Tutorial Video:

CHAPTER 14

Robot Main Control Service (Python)

Provides robot system main controller. Through the `MagicRobot` class, you can perform resource initialization, manage communication connections, and access various sub-controllers such as motion controllers, audio, state monitoring, and sensor controllers.

14.1 Interface Definition

`MagicRobot` is the unified entry class for the robot SDK.

14.1.1 MagicRobot

Item	Content
Class Name	MagicRobot
Constructor	`robot = MagicRobot()`
Function Overview	Constructor, creates MagicRobot instance.
Notes	Constructs internal state.

14.1.2 initialize

Item	Content
Function Name	initialize
Function Declaration	`bool initialize(str local_ip)`
Function Overview	Initialize robot system, including controllers and network modules.
Parameter Description	`local_ip`: Local communication IP address.
Return Value	`True` indicates success, `False` indicates failure.
Notes	Must be called before first use.

14.1.3 shutdown

Item	Content
Function Name	shutdown
Function Declaration	`void shutdown()`
Function Overview	Shutdown robot system and release resources.
Notes	Used in conjunction with initialize.

14.1.4 connect

Item	Content
Function Name	connect
Function Declaration	`Status connect()`
Function Overview	Establish communication connection with robot service.
Return Value	`Status` object, `Status.code == ErrorCode.OK` indicates success.
Notes	Blocking interface, must be called after initialization.

14.1.5 disconnect

Item	Content
Function Name	disconnect
Function Declaration	`Status disconnect()`
Function Overview	Disconnect from robot service.
Return Value	`Status` object, `Status.code == ErrorCode.OK` indicates success.
Notes	Blocking interface, used in conjunction with connect.

14.1.6 get_sdk_version

Item	Content
Function Name	get_sdk_version
Function Declaration	`str get_sdk_version()`
Function Overview	Get current SDK version number.
Return Value	SDK version string (e.g., `0.0.1`).
Notes	Non-blocking interface, convenient for debugging or log marking.

14.1.7 get_motion_control_level

Item	Content
Function Name	get_motion_control_level
Function Declaration	`ControllerLevel get_motion_control_level()`
Function Overview	Get current motion control level (high-level/low-level).
Return Value	`ControllerLevel` enumeration value.
Notes	Non-blocking interface, used to determine current control permissions.

14.1.8 set_motion_control_level

Item	Content
Function Name	set_motion_control_level
Function Declaration	`Status set_motion_control_level(ControllerLevel level)`
Function Overview	Set current motion control level.
Parameter Description	`level`: Control permission enumeration value.
Return Value	`Status` object, `Status.code == ErrorCode.OK` indicates successful setting.
Notes	Blocking interface, used when switching control modes.

14.1.9 get_high_level_motion_controller

Item	Content
Function Name	get_high_level_motion_controller
Function Declaration	`HighLevelMotionController get_high_level_motion_controller()`
Function Overview	Get high-level motion controller object.
Return Value	`HighLevelMotionController` object, used to call high-level control interfaces.
Notes	Non-blocking interface, encapsulates gait, tricks, remote control, etc.

14.1.10 get_low_level_motion_controller

Item	Content
Function Name	get_low_level_motion_controller
Function Declaration	`LowLevelMotionController get_low_level_motion_controller()`
Function Overview	Get low-level motion controller object.
Return Value	`LowLevelMotionController` object, used to control joints or motors.
Notes	Non-blocking interface, directly controls joint motors, gets IMU data, etc.

14.1.11 get_audio_controller

Item	Content
Function Name	get_audio_controller
Function Declaration	`AudioController get_audio_controller()`
Function Overview	Get audio controller object.
Return Value	`AudioController` object, used for audio control.
Notes	Non-blocking interface, plays audio and controls volume.

14.1.12 get_sensor_controller

Item	Content
Function Name	get_sensor_controller
Function Declaration	`SensorController get_sensor_controller()`
Function Overview	Get sensor controller object.
Return Value	`SensorController` object, used to access sensor data.
Notes	Non-blocking interface, encapsulates LiDAR, RGBD, etc. reading.

14.1.13 get_state_monitor

Item	Content
Function Name	get_state_monitor
Function Declaration	`StateMonitor get_state_monitor()`
Function Overview	Get state monitor object.
Return Value	`StateMonitor` object, used to get current robot state information.
Notes	Non-blocking interface, encapsulates reading of BMS, faults, and other state information.

14.1.14 get_slam_nav_controller

项目	内容
函数名	get_slam_nav_controller
函数声明	`SlamNavController get_slam_nav_controller();`
功能概述	获取 SLAM 与导航控制器对象。
返回值	引用类型，用于建图与定位。
备注	非阻塞接口，用于机器人 SLAM 建图与自主导航功能。

CHAPTER 15

High-Level Motion Control Service (Python)

Provides robot system high-level motion control service. Through the `HighLevelMotionController`, you can control robot gait, tricks, and remote control via RPC communication.

15.1 Interface Definition

`HighLevelMotionController` is a high-level motion controller for semantic control, supporting control operations such as walking, tricks, head movement, etc., encapsulating low-level details for upper system calls.

15.1.1 HighLevelMotionController

Item	Content
Class Name	HighLevelMotionController
Constructor	`controller = HighLevelMotionController()`
Function Overview	Constructor, initializes high-level controller state
Notes	Constructs internal control resources

15.1.2 initialize

Item	Content
Function Name	initialize
Function Declaration	`bool initialize()`
Function Overview	Initialize controller, prepare high-level control functions
Return Value	`True` indicates success, `False` indicates failure
Notes	Must be called before first use

15.1.3 shutdown

Item	Content
Function Name	shutdown
Function Declaration	`void shutdown()`
Function Overview	Shutdown controller and release resources
Notes	Used in conjunction with initialize, safely disconnect

15.1.4 set_gait

Item	Content
Function Name	set_gait
Function Declaration	`Status set_gait(GaitMode gait_mode, int timeout_ms)`
Function Overview	Set robot gait mode (such as recovery stand, balance stand, humanoid walk, etc.)
Parameter Description	`gait_mode`: Gait control enumeration
Return Value	`Status` object, `Status.code == ErrorCode.OK` indicates success
Notes	Blocking interface, can switch between multiple gait modes

15.1.5 get_gait

Item	Content
Function Name	get_gait
Function Declaration	`Status get_gait()`
Function Overview	Get robot gait mode (such as recovery stand, balance stand, humanoid walk, etc.)
Return Value	`Status` object, contains current gait mode information
Notes	Blocking interface, gets current gait mode

15.1.6 execute_trick

Item	Content
Function Name	execute_trick
Function Declaration	`Status execute_trick(TrickAction trick_action, int timeout_ms)`
Function Overview	Execute trick actions (such as welcom, etc.)
Parameter Description	`trick_action`: Trick action identifier
Return Value	`Status` object, `Status.code == ErrorCode.OK` indicates success
Notes	Blocking interface, ensure robot can currently execute tricksNote: Trick actions must be performed in GaitMode.GAIT_BALANCE_STAND(46) gait

15.1.7 send_joystick_command

Item	Content
Function Name	send_joystick_command
Function Declaration	`Status send_joystick_command(JoystickCommand joy_command)`
Function Overview	Send real-time joystick control commands
Parameter Description	`joy_command`: Control data containing joystick coordinates
Return Value	`Status` object, `Status.code == ErrorCode.OK` indicates success
Notes	Non-blocking interface, recommended sending frequency is 20Hz

15.1.8 head_move

Item	Content
Function Name	head_move
Function Declaration	`Status head_move(float shake_angle, int timeout_ms);`
Function Overview	Control robot head swinging motion
Parameter Description	`shake_angle`: Head swing angle, unit: rad, range: [-0.698, 0.698]`timeout_ms`: Timeout duration, default 5000 milliseconds
Return Value	`Status::OK` indicates success, others indicate failure
Notes	Blocking interface, controls robot head left-right swinging motion

15.2 Type Definitions

15.2.1 `JoystickCommand` —High-Level Motion Control Joystick Command Structure

Field Name	Type	Description
`left_x_axis`	`float`	Left joystick X-axis direction value (-1.0: left, 1.0: right)
`left_y_axis`	`float`	Left joystick Y-axis direction value (-1.0: down, 1.0: up)
`right_x_axis`	`float`	Right joystick X-axis direction value (rotation -1.0: left, 1.0: right)
`right_y_axis`	`float`	Right joystick Y-axis direction value (purpose not yet defined)

15.3 Enumeration Type Definitions

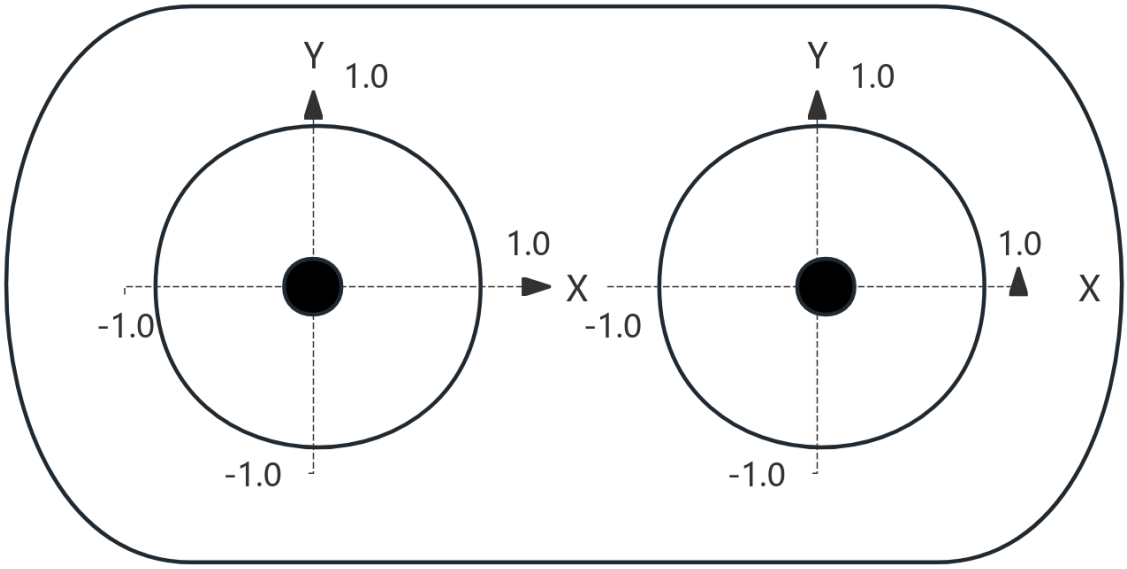
15.3.1 `GaitMode` —Robot Gait Mode Enumeration

Enumeration Value	Value	Description
`GAIT_PASSIVE`	0	Passive
`GAIT_RECOVERY_STAND`	1	Recovery Stand
`GAIT_BALANCE_STAND`	46	Balance Stand (supports movement)
`GAIT_HUMANOID_WALK`	79	Humanoid Walk
`GAIT_LOWLEVL_SDK`	200	Low-Level Control SDK Mode

15.3.2 `TrickAction` —Trick Action Command Enumeration

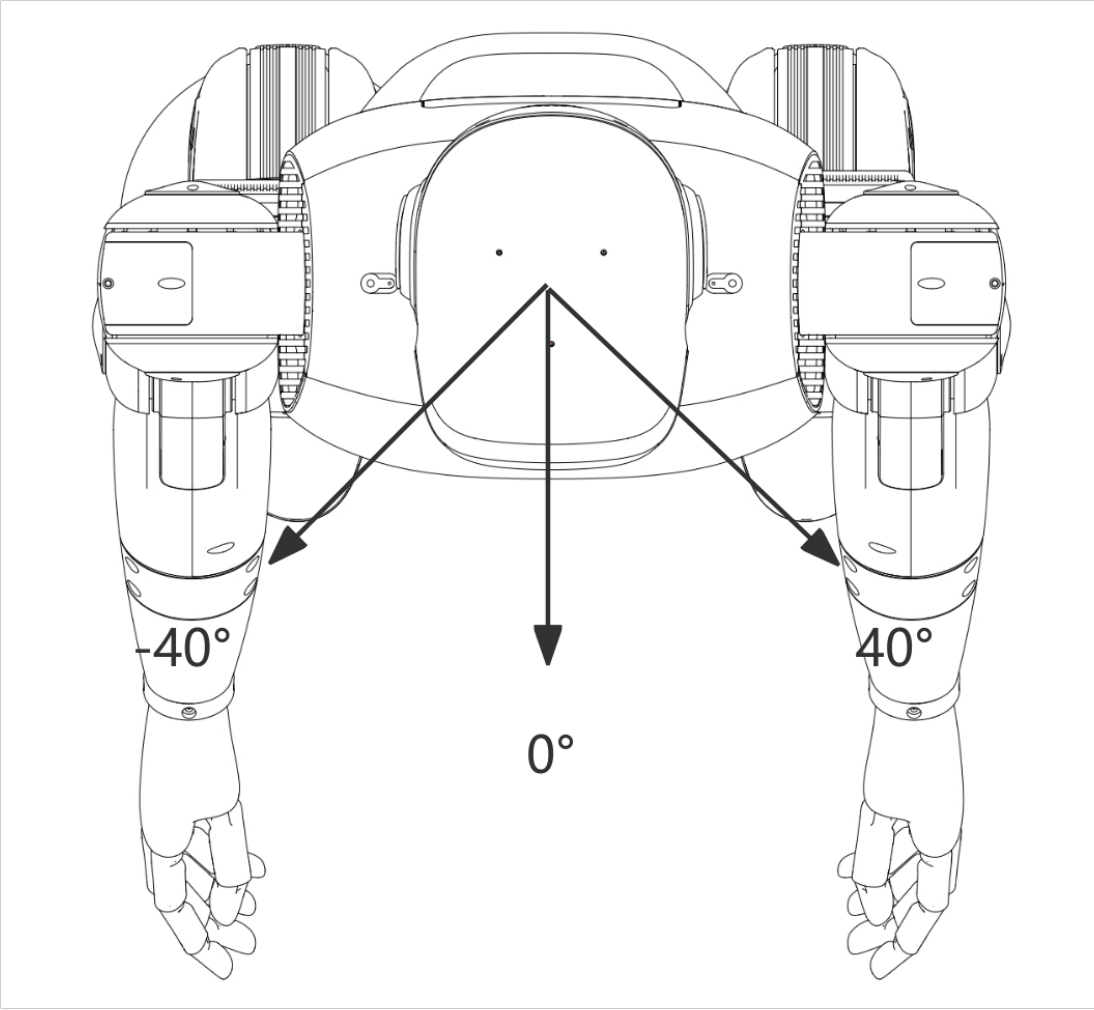
Enumeration Value	Value	Description
ACTION_SHAKE_LEFT_HAND_REACHOUT	215	Handshake (Left Hand) - Reach Out
ACTION_SHAKE_LEFT_HAND_WITHDRAW	216	Handshake (Left Hand) - Withdraw
ACTION_SHAKE_RIGHT_HAND_REACHOUT	217	Handshake (Right Hand) - Reach Out
ACTION_SHAKE_RIGHT_HAND_WITHDRAW	218	Handshake (Right Hand) - Withdraw
ACTION_SHAKE_HEAD	220	Shake Head
ACTION_LEFT_GREETING	300	Greeting (Left Hand)
ACTION_RIGHT_GREETING	301	Greeting (Right Hand)
ACTION_TRUN_LEFT_INTRODUCE_HIGH	304	Turn Left Introduce - High
ACTION_TRUN_LEFT_INTRODUCE_LOW	305	Turn Left Introduce - Low
ACTION_TRUN_RIGHT_INTRODUCE_HIGH	306	Turn Right Introduce - High
ACTION_TRUN_RIGHT_INTRODUCE_LOW	307	Turn Right Introduce - Low
ACTION_WELCOME	340	Welcome
FLY_KISS_LEFT	408	Air Kiss - Left Hand
FLY_KISS_RIGHT	409	Air Kiss - Right Hand
SUPERMAN_WAVE	410	Superman Wave
CLAP_HAND	411	Clap Hands
HOLD_CERT_REACHOUT	412	Hold Certificate - Reach Out
HOLD_CERT_WITHDRAW	413	Hold Certificate - Withdraw
HUG_REACHOUT	414	Hug with Both Hands - Reach Out
HUG_WITHDRAW	415	Hug with Both Hands - Withdraw
TRUN_WAVE_LEFT	417	Turn and Wave - Left Hand
TRUN_WAVE_RIGHT	418	Turn and Wave - Right Hand
RIGHT_HAND_SALUTE	419	Right Hand Salute

15.4 Joystick Diagram



1. The X-axis and Y-axis value ranges for left and right joysticks are [-1.0, 1.0];
2. The up/right direction of the left and right joystick X-axis and Y-axis is positive, as shown in the diagram;

15.5 Head Movement Range Diagram



- Movement Range [-40°, 40°] ([-0.698rad, 0.698rad])

15.6 High-Level Motion Control Robot State Introduction

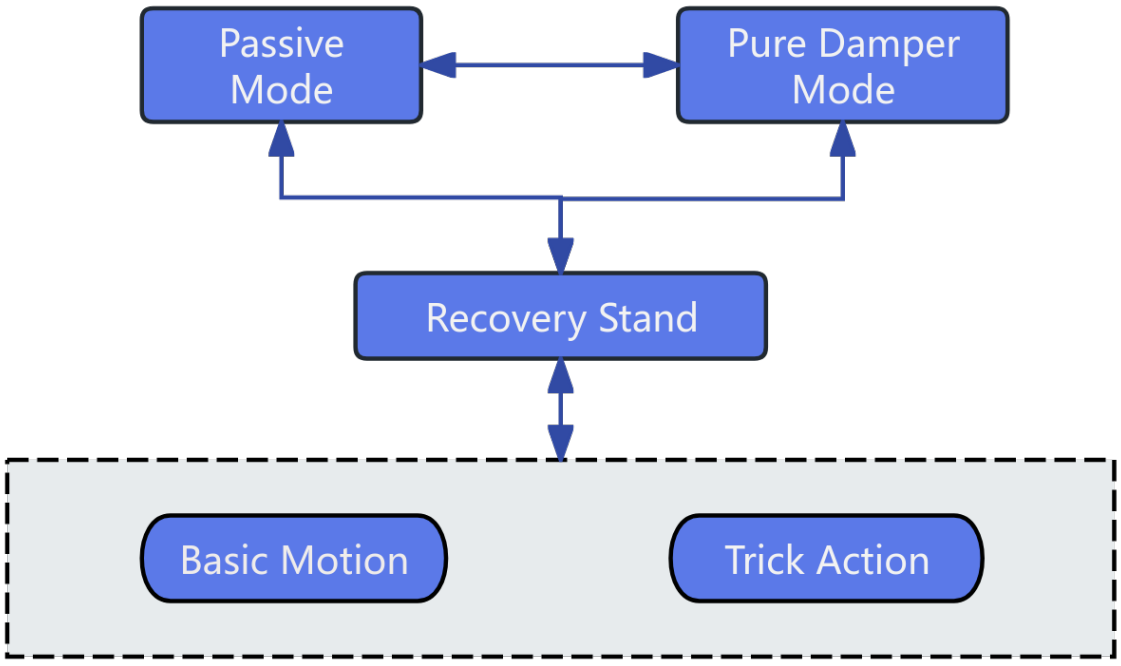
Robot motion includes recovery stand, balance stand, basic motion, and trick action states. During operation, the robot switches between different states through a state machine to achieve different control tasks. The explanations for each state are as follows:

- **Recovery Stand**: Recovery stand is the state connecting robot suspension landing and balance stand. The robot needs to enter the balance stand state before calling corresponding motion services to achieve robot control.
- **Balance Stand**: In the balance stand state, you can call various SDK interfaces to achieve robot trick actions and

basic motion control.

- **Basic Motion**: During motion execution, you can call SDK interfaces to make the robot enter different gaits.
- **Trick Actions**: When entering the special action execution state, other motion control services will be suspended first, waiting for the current action to complete and enter the balance stand state before taking effect again.

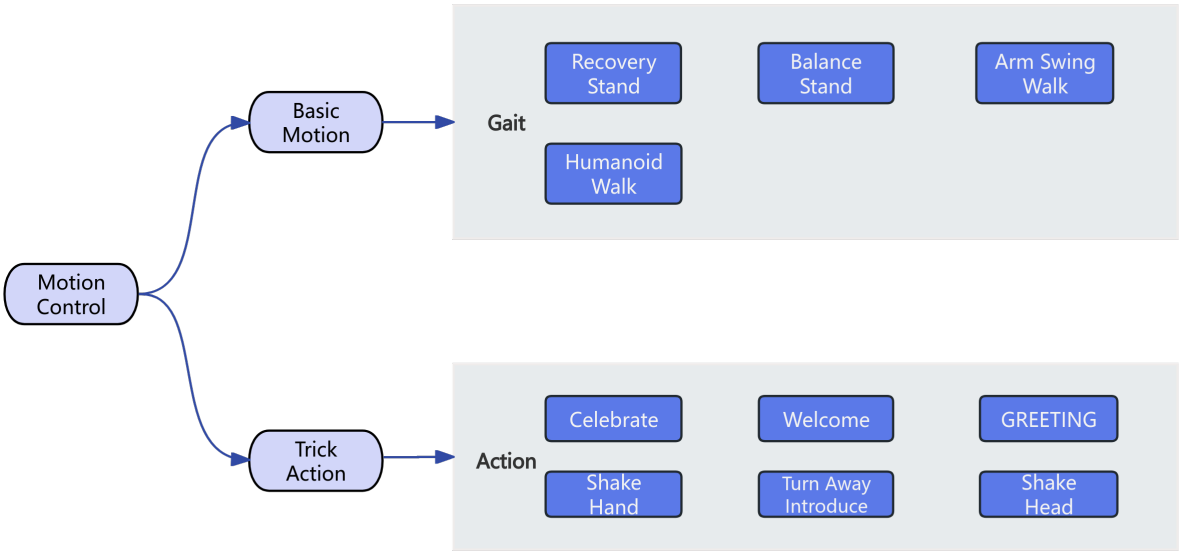
Robot state switching mechanism;



15.7 High-Level Motion Control Interface

Robot high-level motion control services can be divided into basic motion control and trick action control.

- In basic motion control services, you can call corresponding interfaces to switch robot walking gaits according to different terrain scenarios and task requirements.
- In trick action control services, you can call corresponding interfaces to achieve robot built-in special tricks, such as Celebrate, handshake, greeting, etc.



15.7.1 Gait Switching

Current Gait	Gait Switching Process	Diagram
Recovery Stand		
Balance Stand		
Arm Swing Walk		
Humanoid Walk		

15.7.2 Trick Execution

Trick	Trick Execution Process	Diagram
Welcome		
Shake Head		
Greeting (Left Hand)		
Greeting (Right Hand)		
Handshake (Left Hand)		
Handshake (Right Hand)		
Turn Left Introduction		
Turn Right Introduction		

CHAPTER 16

Low-Level Motion Control Service (Python)

Provides robot system low-level motion control service. Through the `LowLevelMotionController`, you can control robot joints and obtain status via topic communication.

16.1 Interface Definition

`LowLevelMotionController` is a motion controller for low-level development, supporting direct control and state subscription of motion components such as arms, legs, head, waist, hands, etc., as well as body IMU data acquisition.

16.1.1 LowLevelMotionController

Item	Content
Class Name	LowLevelMotionController
Constructor	`controller = LowLevelMotionController()`
Function Overview	Constructor, initializes low-level controller object.
Notes	Constructs internal resources.

16.1.2 initialize

Item	Content
Function Name	initialize
Function Declaration	`bool initialize()`
Function Overview	Initialize controller, establish low-level connection.
Return Value	`True` indicates success, `False` indicates failure.
Notes	Must be initialized on first call.

16.1.3 shutdown

Item	Content
Function Name	shutdown
Function Declaration	`void shutdown()`
Function Overview	Shutdown controller, release low-level resources.
Notes	Used in conjunction with initialize.

16.1.4 subscribe_arm_state

Item	Content
Function Name	subscribe_arm_state
Function Declaration	`void subscribe_arm_state(callback)`
Function Overview	Subscribe to arm joint state data
Parameter Description	callback: Data processing function, signature is callback(data: JointState) -> None
Notes	Non-blocking interface.

16.1.5 publish_arm_command

Item	Content
Function Name	publish_arm_command
Function Declaration	`Status publish_arm_command(JointCommand command)`
Function Overview	Publish arm control commands
Parameter Description	command: Target position/velocity, etc.
Return Value	`Status` object, `Status.code == ErrorCode.OK` indicates success.
Notes	Non-blocking interface.

16.1.6 subscribe_leg_state

Item	Content
Function Name	subscribe_leg_state
Function Declaration	`void subscribe_leg_state(callback)`
Function Overview	Subscribe to leg joint state data
Parameter Description	callback: Data processing function, signature is callback(data: JointState) -> None
Notes	Non-blocking interface.

16.1.7 publish_leg_command

Item	Content
Function Name	publish_leg_command
Function Declaration	`Status publish_leg_command(JointCommand command)`
Function Overview	Publish leg control commands
Parameter Description	command: Target position/velocity, etc.
Return Value	`Status` object, `Status.code == ErrorCode.OK` indicates success.
Notes	Non-blocking interface, called when publishing or subscribing.

16.1.8 subscribe_head_state

Item	Content
Function Name	subscribe_head_state
Function Declaration	`void subscribe_head_state(callback)`
Function Overview	Subscribe to head joint state data
Parameter Description	callback: Data processing function, signature is callback(data: JointState) -> None
Notes	Non-blocking interface.

16.1.9 publish_head_command

Item	Content
Function Name	publish_head_command
Function Declaration	`Status publish_head_command(JointCommand command)`
Function Overview	Publish head control commands
Parameter Description	command: Target position/velocity, etc.
Return Value	`Status` object, `Status.code == ErrorCode.OK` indicates success.
Notes	Non-blocking interface.

16.1.10 subscribe_waist_state

Item	Content
Function Name	subscribe_waist_state
Function Declaration	`void subscribe_waist_state(callback)`
Function Overview	Subscribe to waist joint state data
Parameter Description	callback: Data processing function, signature is callback(data: JointState) -> None
Notes	Non-blocking interface.

16.1.11 publish_waist_command

Item	Content
Function Name	publish_waist_command
Function Declaration	`Status publish_waist_command(JointCommand command)`
Function Overview	Publish waist control commands
Parameter Description	command: Target position/velocity, etc.
Return Value	`Status` object, `Status.code == ErrorCode.OK` indicates success.
Notes	Non-blocking interface.

16.1.12 subscribe_hand_state

Item	Content
Function Name	subscribe_hand_state
Function Declaration	`void subscribe_hand_state(callback)`
Function Overview	Subscribe to hand state data
Parameter Description	callback: Data processing function, signature is callback(data: HandState) -> None
Notes	Non-blocking interface.

16.1.13 publish_hand_command

Item	Content
Function Name	publish_hand_command
Function Declaration	`Status publish_hand_command(HandCommand command)`
Function Overview	Publish hand control commands
Parameter Description	command: Hand joint target positions, etc.
Return Value	`Status` object, `Status.code == ErrorCode.OK` indicates success.
Notes	Non-blocking interface.

16.1.14 subscribe_body_imu

Item	Content
Function Name	subscribe_body_imu
Function Declaration	`void subscribe_body_imu(callback)`
Function Overview	Subscribe to body IMU data
Parameter Description	callback: IMU data processing function, signature is callback(data: Imu) -> None
Notes	Non-blocking interface.

16.1.15 subscribe_estimator_state

Item	Content
Function Name	subscribe_estimator_state
Function Declaration	`void subscribe_estimator_state(callback)`
Function Overview	Subscribe to body Estimator state data
Parameter Description	callback: Estimator state data processing function, signature is callback(data: Imu) -> None
Notes	Non-blocking interface.

16.1.16 unsubscribe_arm_state

Item	Content
Function Name	unsubscribe_arm_state
Function Declaration	`void unsubscribe_arm_state()`
Function Overview	Unsubscribe from arm joint state data
Notes	Non-blocking interface, used in conjunction with subscribe_arm_state.

16.1.17 unsubscribe_leg_state

Item	Content
Function Name	unsubscribe_leg_state
Function Declaration	`void unsubscribe_leg_state()`
Function Overview	Unsubscribe from leg joint state data
Notes	Non-blocking interface, used in conjunction with subscribe_leg_state.

16.1.18 unsubscribe_head_state

Item	Content
Function Name	unsubscribe_head_state
Function Declaration	`void unsubscribe_head_state()`
Function Overview	Unsubscribe from head joint state data
Notes	Non-blocking interface, used in conjunction with subscribe_head_state.

16.1.19 unsubscribe_waist_state

Item	Content
Function Name	unsubscribe_waist_state
Function Declaration	`void unsubscribe_waist_state()`
Function Overview	Unsubscribe from waist joint state data
Notes	Non-blocking interface, used in conjunction with subscribe_waist_state.

16.1.20 unsubscribe_hand_state

Item	Content
Function Name	unsubscribe_hand_state
Function Declaration	`void unsubscribe_hand_state()`
Function Overview	Unsubscribe from hand state data
Notes	Non-blocking interface, used in conjunction with subscribe_hand_state.

16.1.21 unsubscribe_body_imu

Item	Content
Function Name	unsubscribe_body_imu
Function Declaration	`void unsubscribe_body_imu()`
Function Overview	Unsubscribe from body IMU data
Notes	Non-blocking interface, used in conjunction with subscribe_body_imu.

16.1.22 unsubscribe_estimator_state

Item	Content
Function Name	unsubscribe_estimator_state
Function Declaration	`void unsubscribe_estimator_state()`
Function Overview	Unsubscribe from body estimator state data
Notes	Non-blocking interface, used in conjunction with subscribe_estimator_state.

16.2 Type Definitions

16.2.1 `SingleHandJointCommand` —Single Hand Joint Control Command

Field Name	Type	Description
`operation_mode`	`int16_t`	Control mode (such as position, torque, impedance, etc.), default value is 0
`pos`	`list[float]`	Desired position array (7 degrees of freedom)

16.2.2 `HandCommand` —Complete Hand Control Command

Field Name	Type	Description
`timestamp`	`int64_t`	Timestamp (unit: nanoseconds)
`cmd`	`list[SingleHandJointCommand]`	Control command array, left hand and right hand in order

16.2.3 `SingleHandJointState` —Single Hand Joint State

Field Name	Type	Description
`status_word`	`int16_t`	Status
`pos`	`list[float]`	Actual position (unit depends on controller definition)
`toq`	`list[float]`	Actual torque (unit: Nm)
`cur`	`list[float]`	Actual current (unit: A)
`error_code`	`int16_t`	Error code (0 indicates normal)

16.2.4 `HandState` —Complete Hand Status Information

Field Name	Type	Description
`timestamp`	`int64_t`	Timestamp (unit: nanoseconds)
`state`	`list[SingleHandJointState]`	All hand joint states (total two), left hand and right hand in order

16.2.5 `SingleJointCommand` —Single Joint Control Command

Field Name	Type	Description
`operation_mode`	`int16_`	Control mode identifier: • 200 = Standby mode • 3 = Parallel triple-loop control (MIT mode) • 4 = Serial triple-loop control
`pos`	`float`	Target position (unit: rad or m, depends on joint type)
`vel`	`float`	Target velocity (unit: rad/s or m/s)
`toq`	`float`	Target torque (unit: Nm)
`kp`	`float`	Position loop control gain (proportional term)
`kd`	`float`	Velocity loop control gain (derivative term)

- For joints 1-5 of the arm, the `operation_mode` needs to be switched from mode 200 (standby) to mode 3 (parallel triple-loop control, MIT mode) before sending commands.
- For joint 1 of the waist, the `operation_mode` needs to be switched from mode 200 (standby) to mode 3 (parallel triple-loop control, MIT mode) before sending commands.
- For joints 1-6 of the legs, the `operation_mode` needs to be switched from mode 200 (standby) to mode 3 (parallel triple-loop control, MIT mode) before sending commands.
- The head joint uses pure position control and does not require setting `operation_mode`.

16.2.6 `JointCommand` —Joint Control Command

Field Name	Type	Description
`timestamp`	`int64_t`	Timestamp (unit: nanoseconds)
`joints`	`list[SingleJointCommand]`	Joint control command array

16.2.7 `SingleJointState` —Single Joint Status

Field Name	Type	Description
`status_word`	`int16_t`	Current joint status (custom state machine encoding)
`posH`	`float`	Actual position (high encoder reading, may be redundant encoder)
`posL`	`float`	Actual position (low encoder reading)
`vel`	`float`	Current velocity (unit: rad/s or m/s)
`toq`	`float`	Current torque (unit: Nm)
`current`	`float`	Current current (unit: A)
`err_code`	`int16_t`	Error code (such as encoder exception, motor overcurrent, etc.)

16.2.8 `JointState` —Joint State

Field Name	Type	Description
`timestamp`	`int64_t`	Timestamp (unit: nanoseconds)
`joints`	`list[SingleJointState]`	Joint state array

16.2.9 `EstimatorState` —State Estimation Data

Field Name	Type	Description
w_base_pos	`list[float]`	Robot base position(m) in the world frame
w_com_pos	`list[float]`	Center of mass position(m) in the world frame
w_com_vel	`list[float]`	Center of mass linear velocity(m/s) in world frame
w_base_vel	`list[float]`	Robot base linear velocity(m/s) in world frame
b_base_vel	`list[float]`	Robot base linear velocity(m/s) in body frame

16.2.10 Joint Motor Order

Head Joint

Index	Joint Name
0	`head_joint`

Arm Joints

Index	Joint Name
0	left_shoulder_pitch_joint
1	left_shoulder_roll_joint
2	left_shoulder_yaw_joint
3	left_elbow_joint
4	left_wrist_yaw_joint
5	left_wrist_roll_joint
6	left_wrist_pitch_joint
7	right_shoulder_pitch_joint
8	right_shoulder_roll_joint
9	right_shoulder_yaw_joint
10	right_elbow_roll_joint
11	right_wrist_yaw_joint
12	right_wrist_roll_joint
13	right_wrist_pitch_joint

Waist Joint

Index	Joint Name
0	waist_yaw_joint

Leg Joints

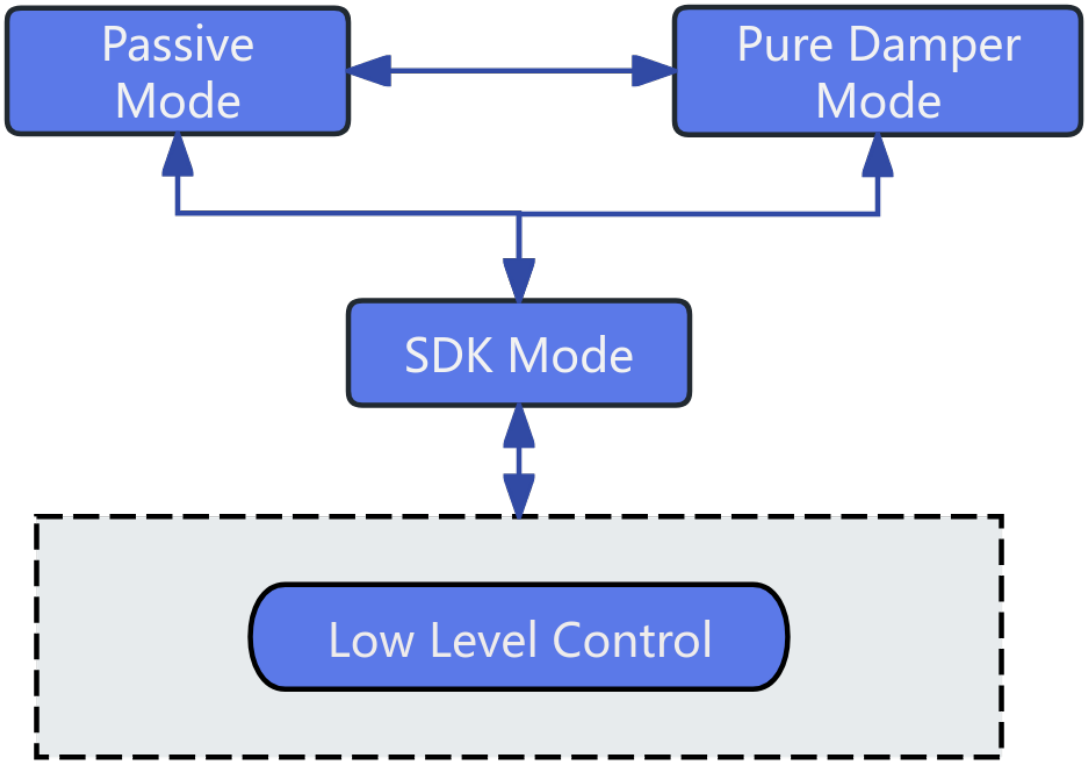
Index	Joint Name
0	left_hip_pitch_joint
1	left_hip_roll_joint
2	left_hip_yaw_joint
3	left_knee_joint
4	left_ankle_pitch_joint
5	left_ankle_roll_joint
6	right_hip_pitch_joint
7	right_hip_roll_joint
8	right_hip_yaw_joint
9	right_knee_joint
10	right_ankle_pitch_joint
11	right_ankle_roll_joint

16.3 URDF Reference

Robot URDF

16.4 Low-Level Motion Control Robot State Introduction

Robot low-level motion mainly develops three-loop control of joints for developers to perform secondary development of robot motion capabilities. Basic control state switching mechanism:



16.5 Notice:

- When using subscription-type SDK interfaces such as Subscribe, do not perform blocking operations within the callback function. Doing so may cause message congestion, processing delays, or even unexpected errors.
- The Z1 robot's upper arm joints have 5-degree-of-freedom and 7-degree-of-freedom SKU versions. For different versions, the joint motor sequence and names are used in order, and nonexistent joints can be ignored.

CHAPTER 17

Sensor Control Service (Python)

Provides robot system sensor (LiDAR/RGBD camera/binocular camera) services. Through the `SensorController`, you can control robot sensors and obtain status via RPC and topic methods.

17.1 Interface Definition

`SensorController` is a management class that encapsulates various robot sensors, supporting initialization, control, and data subscription of LiDAR, RGBD cameras, and binocular cameras.

17.1.1 SensorController

Item	Content
Class Name	SensorController
Constructor	`controller = SensorController()`
Function Overview	Constructor, initializes sensor controller object.
Notes	Constructs internal state.

17.1.2 initialize

Item	Content
Function Name	initialize
Function Declaration	`bool initialize()`
Function Overview	Initialize controller, including resource allocation and driver loading.
Return Value	`True` indicates success, `False` indicates failure.
Notes	Object must be constructed before calling.

17.1.3 shutdown

Item	Content
Function Name	shutdown
Function Declaration	`void shutdown()`
Function Overview	Close all sensor connections and release resources.
Notes	Used in conjunction with initialize.

17.1.4 open_lidar

Item	Content
Function Name	open_lidar
Function Declaration	`Status open_lidar()`
Function Overview	Open LiDAR.
Return Value	`Status` object, `Status.code == ErrorCode.OK` indicates success.
Notes	Blocking interface.

17.1.5 close_lidar

Item	Content
Function Name	close_lidar
Function Declaration	`Status close_lidar()`
Function Overview	Close LiDAR.
Return Value	`Status` object, `Status.code == ErrorCode.OK` indicates success.
Notes	Blocking interface, used in conjunction with open function.

17.1.6 open_head_rgbd_camera

Item	Content
Function Name	open_head_rgbd_camera
Function Declaration	`Status open_head_rgbd_camera()`
Function Overview	Open head RGBD camera.
Return Value	`Status` object, `Status.code == ErrorCode.OK` indicates success.
Notes	Blocking interface.

17.1.7 close_head_rgbd_camera

Item	Content
Function Name	close_head_rgbd_camera
Function Declaration	`Status close_head_rgbd_camera()`
Function Overview	Close head RGBD camera.
Return Value	`Status` object, `Status.code == ErrorCode.OK` indicates success.
Notes	Blocking interface, used in conjunction with open function.

17.1.8 open_binocular_camera

Item	Content
Function Name	open_binocular_camera
Function Declaration	`Status open_binocular_camera()`
Function Overview	Open binocular camera.
Return Value	`Status` object, `Status.code == ErrorCode.OK` indicates success.
Notes	Blocking interface.

17.1.9 close_binocular_camera

Item	Content
Function Name	close_binocular_camera
Function Declaration	`Status close_binocular_camera()`
Function Overview	Close binocular camera.
Return Value	`Status` object, `Status.code == ErrorCode.OK` indicates success.
Notes	Blocking interface, used in conjunction with open function.

17.1.10 subscribe_lidar_imu

Item	Content
Function Name	subscribe_lidar_imu
Function Declaration	`void subscribe_lidar_imu(callback)`
Function Overview	Subscribe to LiDAR IMU data
Parameter Description	callback: Data processing function after receiving data, signature is callback(data: Imu) -> None
Notes	Non-blocking interface, callback function will be called when data is updated.

17.1.11 subscribe_lidar_point_cloud

Item	Content
Function Name	subscribe_lidar_point_cloud
Function Declaration	`void subscribe_lidar_point_cloud(callback)`
Function Overview	Subscribe to LiDAR point cloud data
Parameter Description	callback: Point cloud processing function after receiving data, signature is callback(data: PointCloud2) -> None
Notes	Non-blocking interface, callback function will be called when data is updated.

17.1.12 subscribe_head_rgbd_color_image

Item	Content
Function Name	subscribe_head_rgbd_color_image
Function Declaration	`void subscribe_head_rgbd_color_image(callback)`
Function Overview	Subscribe to head RGBD color image data
Parameter Description	callback: Image processing function after receiving data, signature is callback(data: Image) -> None
Notes	Non-blocking interface, callback function will be called when data is updated.

17.1.13 subscribe_head_rgbd_depth_image

Item	Content
Function Name	subscribe_head_rgbd_depth_image
Function Declaration	`void subscribe_head_rgbd_depth_image(callback)`
Function Overview	Subscribe to head RGBD depth image data
Parameter Description	callback: Depth image processing function after receiving data, signature is callback(data: Image) -> None
Notes	Non-blocking interface, callback function will be called when data is updated.

17.1.14 subscribe_head_rgbd_camera_info

Item	Content
Function Name	subscribe_head_rgbd_camera_info
Function Declaration	`void subscribe_head_rgbd_camera_info(callback)`
Function Overview	Subscribe to head RGBD camera parameter data
Parameter Description	callback: Camera intrinsic parameter processing function after receiving data, signature is callback(data: CameraInfo) -> None
Notes	Non-blocking interface, callback function will be called when data is updated.

17.1.15 subscribe_binocular_image

Item	Content
Function Name	subscribe_binocular_image
Function Declaration	`void subscribe_binocular_image(callback)`
Function Overview	Subscribe to binocular camera image frame data
Parameter Description	callback: Binocular camera data processing function after receiving data, signature is callback(data: BinocularCameraFrame) -> None
Notes	Non-blocking interface, callback function will be called when data is updated.

17.1.16 subscribe_binocular_camera_info

Item	Content
Function Name	subscribe_binocular_camera_info
Function Declaration	`void subscribe_binocular_camera_info(callback)`
Function Overview	Subscribe to binocular camera parameter data
Parameter Description	callback: Camera intrinsic parameter processing function after receiving data, signature is callback(data: CameraInfo) -> None
Notes	Non-blocking interface, callback function will be called when data is updated.

17.2 Data Types

17.2.1 Imu

IMU data structure, containing sensor data such as attitude, angular velocity, linear acceleration, etc.

Field Name	Type	Description
`timestamp`	`int64_t`	Timestamp (nanoseconds)
`temperature`	`float`	Temperature (Celsius)
`orientation`	`Quaternion`	Attitude quaternion
`angular_velocity`	`Vector3`	Angular velocity (rad/s)
`linear_acceleration`	`Vector3`	Linear acceleration (m/s^2)

17.2.2 PointCloud2

Point cloud data structure, containing 3D point cloud information.

Field Name	Type	Description
`header`	`Header`	Standard message header (timestamp + frame_id)
`height`	`int32_t`	Point cloud height (number of rows)
`width`	`int32_t`	Point cloud width (number of columns)
`fields`	`list[PointField]`	Point field array
`is_bigendian`	`bool`	Byte order
`point_step`	`int32_t`	Number of bytes per point
`row_step`	`int32_t`	Number of bytes per row
`data`	`list[uint8_t]`	Raw point cloud data (packed by field)
`is_dense`	`bool`	Whether it is a dense point cloud (no invalid points)

17.2.3 Image

Image data structure, supporting multiple encoding formats.

Field Name	Type	Description
`header`	`Header`	Standard message header (timestamp + frame_id)
`height`	`int32_t`	Image height (pixels)
`width`	`int32_t`	Image width (pixels)
`encoding`	`str`	Image encoding type, such as "rgb8", "mono8", "bgr8"
`is_bigendian`	`bool`	Whether data is in big-endian mode
`step`	`int32_t`	Number of bytes per image row
`data`	`list[uint8_t]`	Raw image byte data

17.2.4 CameraInfo

Camera intrinsic parameters and distortion information, usually published together with Image messages.

Field Name	Type	Description
`header`	`Header`	Standard message header (timestamp + frame_id)
`height`	`int32_t`	Image height (number of rows)
`width`	`int32_t`	Image width (number of columns)
`distortion_model`	`str`	Distortion model, e.g., "plumb_bob"
`D`	`list[double]`	Distortion parameter array
`K`	`list[double]`	Camera intrinsic matrix (9 elements)
`R`	`list[double]`	Rectification matrix (9 elements)
`P`	`list[double]`	Projection matrix (12 elements)
`binning_x`	`int32_t`	Horizontal binning coefficient
`binning_y`	`int32_t`	Vertical binning coefficient
`roi_x_offset`	`int32_t`	ROI start x
`roi_y_offset`	`int32_t`	ROI start y
`roi_height`	`int32_t`	ROI height
`roi_width`	`int32_t`	ROI width
`roi_do_rectify`	`bool`	Whether to perform rectification

17.2.5 BinocularCameraFrame

Binocular camera frame data structure, containing format and image frames.

Field Name	Type	Description
`header`	`Header`	Common message header (timestamp + frame_id)
`format`	`str`	Image format
`data`	`list[uint8_t]`	Left and right eye stitched image data, left half is left eye image, right half is right eye image

17.3 Notice:

When using subscription-type SDK interfaces such as Subscribe, do not perform blocking operations within the callback function. Doing so may cause message congestion, processing delays, or even unexpected errors.

CHAPTER 18

Audio Control Service (Python)

Provides robot system audio service controller. Through the `AudioController`, you can control robot audio and obtain status via RPC methods.

18.1 Interface Definition

`AudioController` is a Python class that encapsulates audio control functionality, mainly used for audio playback control, TTS playback, volume setting and query, etc.

18.1.1 AudioController

Item	Content
Class Name	AudioController
Constructor	`controller = AudioController()`
Function Overview	Initialize audio controller object, construct internal state, allocate resources, etc.
Notes	Constructs internal state.

18.1.2 initialize

Item	Content
Function Name	initialize
Function Declaration	`bool initialize()`
Function Overview	Initialize audio control module, prepare playback resources and devices.
Return Value	`True` indicates success, `False` indicates failure.
Notes	Used in conjunction with `shutdown()`.

18.1.3 shutdown

Item	Content
Function Name	shutdown
Function Declaration	`void shutdown()`
Function Overview	Shutdown audio controller and release resources.
Notes	Ensure to call before destruction.

18.1.4 play

Item	Content
Function Name	play
Function Declaration	`Status play(TtsCommand cmd, int timeout_ms)`
Function Overview	Play TTS (Text-to-Speech) audio command.
Parameter Description	`cmd`: TTS command, containing text, speech rate, tone, etc.
Return Value	`Status` object, `Status.code == ErrorCode.OK` indicates success.
Notes	Blocking interface, ensure module is initialized before calling.

18.1.5 stop

Item	Content
Function Name	stop
Function Declaration	`Status stop()`
Function Overview	Stop current audio playback.
Return Value	`Status` object, `Status.code == ErrorCode.OK` indicates success.
Notes	Blocking interface, usually used to interrupt current speech.

18.1.6 set_volume

Item	Content
Function Name	set_volume
Function Declaration	`Status set_volume(int volume)`
Function Overview	Set audio output volume.
Parameter Description	`volume`: Volume value, usually in range 0~100.
Return Value	`Status` object, `Status.code == ErrorCode.OK` indicates success.
Notes	Blocking interface, takes effect immediately after setting.

18.1.7 get_volume

Item	Content
Function Name	get_volume
Function Declaration	`tuple[Status, int] get_volume()`
Function Overview	Get current audio output volume.
Return Value	Returns tuple `(Status, volume)`, `Status.code == ErrorCode.OK` indicates success.
Notes	Blocking interface, return value needs to be checked before using `volume`.

18.1.8 open_audio_stream

Item	Content
Function Name	open_audio_stream
Function Declaration	`Status open_audio_stream()`
Function Overview	Open audio stream, prepare for audio playback.
Return Value	`Status` object, `Status.code == ErrorCode.OK` indicates success.
Notes	Blocking interface, return value needs to be checked for successful execution

18.1.9 close_audio_stream

Item	Content
Function Name	close_audio_stream
Function Declaration	`Status close_audio_stream()`
Function Overview	Close audio stream.
Return Value	`Status` object, `Status.code == ErrorCode.OK` indicates success.
Notes	Blocking interface, return value needs to be checked for successful execution

18.1.10 subscribe_origin_audio_stream

Item	Content
Function Name	subscribe_origin_audio_stream
Function Declaration	`void subscribe_origin_audio_stream(callback)`
Function Overview	Subscribe to original audio stream data.
Parameter Description	callback: Data processing function after receiving data, signature is callback(data: AudioStream) -> None
Notes	Non-blocking interface.

18.1.11 subscribe_bf_audio_stream

Item	Content
Function Name	subscribe_bf_audio_stream
Function Declaration	`void subscribe_bf_audio_stream(callback)`
Function Overview	Subscribe to BF audio stream data.
Parameter Description	callback: Data processing function after receiving data, signature is callback(data: AudioStream) -> None
Notes	Non-blocking interface.

18.1.12 unsubscribe_origin_audio_stream

Item	Content
Function Name	unsubscribe_origin_audio_stream
Function Declaration	`void unsubscribe_origin_audio_stream()`
Function Overview	Unsubscribe from original audio stream data
Remarks	Non-blocking interface, used in pair with subscribe_origin_audio_stream.

18.1.13 unsubscribe_bf_audio_stream

Item	Content
Function Name	unsubscribe_bf_audio_stream
Function Declaration	`void unsubscribe_bf_audio_stream()`
Function Overview	Unsubscribe from BF audio stream data
Remarks	Non-blocking interface, used in pair with subscribe_bf_audio_stream.

18.1.14 open_wakeup_status_stream

Item	Content
Function Name	open_wakeup_status_stream
Function Declaration	`Status open_wakeup_status_stream()`
Function Overview	Enable voice wake-up status stream
Return Value	Operation status, returns Status.OK on success

18.1.15 close_wakeup_status_stream

Item	Content
Function Name	close_wakeup_status_stream
Function Declaration	`Status close_wakeup_status_stream()`
Function Overview	Disable voice wake-up status stream
Return Value	Operation status, returns Status.OK on success

18.1.16 subscribe_wakeup_status

Item	Content
Function Name	subscribe_wakeup_status
Function Declaration	`void subscribe_wakeup_status(callback)`
Function Overview	Subscribe to voice wake-up status
Parameter Description	callback: Callback function for processing wake-up status when received

18.1.17 unsubscribe_wakeup_status

Item	Content
Function Name	unsubscribe_wakeup_status
Function Declaration	`void unsubscribe_wakeup_status()`
Function Overview	Unsubscribe from voice wake-up status

18.2 Type Definitions

18.2.1 `TtsPriority` —TTS Playback Priority Level

Used to control interrupt behavior between different TTS tasks. Higher priority tasks will interrupt playback of current lower priority tasks.

Enumeration Value	Description
`TtsPriority.HIGH`	Highest priority, e.g.: low battery warning, emergency alert
`TtsPriority.MIDDLE`	Medium priority, e.g.: system prompts, status announcements
`TtsPriority.LOW`	Lowest priority, e.g.: daily voice conversation, background announcements

18.2.2 `TtsMode` —Task Scheduling Strategy Under Same Priority

Used to refine control of playback order and clearing logic for multiple TTS tasks under the same priority condition.

Enumeration Value	Description
`TtsMode.CLEARTOP`	Clear all tasks of current priority (including currently playing and waiting queue), immediately play this request
`TtsMode.ADD`	Append this request to the end of current priority queue, play in order (without interrupting current playback)
`TtsMode.CLEARBUFFER`	Clear unplayed requests in queue, keep current playback, then play this request

18.3 Structure Definitions

18.3.1 `TtsCommand` —TTS Playback Command Structure

Describes complete information for a TTS playback request, supporting setting unique identifier, text content, priority control, and scheduling mode under same priority.

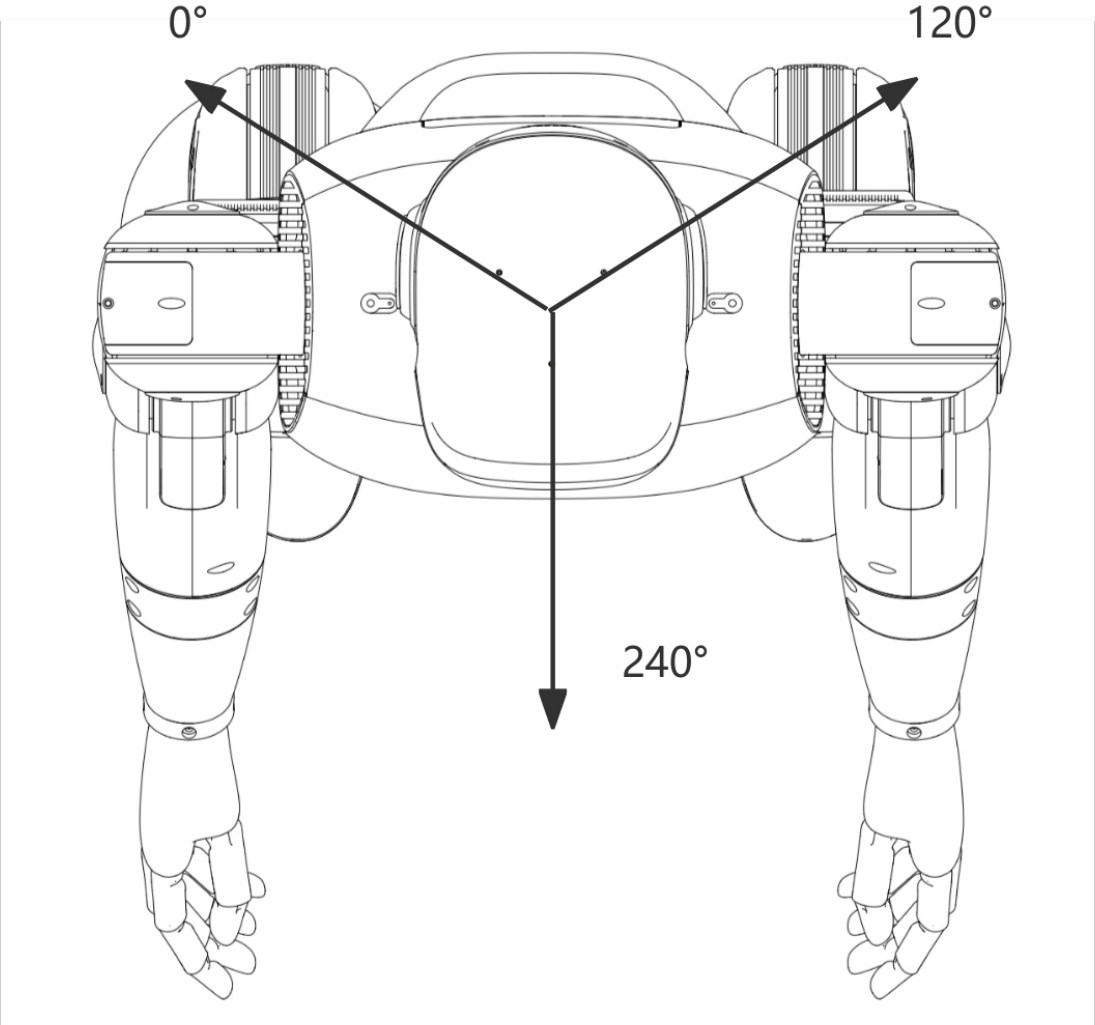
Field Name	Type	Description
`id`	`str`	TTS task unique ID, e.g. `"id_01"`, used to track playback status
`content`	`str`	Text content to be played, e.g. `"Hello, welcome to the intelligent voice system."`
`priority`	`TtsPriority`	Playback priority, controls whether to interrupt currently playing low-priority speech
`mode`	`TtsMode`	Scheduling strategy under same priority, controls whether tasks are appended, overridden, etc.

18.3.2 `AudioStream` - Audio Stream Structure

Describes raw audio stream or BF audio stream data.

Field Name	Type	Description
`data_length`	`int`	Data length
`raw_data`	`bytes`	Audio stream data

18.4 DOA



18.5 Notice:

When using subscription-type SDK interfaces such as Subscribe, do not perform blocking operations within the callback function. Doing so may cause message congestion, processing delays, or even unexpected errors.

CHAPTER 19

State Monitor Service (Python)

Provides robot state monitoring interface class. Through the `StateMonitor`, you can provide state query and other interfaces.

19.1 Interface Definition

`StateMonitor` is a robot system state monitoring management class, typically used to control robot state management, supporting state queries.

19.1.1 StateMonitor

Item	Content
Function Name	StateMonitor
Function Declaration	`StateMonitor();`
Function Overview	Constructor, initializes state monitor object.
Notes	Constructs internal state.

19.1.2 ~StateMonitor

Item	Content
Function Name	~StateMonitor
Function Declaration	`virtual ~StateMonitor();`
Function Overview	Destructor, releases resources.
Notes	Sensors should be closed before calling.

19.1.3 Initialize

Item	Content
Function Name	Initialize
Function Declaration	`bool Initialize();`
Function Overview	Initialize controller, including resource allocation and driver loading.
Return Value	`true` indicates success, `false` indicates failure.
Notes	Object must be constructed before calling.

19.1.4 Shutdown

Item	Content
Function Name	Shutdown
Function Declaration	`void Shutdown();`
Function Overview	Shutdown and release resources.
Notes	Used in conjunction with Initialize.

19.1.5 get_current_state

Item	Content
Function Name	`get_current_state`
Function Declaration	`RobotState get_current_state()`
Function Overview	Get current robot aggregated state
Return Value	`tuple[Status, RobotState]` object
Notes	Non-blocking interface, gets recently monitored robot state data, including BMS/fault state monitoring, etc., will be iteratively expanded in the future

19.1.6 `RobotState` —Robot State Data Structure

Used to represent overall robot state information:

Field Name	Type	Description
`faults`	`list[Fault]`	Fault information list
`bms_data`	`BmsData`	Battery Management System data

19.1.7 `BmsData` —Battery Management System Data Structure

Represents battery state information:

Field Name	Type	Description
`battery_percentage`	`float`	Current battery remaining power (percentage, 0~100)
`battery_health`	`float`	Battery health status (higher is better)
`battery_state`	`BatteryState`	Battery state (see enumeration below)
`power_supply_status`	`PowerSupplyStatus`	Battery charge/discharge state (see enumeration below)

19.1.8 Enumeration Type Definitions

`BatteryState` —Battery State Enumeration Type

Used to represent the current state of the battery, used for battery state judgment and processing in the system:

Enumeration Value	Value	Description
`BatteryState.UNKNOWN`	0	Unknown state
`BatteryState.GOOD`	1	Battery state good
`BatteryState.OVERHEAT`	2	Battery overheating
`BatteryState.DEAD`	3	Battery damaged
`BatteryState.OVERVOLTAGE`	4	Battery overvoltage
`BatteryState.UNSPEC_FAILURE`	5	Unknown fault
`BatteryState.COLD`	6	Battery overcooled
`BatteryState.WATCHDOG_TIMER_EXPIRE`	7	Watchdog timer timeout
`BatteryState.SAFETY_TIMER_EXPIRE`	8	Safety timer timeout

`PowerSupplyStatus` —Battery Charge/Discharge State

Used to represent the current battery charge/discharge state:

Enumeration Value	Value	Description
`PowerSupplyStatus.UNKNOWN`	0	Unknown state
`PowerSupplyStatus.CHARGING`	1	Battery charging
`PowerSupplyStatus.DISCHARGING`	2	Battery discharging
`PowerSupplyStatus.NOTCHARGING`	3	Battery not charging/discharging
`PowerSupplyStatus.FULL`	4	Battery fully charged

19.2 Error Code Mapping Table

Error Code (Hexadecimal)	Error Description
0x0000	No fault
0x1101	Service invocation failed
0x1301	Central control node lost
0x1302	App node lost
0x1303	Audio node lost
0x1304	Stereo camera node lost
0x1305	LIDAR node lost
0x1306	SLAM node lost
0x1307	Navigation node lost
0x1308	AI node lost
0x1309	Head node lost
0x130A	Point cloud node lost
0x2201	No LIDAR data received
0x2202	No stereo camera data received
0x2203	Stereo camera data error
0x2204	Stereo camera initialization failed
0x220B	No odometry data received
0x220C	No IMU data received
0x2215	Depth camera not detected
0x3101	Failed to connect robot to app
0x3102	Heartbeat lost - assertion failed
0x4201	Failed to open head serial port
0x4202	No head data received
0x5201	No navigation TF data
0x5202	No navigation map data
0x5203	No navigation localization data
0x5204	No navigation LIDAR data

continues on next page

Table 1 – continued from previous page

Error Code (Hexadecimal)	Error Description
0x5205	No navigation depth camera data
0x5206	No navigation multi-line LIDAR data
0x5207	No navigation odometry data
0x6201	SLAM localization error
0x6102	No SLAM LIDAR data
0x6103	No SLAM odometry data
0x6104	SLAM map data error
0x7201	LCM connection timeout
0x8201	Left leg hardware error
0x8202	Right leg hardware error
0x8203	Left arm hardware error
0x8204	Right arm hardware error
0x8205	Waist hardware error
0x8206	Head hardware error
0x8207	Hand hardware error
0x8208	Gripper hardware error
0x8209	IMU hardware error
0x820A	Power system hardware error
0x820B	Leg force sensor hardware error
0x820C	Arm force sensor hardware error
0x9201	ECAT (EtherCAT) hardware error
0xA201	Motion posture error
0xA202	Foot position deviation during movement
0xA203	Joint velocity error during motion

CHAPTER 20

SLAM Navigation Control Service (Python)

Provides SLAM (Simultaneous Localization and Mapping) and navigation control services for robot systems. Through SlamNavController, RPC communication can be used to control robot mapping, localization, navigation and other functions.

20.1 Interface Definition

`SlamNavController` is a controller for SLAM and navigation control, supporting control operations such as mapping, localization, navigation, and map management, encapsulating underlying details for upper-level system calls.

20.1.1 SlamNavController

Item	Content
Class Name	SlamNavController
Class Declaration	`SlamNavController()`
Function Overview	Constructor, initializes SLAM navigation controller state
Remarks	Constructs internal control resources

20.1.2 initialize

Item	Content
Method Name	initialize
Method Declaration	`bool initialize()`
Function Overview	Initializes SLAM navigation controller, prepares SLAM and navigation functions
Return Value	`True` indicates success, `False` indicates failure
Remarks	Must be called before first use

20.1.3 shutdown

Item	Content
Method Name	shutdown
Method Declaration	`void shutdown()`
Function Overview	Closes controller and releases resources
Remarks	Used in conjunction with initialize, safely disconnects

20.1.4 activate_slam_mode

Item	Content
Method Name	activate_slam_mode
Method Declaration	`Status activate_slam_mode(SlamMode mode, str map_path = "", int timeout_ms)`
Function Overview	Activates SLAM mode and starts mapping or localization mode
Parameter Description	`mode`: SLAM mode enumeration`map_path`: Map path (used in localization mode), can be obtained through get_map_path`timeout_ms`: Timeout time (milliseconds), default value is 10000
Return Value	`Status::OK` indicates success, others indicate failure
Remarks	Blocking interface, supports mapping and localization mode switching

20.1.5 start_mapping

Item	Content
Method Name	start_mapping
Method Declaration	`Status start_mapping(int timeout_ms)`
Function Overview	Starts mapping
Parameter Description	`timeout_ms`: Timeout time (milliseconds), default value is 10000
Return Value	`Status::OK` indicates success, others indicate failure
Remarks	Blocking interface, mapping mode must be activated first

20.1.6 cancel_mapping

Item	Content
Method Name	cancel_mapping
Method Declaration	`Status cancel_mapping(int timeout_ms)`
Function Overview	Cancels mapping
Parameter Description	`timeout_ms`: Timeout time (milliseconds), default value is 10000
Return Value	`Status::OK` indicates success, others indicate failure
Remarks	Blocking interface, cancels current mapping task

20.1.7 save_map

Item	Content
Method Name	save_map
Method Declaration	`Status save_map(str map_name, int timeout_ms)`
Function Overview	Ends mapping and saves the map
Parameter Description	`map_name`: Map name`timeout_ms`: Timeout time (milliseconds), default value is 10000
Return Value	`Status::OK` indicates success, others indicate failure
Remarks	Blocking interface, must be called in mapping mode

20.1.8 load_map

Item	Content
Method Name	load_map
Method Declaration	`Status load_map(str map_name, int timeout_ms)`
Function Overview	Loads map and sets it as current map
Parameter Description	`map_name`: Map name`timeout_ms`: Timeout time (milliseconds), default value is 10000
Return Value	`Status::OK` indicates success, others indicate failure
Remarks	Blocking interface, loads map with specified name

20.1.9 delete_map

Item	Content
Method Name	delete_map
Method Declaration	`Status delete_map(str map_name, int timeout_ms)`
Function Overview	Deletes map
Parameter Description	`map_name`: Name of map to delete`timeout_ms`: Timeout time (milliseconds), default value is 10000
Return Value	`Status::OK` indicates success, others indicate failure
Remarks	Blocking interface, permanently deletes specified map

20.1.10 get_map_path

Item	Content
Method Name	get_map_path
Method Declaration	`tuple[Status, List[str]] get_map_path(str map_name, int timeout_ms)`
Function Overview	Get map path
Parameter Description	`map_name`: Map name`timeout_ms`: Timeout time (milliseconds), default value is 10000
Return Value	`Status::OK` indicates success, others indicate failure`List[str]`: Map path (output parameter)
Remarks	Blocking interface, gets the storage path of the specified map

20.1.11 get_all_map_info

Item	Content
Method Name	get_all_map_info
Method Declaration	`tuple[Status, AllMapInfo] get_all_map_info(int timeout_ms)`
Function Overview	Get all map information
Parameter Description	`timeout_ms`: Timeout time (milliseconds), default value is 10000
Return Value	`Status::OK`: indicates success, others indicate failure`AllMapInfo`: All map information (output parameter)
Remarks	Blocking interface, gets detailed information of all maps in the system

20.1.12 init_pose

Item	Content
Method Name	init_pose
Method Declaration	`Status init_pose(Pose3DEuler pose, int timeout_ms)`
Function Overview	Initializes pose
Parameter Description	`pose`: Pose information to publish`timeout_ms`: Timeout time (milliseconds), default value is 15000
Return Value	`Status::OK` indicates success, others indicate failure
Remarks	Blocking interface, sets robot initial pose; when publishing pose, a fixed -1.57rad offset needs to be applied to the Yaw direction because there is a -1.57rad offset between the mechanical installation of the LiDAR and the robot body

20.1.13 get_current_localization_info

Item	Content
Method Name	get_current_localization_info
Method Declaration	`Status get_current_localization_info(LocalizationInfo pose_info, int timeout_ms)`
Function Overview	Gets current pose information
Parameter Description	`pose_info`: Current position and orientation information (output parameter)`timeout_ms`: Timeout time (milliseconds), default value is 10000
Return Value	`Status::OK` indicates success, others indicate failure
Remarks	Blocking interface, gets robot current pose status

20.1.14 activate_nav_mode

Item	Content
Method Name	activate_nav_mode
Method Declaration	`Status activate_nav_mode(NavMode mode, str map_path = "", int timeout_ms)`
Function Overview	Activates navigation mode
Parameter Description	`mode`: Target navigation mode`map_path`: Map path (used in grid map mode), can be obtained through get_map_path`timeout_ms`: Timeout time (milliseconds), default value is 10000
Return Value	`Status::OK` indicates success, others indicate failure
Remarks	Blocking interface, activates specified navigation mode

20.1.15 set_nav_target

Item	Content
Method Name	set_nav_target
Method Declaration	`Status set_nav_target(NavTarget goal, int timeout_ms)`
Function Overview	Sets global navigation target point and starts navigation task
Parameter Description	`goal`: Global coordinates of target point`timeout_ms`: Timeout time (milliseconds), default value is 10000
Return Value	`Status::OK` indicates success, others indicate failure
Remarks	Blocking interface, sets navigation target and starts navigation

20.1.16 pause_nav_task

Item	Content
Method Name	pause_nav_task
Method Declaration	`Status pause_nav_task()`
Function Overview	Pauses current navigation task
Return Value	`Status::OK` indicates success, others indicate failure
Remarks	Non-blocking interface, pauses navigation task

20.1.17 resume_nav_task

Item	Content
Method Name	resume_nav_task
Method Declaration	`Status resume_nav_task()`
Function Overview	Resumes paused navigation task
Return Value	`Status::OK` indicates success, others indicate failure
Remarks	Non-blocking interface, resumes paused navigation task

20.1.18 cancel_nav_task

Item	Content
Method Name	cancel_nav_task
Method Declaration	`Status cancel_nav_task()`
Function Overview	Cancels current navigation task
Return Value	`Status::OK` indicates success, others indicate failure
Remarks	Non-blocking interface, cancels current navigation task

20.1.19 get_nav_task_status

Item	Content
Method Name	`get_nav_task_status`
Method Declaration	`tuple[Status, NavStatus] get_nav_task_status()`
Function Overview	Retrieves the current status information of the navigation task.
Return Value	`Status::OK` indicates success; others indicate failure. Returns a `NavStatus` object (empty on failure).
Remarks	This is a blocking interface for querying the navigation task status. Returns a `Status` code along with a `NavStatus` object, which can be used to check navigation progress and status.

20.1.20 open_odometry_stream

Item	Content
Function Name	open_odometry_stream
Function Declaration	`Status open_odometry_stream()`
Function Overview	Open odometry stream
Return Value	`Status` object, `Status.code == ErrorCode.OK` indicates success
Remarks	Blocking interface, check return value to ensure successful execution

20.1.21 close_odometry_stream

Item	Content
Function Name	close_odometry_stream
Function Declaration	`Status close_odometry_stream()`
Function Overview	Close odometry stream
Return Value	`Status` object, `Status.code == ErrorCode.OK` indicates success
Remarks	Blocking interface, used in conjunction with open_odometry_stream

20.1.22 subscribe_odometry

Item	Content
Function Name	subscribe_odometry
Function Declaration	`void subscribe_odometry(callback)`
Function Overview	Subscribe to odometry data
Parameter Description	callback: Processing function after receiving odometry data, signature is callback(data: Odometry) -> None
Remarks	Non-blocking interface, callback function will be called when odometry data is updated

20.1.23 unsubscribe_odometry

Item	Content
Function Name	unsubscribe_odometry
Function Declaration	`void unsubscribe_odometry()`
Function Overview	Unsubscribe from odometry data
Remarks	Non-blocking interface. Used in conjunction with subscribe_odometry

20.1.24 get_point_cloud_map

Item	Content
Function Name	get_point_cloud_map
Function Declaration	`tuple[Status, PointCloud2] get_point_cloud_map(int timeout_ms)`
Function Overview	Get point cloud map data
Parameter Description	`timeout_ms`: Timeout duration (milliseconds)
Return Value	Returns a tuple, first element is a `Status` object, `Status.code == ErrorCode.OK` indicates success; second element is the point cloud map data
Remarks	Blocking interface, gets current point cloud map data

20.1.25 unsubscribe_localization_point_cloud_map

Item	Content
Function Name	unsubscribe_localization_point_cloud_map
Function Declaration	`void unsubscribe_localization_point_cloud_map()`
Function Overview	Unsubscribe from localization point cloud map data
Remarks	Non-blocking interface. Used in conjunction with subscribe_localization_point_cloud_map

20.2 Type Definitions

20.2.1 `Pose3DEuler` —3D Pose Structure

Field Name	Type	Description
`position`	`List[float]`	Position coordinates (x, y, z)
`orientation`	`List[float]`	Euler angles (roll, pitch, yaw)

20.2.2 `NavTarget` —Navigation Target Point Structure

Field Name	Type	Description
`id`	`int`	Target point ID
`frame_id`	`str`	Target point coordinate frame ID
`goal`	`Pose3DEuler`	Target point pose

20.2.3 `LocalizationInfo` —Pose Information Structure

Field Name	Type	Description
`is_localization`	`bool`	Whether localized
`pose`	`Pose3DEuler`	Current pose

20.2.4 `NavStatus` —Navigation Status Structure

Field Name	Type	Description
`id`	`int`	Target point ID, -1 indicates no target point
`status`	`NavStatusType`	Navigation status type
`message`	`str`	Navigation status message

20.2.5 `PolyRegion` —Polygon Region Structure

Field Name	Type	Description
`points`	`List[Point2D]`	Polygon vertex list

20.2.6 `Point2D` —2D Point Structure

Field Name	Type	Description
`x`	`float`	X coordinate
`y`	`float`	Y coordinate

20.3 Enumeration Type Definitions

20.3.1 `SlamMode` —SLAM Mode Enumeration

Enum Value	Value	Description
`IDLE`	0	Idle mode
`LOCALIZATION`	1	Localization mode
`MAPPING`	2	Mapping mode

20.3.2 `NavMode` —Navigation Mode Enumeration

Enum Value	Value	Description
`IDLE`	0	Idle mode
`GRID_MAP`	1	Grid map navigation mode

20.3.3 `NavStatusType` —Navigation Status Type Enumeration

Enum Value	Value	Description
`NONE`	0	No status
`RUNNING`	1	Running
`END_SUCCESS`	2	Successfully ended
`END_FAILED`	3	Failed to end
`PAUSE`	4	Paused
`CONTINUE`	5	Continue
`CANCEL`	6	Canceled

20.4 SLAM Navigation Control Introduction

The robot’s SLAM navigation control service can be divided into SLAM functions and navigation functions.

- In SLAM functions, corresponding interfaces can be called to implement mapping, localization, map management and other functions.
- In navigation functions, corresponding interfaces can be called to implement target navigation, navigation control and other functions.

20.4.1 Applicable Scenarios and Scope

- Static indoor flat areas smaller than 100 m × 100 m with rich features. Do not exceed the recommended range.
- This functionality is applicable to the education and research industry and is not recommended for commercial applications. For commercial use, please contact sales.

20.4.2 SLAM Function Flow

Function	Operation Flow
Mapping	Activate mapping mode → Start mapping → Save map
Map Management	Load map, get map information, delete map, get map path, etc.

20.4.3 Navigation Function Flow

Function	Operation Flow
Localization	Load map → Activate localization mode → Initialize pose → Get localization status
Navigation	Localization success → Activate navigation mode → Set target pose → Get navigation status
Navigation Control	Set target pose → PauseNavTask navigation → ResumeNavTask navigation → CancelNavTask navigation

20.4.4 Localization Mode Initialization

When SLAM is in localization mode, an initial pose can be specified to quickly complete relocalization and initialization. For large-scale maps, specifying the initial pose is mandatory.

Small Map Mode

满足如下条件:

The following conditions must be met:

- Condition 1: The map should not be too large. For example, in a single room, it is best to keep the map area within 10m × 10m.
- Condition 2: Modify the configuration to adapt to this mode:

```
# Log in to the robot
ssh eame@192.168.54.119
# Modify the following configuration
# vim /opt/eame/eamegrapher_3d/share/eamegrapher_3d/config/params.yaml
reloc_options: true
```

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```
# After modifying the YAML file for the first time, restart the SLAM module for the␣
↪change to take effect:
sudo systemctl restart slam.service
```

Large Map Mode

The following conditions must be met:

- Condition 1: The robot must be located at the mapping origin (the starting position when mapping began), and the robot's orientation must remain consistent.
- Condition 2: Modify the configuration to adapt to this mode:

When using the SDK for SLAM navigation (unlike the app, which allows convenient visual positioning), you must modify the SLAM configuration to fix the map orientation and facilitate localization:

```
# Log in to the robot
ssh eame@192.168.54.119
# Modify the following configuration
# vim /opt/eame/eamegrapher_3d/share/eamegrapher_3d/config/params.yaml
align_map: false

# After modifying the YAML file for the first time, restart the SLAM module for the␣
↪change to take effect:
sudo systemctl restart slam.service
```

- Condition 3: When initializing the pose, apply a 180° (3.14 rad) offset to the yaw angle:

because the LiDAR's mechanical installation differs from the robot body orientation by 180°.

20.4.5 Map Noise Removal and Obstacle Addition

- Software Name: GIMP
- Download Link: https://www.gimp.org/downloads/
- Operating System: Ubuntu
- File to Edit: /home/eame/cust_para/maps/${map_name}/map/map.pgm Log in to the robot (ssh eame@192.168.54.119), open the .pgm map file with GIMP for editing, and replace the original file after modifications are complete.
- Editing Tutorial Video:

CHAPTER 21

High-Level Motion Control Example

This example demonstrates how to use the Magicbot-Z1 SDK for initialization, robot connection, high-level motion control (gait, tricks, remote control), and other basic operations.

21.1 C++:

Example file: `high_level_motion_example.cpp`

```cpp
#include "magic_robot.h"
#include "magic_sdk_version.h"

#include <termios.h>
#include <unistd.h>
#include <csignal>

#include <iostream>

using namespace magic::z1;

magic::z1::MagicRobot robot;

void signalHandler(int signum) {
  std::cout << "Interrupt signal (" << signum << ") received.\n";
```

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```
  robot.Shutdown();
  // Exit process
  exit(signum);
}

void print_help() {
  std::cout << "Key Function Demo Program\n\n";
  std::cout << "High-Level Motion Control Function Description:\n";
  std::cout << "  1        Function 1: Recovery stand\n";
  std::cout << "  2        Function 2: Balance stand\n";
  std::cout << "  3        Function 3: Execute trick - greeting action\n";
  std::cout << "  w        Function w: Move forward\n";
  std::cout << "  a        Function a: Move left\n";
  std::cout << "  s        Function s: Move backward\n";
  std::cout << "  d        Function d: Move right\n";
  std::cout << "  x        Function x: Stop moving\n";
  std::cout << "  t        Function t: Turn left\n";
  std::cout << "  g        Function g: Turn right\n";
  std::cout << "  u        Function u: Reset head move\n";
  std::cout << "  j        Function j: Move head left\n";
  std::cout << "  k        Function k: Move head right\n";
  std::cout << "\n";
  std::cout << "  ?        Function ?: Print help\n";
  std::cout << "  ESC      Exit program\n";
}

int getch() {
  struct termios oldt, newt;
  int ch;
  tcgetattr(STDIN_FILENO, &oldt);  // Get current terminal settings
  newt = oldt;
  newt.c_lflag &= ~(ICANON | ECHO);  // Disable buffering and echo
  tcsetattr(STDIN_FILENO, TCSANOW, &newt);
  ch = getchar();                              // Read key press
  tcsetattr(STDIN_FILENO, TCSANOW, &oldt);  // Restore settings
  return ch;
}

void RecoveryStand() {
```

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```
  // Get high-level motion controller
  auto& controller = robot.GetHighLevelMotionController();

  // Set gait
  auto status = controller.SetGait(GaitMode::GAIT_RECOVERY_STAND);
  if (status.code != ErrorCode::OK) {
    std::cerr << "set robot gait failed"
              << ", code: " << status.code
              << ", message: " << status.message << std::endl;
    return;
  }
}

void BalanceStand() {
  // Get high-level motion controller
  auto& controller = robot.GetHighLevelMotionController();

  // Set posture display gait
  auto status = controller.SetGait(GaitMode::GAIT_BALANCE_STAND);
  if (status.code != ErrorCode::OK) {
    std::cerr << "set robot gait failed"
              << ", code: " << status.code
              << ", message: " << status.message << std::endl;
    return;
  }
  std::cout << "robot gait set to GAIT_BALANCE_STAND successfully." << std::endl;
}

void ExecuteTrick() {
  // Get high-level motion controller
  auto& controller = robot.GetHighLevelMotionController();

  // Execute trick
  auto status = controller.ExecuteTrick(TrickAction::ACTION_LEFT_GREETING);
  if (status.code != ErrorCode::OK) {
    std::cerr << "execute robot trick failed"
              << ", code: " << status.code
              << ", message: " << status.message << std::endl;
    return;
  }
```

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```
  std::cout << "robot trick executed successfully." << std::endl;
}

void JoyStickCommand(float left_x_axis,
                     float left_y_axis,
                     float right_x_axis,
                     float right_y_axis) {
  // Get high-level motion controller
  auto& controller = robot.GetHighLevelMotionController();

  JoystickCommand joy_command;
  joy_command.left_x_axis = left_x_axis;
  joy_command.left_y_axis = left_y_axis;
  joy_command.right_x_axis = right_x_axis;
  joy_command.right_y_axis = right_y_axis;
  controller.SendJoyStickCommand(joy_command);
}

void HeadMove(float shake_angle) {
  // Get high-level motion controller
  auto& controller = robot.GetHighLevelMotionController();
  auto status = controller.HeadMove(shake_angle);
  if (status.code != ErrorCode::OK) {
    std::cerr << "head move failed"
              << ", code: " << status.code
              << ", message: " << status.message << std::endl;
    return;
  }
  std::cout << "head move successfully." << std::endl;
  std::cout << "shake_angle: " << shake_angle << std::endl;
}

int main(int argc, char* argv[]) {
  // Bind SIGINT (Ctrl+C)
  signal(SIGINT, signalHandler);

  std::cout << "SDK Version: " << SDK_VERSION_STRING << std::endl;

  print_help();
```

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```
  std::string local_ip = "192.168.54.111";
  // Configure local IP address for direct ethernet connection to robot and␣
↪initialize SDK
  if (!robot.Initialize(local_ip)) {
    std::cerr << "robot sdk initialize failed." << std::endl;
    robot.Shutdown();
    return -1;
  }

  // Connect to robot
  auto status = robot.Connect();
  if (status.code != ErrorCode::OK) {
    std::cerr << "connect robot failed"
              << ", code: " << status.code
              << ", message: " << status.message << std::endl;
    robot.Shutdown();
    return -1;
  }

  // Switch motion controller to high-level controller, default is high-level␣
↪controller
  status = robot.SetMotionControlLevel(ControllerLevel::HighLevel);
  if (status.code != ErrorCode::OK) {
    std::cerr << "switch robot motion control level failed"
              << ", code: " << status.code
              << ", message: " << status.message << std::endl;
    robot.Shutdown();
    return -1;
  }

  std::cout << "Press any key to continue (ESC to exit)..."
            << std::endl;

  // Wait for user input
  while (1) {
    int key = getch();
    if (key == 27)
      break;  // ESC key ASCII code is 27

    std::cout << "Key ASCII: " << key << ", Character: " << static_cast<char>(key) <<␣
```

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```
↪std::endl;
    switch (key) {
      case '1': {
        RecoveryStand();
        break;
      }
      case '2': {
        BalanceStand();
        break;
      }
      case '3': {
        ExecuteTrick();
        break;
      }
      case 'W':
      case 'w': {
        JoyStickCommand(0.0, 1.0, 0.0, 0.0);  // Move forward
        break;
      }
      case 'A':
      case 'a': {
        JoyStickCommand(-1.0, 0.0, 0.0, 0.0);  // Move left
        break;
      }
      case 'S':
      case 's': {
        JoyStickCommand(0.0, -1.0, 0.0, 0.0);  // Move backward
        break;
      }
      case 'D':
      case 'd': {
        JoyStickCommand(1.0, 0.0, 0.0, 0.0);  // Move right
        break;
      }
      case 'X':
      case 'x': {
        JoyStickCommand(0.0, 0.0, 0.0, 0.0);  // Stop
        break;
      }
      case 'T':
```

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```
    case 't': {
      JoyStickCommand(0.0, 0.0, -1.0, 1.0);  // Turn left
      break;
    }
    case 'G':
    case 'g': {
      JoyStickCommand(0.0, 0.0, 1.0, 1.0);  // Turn right
      break;
    }
    case 'U':
    case 'u': {
      HeadMove(0.0);
      break;
    }
    case 'J':
    case 'j': {
      HeadMove(-0.5);
      break;
    }
    case 'K':
    case 'k': {
      HeadMove(0.5);
      break;
    }
    case '?': {
      print_help();
      break;
    }
    default:
      std::cout << "Unknown key: " << key << std::endl;
      break;
  }
}

// Disconnect from robot
status = robot.Disconnect();
if (status.code != ErrorCode::OK) {
  std::cerr << "disconnect robot failed"
            << ", code: " << status.code
            << ", message: " << status.message << std::endl;
```

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```
    robot.Shutdown();
    return -1;
  }

  robot.Shutdown();

  return 0;
}
```

21.2 Python

Example file: `high_level_motion_example.py`

```
#!/usr/bin/env python3

import sys
import time
import signal
import logging
from typing import Optional

import magicbot_z1_python as magicbot

# Configure logging format and level
logging.basicConfig(
    level=logging.INFO,  # Minimum log level
    format="%(asctime)s [%(levelname)s] %(message)s",
    datefmt="%Y-%m-%d %H:%M:%S",
)

# Global variables
robot: Optional[magicbot.MagicRobot] = None
running = True


def signal_handler(signum, frame):
    """Signal handler function for graceful exit"""
    global running, robot
    logging.info("Received interrupt signal (%s), exiting...", signum)
    running = False
```

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```
    if robot:
        robot.disconnect()
        logging.info("Robot disconnected")
        robot.shutdown()
        logging.info("Robot shutdown")
    exit(-1)


def print_help():
    """Print help information"""
    logging.info("High-Level Motion Control Function Demo Program")
    logging.info("")
    logging.info("High-Level Motion Control Functions:")
    logging.info("  1        Function 1: Recovery stand")
    logging.info("  2        Function 2: Balance stand")
    logging.info("  3        Function 3: Execute trick - welcome action")
    logging.info("  w        Function w: Move forward")
    logging.info("  a        Function a: Move left")
    logging.info("  s        Function s: Move backward")
    logging.info("  d        Function d: Move right")
    logging.info("  x        Function x: stop move")
    logging.info("  t        Function t: Turn left")
    logging.info("  g        Function g: Turn right")
    logging.info("  u        Function u: Reset head move")
    logging.info("  j        Function j: Move head left")
    logging.info("  k        Function k: Move head right")
    logging.info("")
    logging.info("  ?        Function ?: Print help")
    logging.info("  ESC      Exit program")


def get_user_input():
    """Get user input - 读取一行数据"""
    try:
        # 方法 1: 使用 input() 读取一行 (推荐)
        return input("请输入命令: ").strip()
    except (EOFError, KeyboardInterrupt):
        return ""
```

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```
def recovery_stand():
    """Recovery stand"""
    global robot
    try:
        logging.info("=== Executing Recovery Stand ===")

        # Get high-level motion controller
        controller = robot.get_high_level_motion_controller()

        # Set gait to recovery stand
        status = controller.set_gait(magicbot.GaitMode.GAIT_RECOVERY_STAND, 10000)
        if status.code != magicbot.ErrorCode.OK:
            logging.error(
                "Failed to set robot gait, code: %s, message: %s",
                status.code,
                status.message,
            )
            return False

        logging.info("Robot gait set to recovery stand")
        return True

    except Exception as e:
        logging.error("Exception occurred while executing recovery stand: %s", e)
        return False


def balance_stand():
    """Balance stand"""
    global robot
    try:
        logging.info("=== Executing Balance Stand ===")

        # Get high-level motion controller
        controller = robot.get_high_level_motion_controller()

        # Set gait to balance stand
        status = controller.set_gait(magicbot.GaitMode.GAIT_BALANCE_STAND, 10000)
        if status.code != magicbot.ErrorCode.OK:
            logging.error(
```

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```
                "Failed to set robot gait, code: %s, message: %s",
                status.code,
                status.message,
            )
            return False

        logging.info("Robot gait set to balance stand (supports movement)")
        return True

    except Exception as e:
        logging.error("Exception occurred while executing balance stand: %s", e)
        return False


def get_action(cmd):
    if cmd == "215":
        return magicbot.TrickAction.ACTION_SHAKE_LEFT_HAND_REACHOUT
    elif cmd == "216":
        return magicbot.TrickAction.ACTION_SHAKE_LEFT_HAND_WITHDRAW
    elif cmd == "217":
        return magicbot.TrickAction.ACTION_SHAKE_RIGHT_HAND_REACHOUT
    elif cmd == "218":
        return magicbot.TrickAction.ACTION_SHAKE_RIGHT_HAND_WITHDRAW
    elif cmd == "220":
        return magicbot.TrickAction.ACTION_SHAKE_HEAD
    elif cmd == "300":
        return magicbot.TrickAction.ACTION_LEFT_GREETING
    elif cmd == "301":
        return magicbot.TrickAction.ACTION_RIGHT_GREETING
    elif cmd == "304":
        return magicbot.TrickAction.ACTION_TRUN_LEFT_INTRODUCE_HIGH
    elif cmd == "305":
        return magicbot.TrickAction.ACTION_TRUN_LEFT_INTRODUCE_LOW
    elif cmd == "306":
        return magicbot.TrickAction.ACTION_TRUN_RIGHT_INTRODUCE_HIGH
    elif cmd == "307":
        return magicbot.TrickAction.ACTION_TRUN_RIGHT_INTRODUCE_LOW
    elif cmd == "340":
        return magicbot.TrickAction.ACTION_WELCOME
    else:
```

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```
        return magicbot.TrickAction.ACTION_NONE


def execute_trick_action(cmd):
    """Execute trick - welcome action"""
    global robot
    try:
        logging.info("=== Executing Trick - %s Action ===", cmd)

        # Get high-level motion controller
        controller = robot.get_high_level_motion_controller()

        # Execute welcome trick
        status = controller.execute_trick(get_action(cmd), 10000)
        if status.code != magicbot.ErrorCode.OK:
            logging.error(
                "Failed to execute robot trick, code: %s, message: %s",
                status.code,
                status.message,
            )
            return False

        logging.info("Robot trick executed successfully")
        return True

    except Exception as e:
        logging.error("Exception occurred while executing trick: %s", e)
        return False


def joystick_command(left_x_axis, left_y_axis, right_x_axis, right_y_axis):
    """Send joystick control command"""
    global robot
    try:
        # Get high-level motion controller
        controller = robot.get_high_level_motion_controller()

        # Create joystick command
        joy_command = magicbot.JoystickCommand()
        joy_command.left_x_axis = left_x_axis
```

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```
        joy_command.left_y_axis = left_y_axis
        joy_command.right_x_axis = right_x_axis
        joy_command.right_y_axis = right_y_axis

        # Send joystick command
        controller.send_joystick_command(joy_command)
    except Exception as e:
        logging.error("Exception occurred while sending joystick command: %s", e)


def move_forward():
    """Move forward"""
    logging.info("=== Moving Forward ===")
    return joystick_command(0.0, 1.0, 0.0, 0.0)


def move_backward():
    """Move backward"""
    logging.info("=== Moving Backward ===")
    return joystick_command(0.0, -1.0, 0.0, 0.0)


def move_left():
    """Move left"""
    logging.info("=== Moving Left ===")
    return joystick_command(-1.0, 0.0, 0.0, 0.0)


def move_right():
    """Move right"""
    logging.info("=== Moving Right ===")
    return joystick_command(1.0, 0.0, 0.0, 0.0)


def turn_left():
    """Turn left"""
    logging.info("=== Turning Left ===")
    return joystick_command(0.0, 0.0, -1.0, 0.0)
```

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```
def turn_right():
    """Turn right"""
    logging.info("=== Turning Right ===")
    return joystick_command(0.0, 0.0, 1.0, 0.0)


def stop_move():
    """Stop move"""
    logging.info("=== Stopping Move ===")
    return joystick_command(0.0, 0.0, 0.0, 0.0)


def head_move_reset():
    """Reset head move"""
    logging.info("=== Resetting Head Move ===")
    return head_move(0.0)


def head_move_left():
    """Move head left"""
    logging.info("=== Moving Head Left ===")
    return head_move(-0.5)


def head_move_right():
    """Move head right"""
    logging.info("=== Moving Head Right ===")
    return head_move(0.5)


def main():
    """Main function"""
    global robot, running

    # Bind signal handler
    signal.signal(signal.SIGINT, signal_handler)

    logging.info("Robot model: %s", magicbot.get_robot_model())

    # Create robot instance
```

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```
    robot = magicbot.MagicRobot()

    try:
        # Configure local IP address for direct network connection and initialize SDK
        local_ip = "192.168.54.111"
        if not robot.initialize(local_ip):
            logging.error("Failed to initialize robot SDK")
            robot.shutdown()
            return -1

        # Connect to robot
        status = robot.connect()
        if status.code != magicbot.ErrorCode.OK:
            logging.error(
                "Failed to connect to robot, code: %s, message: %s",
                status.code,
                status.message,
            )
            robot.shutdown()
            return -1

        logging.info("Successfully connected to robot")

        # Switch motion control controller to high-level controller
        status = robot.set_motion_control_level(magicbot.ControllerLevel.HighLevel)
        if status.code != magicbot.ErrorCode.OK:
            logging.error(
                "Failed to switch robot motion control level, code: %s, message: %s",
                status.code,
                status.message,
            )
            robot.shutdown()
            return -1

        logging.info("Switched to high-level motion controller")

        # Initialize high-level motion controller
        controller = robot.get_high_level_motion_controller()
        if not controller.initialize():
            logging.error("Failed to initialize high-level motion controller")
```

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```
            robot.disconnect()
            robot.shutdown()
            return -1

        logging.info("Successfully initialized high-level motion controller")

        print_help()
        logging.info("Press any key to continue (ESC to exit)...")

        # Main loop
        while running:
            try:
                str_input = get_user_input()

                # 按空格分割输入参数
                parts = str_input.strip().split()

                if not parts:
                    time.sleep(0.01)  # Brief delay
                    continue

                # 解析参数
                key = parts[0]
                args = parts[1:] if len(parts) > 1 else []
                if key == "\x1b":  # ESC key
                    break

                if key == "1":
                    recovery_stand()
                elif key == "2":
                    balance_stand()
                elif key == "3":
                    cmd = args[0] if args else 340
                    execute_trick_action(cmd)
                elif key.upper() == "W":
                    move_forward()
                elif key.upper() == "A":
                    move_left()
                elif key.upper() == "S":
                    move_backward()
```

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```
                elif key.upper() == "D":
                    move_right()
                elif key.upper() == "X":
                    stop_move()
                elif key.upper() == "T":
                    turn_left()
                elif key.upper() == "G":
                    turn_right()
                elif key.upper() == "U":
                    head_move_reset()
                elif key.upper() == "J":
                    head_move_left()
                elif key.upper() == "K":
                    head_move_right()
                elif key.upper() == "?":
                    print_help()
                else:
                    logging.info("Unknown key: %s", key)

                time.sleep(0.01)  # Brief delay

            except KeyboardInterrupt:
                break
            except Exception as e:
                logging.error("Exception occurred while processing user input: %s", e)

    except Exception as e:
        logging.error("Exception occurred during program execution: %s", e)
        return -1

    finally:
        # Clean up resources
        try:
            logging.info("Clean up resources")
            # Close high-level motion controller
            controller = robot.get_high_level_motion_controller()
            controller.shutdown()
            logging.info("High-level motion controller closed")

            # Disconnect
```

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```
            robot.disconnect()
            logging.info("Robot connection disconnected")

            # Shutdown robot
            robot.shutdown()
            logging.info("Robot shutdown")

        except Exception as e:
            logging.error("Exception occurred while cleaning up resources: %s", e)


if __name__ == "__main__":
    sys.exit(main())
```

21.3 Running Instructions

21.3.1 Environment Setup

```
export PYTHONPATH=/opt/magic_robotics/magicbot_z1_sdk/lib:$PYTHONPATH
export LD_LIBRARY_PATH=/opt/magic_robotics/magicbot_z1_sdk/lib:$LD_LIBRARY_PATH
```

21.3.2 Run Example

```
# C++
./high_level_motion_example
# Python
python3 high_level_motion_example.py
```

21.3.3 Control Instructions

- `1`: Recovery stand
- `2`: Balance stand
- `3`: Celebration action
- `w/a/s/d/x`: Forward/Left/Backward/Right/Stop movement
- `t/g`: Turn left/right
- `j/k/u`: Head left/right/reset
- `?`: Print help information

Note: The humanoid robot must land on the ground in the `recovery stand` state. After landing, switch to `balance stand`, and only then can perform tricks or other actions.

21.3.4 Stop Program

- Press `ESC` to safely stop the program
- The program will automatically clean up all resources

CHAPTER 22

Low-Level Motion Control Example

This example demonstrates how to use the Magicbot-Z1 SDK for initialization, robot connection, low-level motion control (hands, arms, legs, waist, head), IMU sensor data reading, and other basic operations.

22.1 C++:

Example file: `low_level_motion_example.cpp`

```cpp
#include "magic_robot.h"
#include "magic_sdk_version.h"

#include <unistd.h>
#include <csignal>

#include <iostream>

using namespace magic::z1;

magic::z1::MagicRobot robot;

std::atomic<bool> running(true);

void signalHandler(int signum) {
```

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```
  std::cout << "Interrupt signal (" << signum << ") received.\n";

  running = false;

  robot.Shutdown();
  // Exit process
  exit(signum);
}

int main() {
  // Bind SIGINT (Ctrl+C)
  signal(SIGINT, signalHandler);

  std::cout << "SDK Version: " << SDK_VERSION_STRING << std::endl;

  std::string local_ip = "192.168.54.111";
  // Configure local IP address for direct ethernet connection to robot and␣
↪initialize SDK
  if (!robot.Initialize(local_ip)) {
    std::cerr << "robot sdk initialize failed." << std::endl;
    robot.Shutdown();
    return -1;
  }

  // Connect to robot
  auto status = robot.Connect();
  if (status.code != ErrorCode::OK) {
    std::cerr << "connect robot failed"
              << ", code: " << status.code
              << ", message: " << status.message << std::endl;
    robot.Shutdown();
    return -1;
  }

  // Switch motion controller to low-level controller, default is high-level␣
↪controller
  status = robot.SetMotionControlLevel(ControllerLevel::LowLevel);
  if (status.code != ErrorCode::OK) {
    std::cerr << "switch robot motion control level failed"
              << ", code: " << status.code
```

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```
              << ", message: " << status.message << std::endl;
    robot.Shutdown();
    return -1;
  }

  // Get low-level controller
  auto& controller = robot.GetLowLevelMotionController();

  // Subscribe to IMU data
  controller.SubscribeBodyImu([](const std::shared_ptr<Imu> msg) {
    static int32_t count = 0;
    if (count++ % 1000 == 1) {
      std::cout << "++++++++++ receive imu data." << std::endl;
      std::cout << "timestamp: " << msg->timestamp << std::endl;
      std::cout << "temperature: " << msg->temperature << std::endl;
      std::cout << "orientation: " << msg->orientation[0] << ", " << msg->
↪orientation[1] << ", " << msg->orientation[2] << ", " << msg->orientation[3] <<␣
↪std::endl;
      std::cout << "angular_velocity: " << msg->angular_velocity[0] << ", " << msg->
↪angular_velocity[1] << ", " << msg->angular_velocity[2] << std::endl;
      std::cout << "linear_acceleration: " << msg->linear_acceleration[0] << ", " <<␣
↪msg->linear_acceleration[1] << ", " << msg->linear_acceleration[2] << std::endl;
    }
    // TODO: handle imu data
  });

  // Subscribe to arm data
  controller.SubscribeArmState([](const std::shared_ptr<JointState> msg) {
    static int32_t count = 0;
    if (count++ % 1000 == 1) {
      std::cout << "++++++++++ receive arm joint data." << std::endl;
      std::cout << "timestamp: " << msg->timestamp << std::endl;
      std::cout << "pos: " << msg->joints[0].posH << ", " << msg->joints[0].posL <<␣
↪std::endl;
      std::cout << "vel: " << msg->joints[0].vel << std::endl;
      std::cout << "toq: " << msg->joints[0].toq << std::endl;
      std::cout << "current: " << msg->joints[0].current << std::endl;
      std::cout << "error_code: " << msg->joints[0].err_code << std::endl;
    }
    // TODO: handle arm joint data
```

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```
  });

  // Using arm joint control as an example:
  // Subsequent joint control commands, joint operation mode is 1, indicating joint␣
↪is in position control mode
  auto now = std::chrono::steady_clock::now();
  while (running.load()) {
    // Left arm joints, refer to documentation:
    // Left or right arm joints 1-5 operation_mode needs to switch from mode 200 to␣
↪mode 4 (series PID mode) for command execution;
    JointCommand arm_command;
    arm_command.joints.resize(kArmJointNum);
    for (int ii = 0; ii < kArmJointNum; ii++) {
      // Set joint to ready state
      arm_command.joints[ii].operation_mode = 200;
      // TODO: Set target position, velocity, torque and gains
      arm_command.joints[ii].pos = 0.0;
      arm_command.joints[ii].vel = 0.0;
      arm_command.joints[ii].toq = 0.0;
      arm_command.joints[ii].kp = 0.0;
      arm_command.joints[ii].kd = 0.0;
    }
    // Publish control command
    controller.PublishArmCommand(arm_command);

    // Send control commands at 500Hz frequency (2ms)
    now += std::chrono::microseconds(2000);
    std::this_thread::sleep_until(now);
  }

  // Disconnect from robot
  status = robot.Disconnect();
  if (status.code != ErrorCode::OK) {
    std::cerr << "disconnect robot failed"
              << ", code: " << status.code
              << ", message: " << status.message << std::endl;
    robot.Shutdown();
    return -1;
  }
```

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```
  robot.Shutdown();

  return 0;
}
```

22.2 Python

Example file: `low_level_motion_example.py`

```python
#!/usr/bin/env python3

import sys
import time
import signal
import logging
from typing import Optional

import magicbot_z1_python as magicbot

# Configure logging format and level
logging.basicConfig(
    level=logging.INFO,  # Minimum log level
    format="%(asctime)s [%(levelname)s] %(message)s",
    datefmt="%Y-%m-%d %H:%M:%S",
)

# Global variables
robot: Optional[magicbot.MagicRobot] = None
running = True

body_imu_counter = 0
arm_state_counter = 0
leg_state_counter = 0
head_state_counter = 0
waist_state_counter = 0


def signal_handler(signum, frame):
    """Signal handler function for graceful exit"""
    global robot, running
```

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```
    running = False
    logging.info("Received interrupt signal (%s), exiting...", signum)

    if robot:
        robot.disconnect()
        logging.info("Robot disconnected")
        robot.shutdown()
        logging.info("Robot shutdown")
    exit(-1)


def body_imu_callback(imu_data):
    """Body IMU data callback function"""
    global body_imu_counter
    if body_imu_counter % 1000 == 0:
        logging.info("++++++++++++++ Received body IMU data")
        # Print IMU data
        logging.info("Received body IMU data, timestamp: %d", imu_data.timestamp)
        logging.info("Received body IMU data, orientation: [%f,%f,%f,%f]", imu_data.
↪orientation[0], imu_data.orientation[1], imu_data.orientation[2], imu_data.
↪orientation[3])
        logging.info(
            "Received body IMU data, angular_velocity: [%f,%f,%f]",
            imu_data.angular_velocity[0],
            imu_data.angular_velocity[1],
            imu_data.angular_velocity[2],
        )
        logging.info(
            "Received body IMU data, linear_acceleration: [%f,%f,%f]",
            imu_data.linear_acceleration[0],
            imu_data.linear_acceleration[1],
            imu_data.linear_acceleration[2],
        )
        logging.info("Received body IMU data, temperature: %f", imu_data.temperature)
    body_imu_counter += 1


def arm_state_callback(joint_state):
    """Arm joint state callback function"""
    global arm_state_counter
```

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```
    if arm_state_counter % 1000 == 0:
        logging.info("++++++++++++++ Received arm joint state data")
        # Print joint state data
        logging.info(
            "Received arm joint state data, status_word: %d",
            joint_state.joints[0].status_word,
        )
        logging.info(
            "Received arm joint state data, posH: %f", joint_state.joints[0].posH
        )
        logging.info(
            "Received arm joint state data, posL: %f", joint_state.joints[0].posL
        )
        logging.info(
            "Received arm joint state data, vel: %f", joint_state.joints[0].vel
        )
        logging.info(
            "Received arm joint state data, toq: %f", joint_state.joints[0].toq
        )
        logging.info(
            "Received arm joint state data, current: %f", joint_state.joints[0].
↪current
        )
        logging.info(
            "Received arm joint state data, error_code: %d",
            joint_state.joints[0].err_code,
        )
    arm_state_counter += 1


def leg_state_callback(joint_state):
    """Leg joint state callback function"""
    global leg_state_counter
    if leg_state_counter % 1000 == 0:
        logging.info("++++++++++++++ Received leg joint state data")
        # Print joint state data
        logging.info(
            "Received leg joint state data, status_word: %d",
            joint_state.joints[0].status_word,
        )
```

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```
        logging.info(
            "Received leg joint state data, posH: %f", joint_state.joints[0].posH
        )
        logging.info(
            "Received leg joint state data, posL: %f", joint_state.joints[0].posL
        )
        logging.info(
            "Received leg joint state data, vel: %f", joint_state.joints[0].vel
        )
        logging.info(
            "Received leg joint state data, toq: %f", joint_state.joints[0].toq
        )
        logging.info(
            "Received leg joint state data, current: %f", joint_state.joints[0].
↪current
        )
        logging.info(
            "Received leg joint state data, error_code: %d",
            joint_state.joints[0].err_code,
        )
    leg_state_counter += 1


def head_state_callback(joint_state):
    """Head joint state callback function"""
    global head_state_counter
    if head_state_counter % 1000 == 0:
        logging.info("++++++++++++++ Received head joint state data")
        # Print joint state data
        logging.info(
            "Received head joint state data, status_word: %d",
            joint_state.joints[0].status_word,
        )
        logging.info(
            "Received head joint state data, posH: %f", joint_state.joints[0].posH
        )
        logging.info(
            "Received head joint state data, posL: %f", joint_state.joints[0].posL
        )
        logging.info(
```

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```
            "Received head joint state data, vel: %f", joint_state.joints[0].vel
        )
        logging.info(
            "Received head joint state data, toq: %f", joint_state.joints[0].toq
        )
        logging.info(
            "Received head joint state data, current: %f", joint_state.joints[0].
↪current
        )
        logging.info(
            "Received head joint state data, error_code: %d",
            joint_state.joints[0].err_code,
        )
    head_state_counter += 1


def waist_state_callback(joint_state):
    """Waist joint state callback function"""
    global waist_state_counter
    if waist_state_counter % 1000 == 0:
        logging.info("++++++++++++++ Received waist joint state data")
        # Print joint state data
        logging.info(
            "Received waist joint state data, status_word: %d",
            joint_state.joints[0].status_word,
        )
        logging.info(
            "Received waist joint state data, posH: %f", joint_state.joints[0].posH
        )
        logging.info(
            "Received waist joint state data, posL: %f", joint_state.joints[0].posL
        )
        logging.info(
            "Received waist joint state data, vel: %f", joint_state.joints[0].vel
        )
        logging.info(
            "Received waist joint state data, toq: %f", joint_state.joints[0].toq
        )
        logging.info(
            "Received waist joint state data, current: %f",
```

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```
            joint_state.joints[0].current,
        )
        logging.info(
            "Received waist joint state data, error_code: %d",
            joint_state.joints[0].err_code,
        )
    waist_state_counter += 1


def main():
    """Main function"""
    global robot

    # Bind signal handler
    signal.signal(signal.SIGINT, signal_handler)

    logging.info("Robot model: %s", magicbot.get_robot_model())

    # Create robot instance
    robot = magicbot.MagicRobot()

    try:
        # Configure local IP address for direct network connection and initialize SDK
        local_ip = "192.168.54.111"
        if not robot.initialize(local_ip):
            logging.error("Failed to initialize robot SDK")
            robot.shutdown()
            return -1

        # Connect to robot
        status = robot.connect()
        if status.code != magicbot.ErrorCode.OK:
            logging.error(
                "Failed to connect to robot, code: %s, message: %s",
                status.code,
                status.message,
            )
            robot.shutdown()
            return -1
```

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```
        logging.info("Successfully connected to robot")

        # Switch motion control controller to low-level controller, default is high-
↪level controller
        status = robot.set_motion_control_level(magicbot.ControllerLevel.LowLevel)
        if status.code != magicbot.ErrorCode.OK:
            logging.error(
                "Failed to switch robot motion control level, code: %s, message: %s",
                status.code,
                status.message,
            )
            robot.shutdown()
            return -1

        logging.info("Switched to low-level motion controller")

        # Get low-level motion controller
        controller = robot.get_low_level_motion_controller()

        # Subscribe to body IMU data
        controller.subscribe_body_imu(body_imu_callback)
        logging.info("Subscribed to body IMU data")

        # Subscribe to arm joint state
        controller.subscribe_arm_state(arm_state_callback)
        logging.info("Subscribed to arm joint state")

        # Subscribe to leg joint state
        controller.subscribe_leg_state(leg_state_callback)
        logging.info("Subscribed to leg joint state")

        # Subscribe to head joint state
        controller.subscribe_head_state(head_state_callback)
        logging.info("Subscribed to head joint state")

        # Subscribe to waist joint state
        controller.subscribe_waist_state(waist_state_callback)
        logging.info("Subscribed to waist joint state")

        # Main loop
```

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```
        interval = 0.002  # 2ms
        next_t = time.perf_counter() + interval

        global running
        while running:
            # Create arm joint control command
            arm_command = magicbot.JointCommand()
            leg_command = magicbot.JointCommand()
            waist_command = magicbot.JointCommand()
            head_command = magicbot.JointCommand()

            # Set all joints to preparation state (operation mode 200)
            for i in range(magicbot.ARM_JOINT_NUM):
                joint = magicbot.SingleJointCommand()
                joint.operation_mode = 200  # Preparation state
                joint.pos = 0.0
                joint.vel = 0.0
                joint.toq = 0.0
                joint.kp = 0.0
                joint.kd = 0.0
                arm_command.joints.append(joint)

            for i in range(magicbot.LEG_JOINT_NUM):
                joint = magicbot.SingleJointCommand()
                joint.operation_mode = 200  # Preparation state
                joint.pos = 0.0
                joint.vel = 0.0
                joint.toq = 0.0
                joint.kp = 0.0
                joint.kd = 0.0
                leg_command.joints.append(joint)

            for i in range(magicbot.HEAD_JOINT_NUM):
                joint = magicbot.SingleJointCommand()
                joint.operation_mode = 200  # Preparation state
                joint.pos = 0.0
                joint.vel = 0.0
                joint.toq = 0.0
                joint.kp = 0.0
                joint.kd = 0.0
```

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```
            head_command.joints.append(joint)

        for i in range(magicbot.WAIST_JOINT_NUM):
            joint = magicbot.SingleJointCommand()
            joint.operation_mode = 200  # Preparation state
            joint.pos = 0.0
            joint.vel = 0.0
            joint.toq = 0.0
            joint.kp = 0.0
            joint.kd = 0.0
            waist_command.joints.append(joint)

        # Publish arm joint control command
        controller.publish_arm_command(arm_command)

        # Publish leg joint control command
        controller.publish_leg_command(leg_command)

        # Publish waist joint control command
        controller.publish_waist_command(waist_command)

        # Publish head joint control command
        controller.publish_head_command(head_command)

        next_t += interval
        sleep_time = next_t - time.perf_counter()
        if sleep_time > 0:
            time.sleep(sleep_time)

except Exception as e:
    logging.error("Exception occurred during program execution: %s", e)
    return -1

finally:
    # Clean up resources
    try:
        logging.info("Clean up resources")
        # Close low-level motion controller
        controller = robot.get_low_level_motion_controller()
        controller.shutdown()
```

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```
            logging.info("Low-level motion controller closed")

            # Disconnect
            robot.disconnect()
            logging.info("Robot connection disconnected")

            # Shutdown robot
            robot.shutdown()
            logging.info("Robot shutdown")

        except Exception as e:
            logging.error("Exception occurred while cleaning up resources: %s", e)


if __name__ == "__main__":
    sys.exit(main())
```

22.3 Running Instructions

22.3.1 Environment Setup

```
export PYTHONPATH=/opt/magic_robotics/magicbot_z1_sdk/lib:$PYTHONPATH
export LD_LIBRARY_PATH=/opt/magic_robotics/magicbot_z1_sdk/lib:$LD_LIBRARY_PATH
```

22.3.2 Run Example

```
# C++
./low_level_motion_example
# Python
python3 low_level_motion_example.py
```

22.3.3 Stop Program

- Press `Ctrl+C` to safely stop the program
- The program will automatically clean up all resources

CHAPTER 23

Sensor Control Example

This example demonstrates how to use the Magicbot-Z1 SDK for initialization, robot connection, robot sensor control (LiDAR, RGBD camera, binocular camera), and other basic operations.

23.1 C++

Example file: `sensor_example.cpp`

```cpp
#include "magic_robot.h"
#include "magic_sdk_version.h"
#include "magic_type.h"

#include <termios.h>
#include <unistd.h>
#include <csignal>

#include <atomic>
#include <iomanip>
#include <iostream>
#include <map>
#include <string>

using namespace magic::z1;
```

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```
// Global variables
magic::z1::MagicRobot robot;
std::atomic<bool> running(true);

// Counters for data reception
std::atomic<int> lidar_imu_counter(0);
std::atomic<int> lidar_pointcloud_counter(0);
std::atomic<int> head_rgbd_color_counter(0);
std::atomic<int> head_rgbd_depth_counter(0);
std::atomic<int> head_rgbd_camera_info_counter(0);
std::atomic<int> binocular_image_counter(0);

void signalHandler(int signum) {
  std::cout << "\nInterrupt signal (" << signum << ") received.\n";
  running = false;
  robot.Shutdown();
  exit(signum);
}

/**
 * @class SensorManager
 * @brief Manages sensor subscriptions for MagicBot Z1
 */
class SensorManager {
 public:
  explicit SensorManager(sensor::SensorController& controller)
      : sensor_controller_(controller) {
    // Initialize sensor states
    sensors_state_["lidar"] = false;
    sensors_state_["head_rgbd_camera"] = false;
    sensors_state_["binocular_camera"] = false;

    // Initialize subscription states
    subscriptions_["lidar_imu"] = false;
    subscriptions_["lidar_point_cloud"] = false;
    subscriptions_["head_rgbd_color_image"] = false;
    subscriptions_["head_rgbd_depth_image"] = false;
    subscriptions_["head_rgbd_camera_info"] = false;
    subscriptions_["binocular_image"] = false;
```

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```
}

// === LiDAR Control ===
bool OpenLidar() {
  if (sensors_state_["lidar"]) {
    std::cout << "[WARN] LiDAR already opened" << std::endl;
    return true;
  }

  auto status = sensor_controller_.OpenLidar();
  if (status.code != ErrorCode::OK) {
    std::cerr << "[ERROR] Failed to open LiDAR: " << status.message << std::endl;
    return false;
  }

  sensors_state_["lidar"] = true;
  std::cout << "[INFO] ✓ LiDAR opened successfully" << std::endl;
  return true;
}

bool CloseLidar() {
  if (!sensors_state_["lidar"]) {
    std::cout << "[WARN] LiDAR already closed" << std::endl;
    return true;
  }

  auto status = sensor_controller_.CloseLidar();
  if (status.code != ErrorCode::OK) {
    std::cerr << "[ERROR] Failed to close LiDAR: " << status.message << std::endl;
    return false;
  }

  sensors_state_["lidar"] = false;
  std::cout << "[INFO] ✓ LiDAR closed" << std::endl;
  return true;
}

// === Head RGBD Camera Control ===
bool OpenHeadRgbdCamera() {
  if (sensors_state_["head_rgbd_camera"]) {
```

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```
      std::cout << "[WARN] Head RGBD camera already opened" << std::endl;
      return true;
    }

    auto status = sensor_controller_.OpenHeadRgbdCamera();
    if (status.code != ErrorCode::OK) {
      std::cerr << "[ERROR] Failed to open head RGBD camera: " << status.message <<␣
↪std::endl;
      return false;
    }

    sensors_state_["head_rgbd_camera"] = true;
    std::cout << "[INFO] ✓ Head RGBD camera opened" << std::endl;
    return true;
  }

  bool CloseHeadRgbdCamera() {
    if (!sensors_state_["head_rgbd_camera"]) {
      std::cout << "[WARN] Head RGBD camera already closed" << std::endl;
      return true;
    }

    auto status = sensor_controller_.CloseHeadRgbdCamera();
    if (status.code != ErrorCode::OK) {
      std::cerr << "[ERROR] Failed to close head RGBD camera: " << status.message <<␣
↪std::endl;
      return false;
    }

    sensors_state_["head_rgbd_camera"] = false;
    std::cout << "[INFO] ✓ Head RGBD camera closed" << std::endl;
    return true;
  }

  // === Binocular Camera Control ===
  bool OpenBinocularCamera() {
    if (sensors_state_["binocular_camera"]) {
      std::cout << "[WARN] Binocular camera already opened" << std::endl;
      return true;
    }
```

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```
    auto status = sensor_controller_.OpenBinocularCamera();
    if (status.code != ErrorCode::OK) {
      std::cerr << "[ERROR] Failed to open binocular camera: " << status.message <<␣
↪std::endl;
      return false;
    }

    sensors_state_["binocular_camera"] = true;
    std::cout << "[INFO] ✓ Binocular camera opened" << std::endl;
    return true;
  }

  bool CloseBinocularCamera() {
    if (!sensors_state_["binocular_camera"]) {
      std::cout << "[WARN] Binocular camera already closed" << std::endl;
      return true;
    }

    auto status = sensor_controller_.CloseBinocularCamera();
    if (status.code != ErrorCode::OK) {
      std::cerr << "[ERROR] Failed to close binocular camera: " << status.message <<␣
↪std::endl;
      return false;
    }

    sensors_state_["binocular_camera"] = false;
    std::cout << "[INFO] ✓ Binocular camera closed" << std::endl;
    return true;
  }

  // === LiDAR Subscribe Methods ===
  void ToggleLidarImuSubscription() {
    if (subscriptions_["lidar_imu"]) {
      sensor_controller_.UnsubscribeLidarImu();
      subscriptions_["lidar_imu"] = false;
      std::cout << "[INFO] 🔕 LiDAR IMU unsubscribed" << std::endl;
    } else {
      sensor_controller_.SubscribeLidarImu([](const std::shared_ptr<Imu>& imu) {
        int count = ++lidar_imu_counter;
```

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```
        if (count % 100 == 0) {
          std::cout << "========== LiDAR IMU Data ==========" << std::endl;
          std::cout << "Counter: " << count << std::endl;
          std::cout << "Timestamp: " << imu->timestamp << std::endl;
          std::cout << std::fixed << std::setprecision(4);
          std::cout << "Orientation (x,y,z,w): ["
                    << imu->orientation[0] << ", "
                    << imu->orientation[1] << ", "
                    << imu->orientation[2] << ", "
                    << imu->orientation[3] << "]" << std::endl;
          std::cout << "Angular velocity (x,y,z): ["
                    << imu->angular_velocity[0] << ", "
                    << imu->angular_velocity[1] << ", "
                    << imu->angular_velocity[2] << "]" << std::endl;
          std::cout << "Linear acceleration (x,y,z): ["
                    << imu->linear_acceleration[0] << ", "
                    << imu->linear_acceleration[1] << ", "
                    << imu->linear_acceleration[2] << "]" << std::endl;
          std::cout << std::setprecision(2);
          std::cout << "Temperature: " << imu->temperature << std::endl;
          std::cout << "======================================" << std::endl;
        }
      });
      subscriptions_["lidar_imu"] = true;
      std::cout << "[INFO] ✓ LiDAR IMU subscribed" << std::endl;
    }
  }

  void ToggleLidarPointCloudSubscription() {
    if (subscriptions_["lidar_point_cloud"]) {
      sensor_controller_.UnsubscribeLidarPointCloud();
      subscriptions_["lidar_point_cloud"] = false;
      std::cout << "[INFO] □ LiDAR point cloud unsubscribed" << std::endl;
    } else {
      sensor_controller_.SubscribeLidarPointCloud([](const std::shared_ptr
↪<PointCloud2>& pointcloud) {
        int count = ++lidar_pointcloud_counter;
        if (count % 10 == 0) {
          std::cout << "========== LiDAR Point Cloud ==========" << std::endl;
          std::cout << "Counter: " << count << std::endl;
```

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```
          std::cout << "Data size: " << pointcloud->data.size() << " bytes" <<␣
↪std::endl;
          std::cout << "Width: " << pointcloud->width << std::endl;
          std::cout << "Height: " << pointcloud->height << std::endl;
          std::cout << "Is dense: " << (pointcloud->is_dense ? "true" : "false") <<␣
↪std::endl;
          std::cout << "Point step: " << pointcloud->point_step << std::endl;
          std::cout << "Row step: " << pointcloud->row_step << std::endl;
          std::cout << "Number of fields: " << pointcloud->fields.size() << std::endl;
          if (!pointcloud->fields.empty()) {
            std::cout << "First field name: " << pointcloud->fields[0].name <<␣
↪std::endl;
          }
          std::cout << "=======================================" << std::endl;
        }
      });
      subscriptions_["lidar_point_cloud"] = true;
      std::cout << "[INFO] ✓ LiDAR point cloud subscribed" << std::endl;
    }
  }

  // === Head RGBD Subscribe Methods ===
  void ToggleHeadRgbdColorImageSubscription() {
    if (subscriptions_["head_rgbd_color_image"]) {
      sensor_controller_.UnsubscribeHeadRgbdColorImage();
      subscriptions_["head_rgbd_color_image"] = false;
      std::cout << "[INFO] ⍰ Head RGBD color image unsubscribed" << std::endl;
    } else {
      sensor_controller_.SubscribeHeadRgbdColorImage([](const std::shared_ptr<Image>&␣
↪img) {
        int count = ++head_rgbd_color_counter;
        if (count % 15 == 0) {
          std::cout << "========== Head RGBD Color Image ==========" << std::endl;
          std::cout << "Counter: " << count << std::endl;
          std::cout << "Size: " << img->data.size() << " bytes" << std::endl;
          std::cout << "Resolution: " << img->width << "x" << img->height <<␣
↪std::endl;
          std::cout << "Encoding: " << img->encoding << std::endl;
          std::cout << "=======================================" << std::endl;
        }
```

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```
      });
      subscriptions_["head_rgbd_color_image"] = true;
      std::cout << "[INFO] ✓ Head RGBD color image subscribed" << std::endl;
    }
  }

  void ToggleHeadRgbdDepthImageSubscription() {
    if (subscriptions_["head_rgbd_depth_image"]) {
      sensor_controller_.UnsubscribeHeadRgbdDepthImage();
      subscriptions_["head_rgbd_depth_image"] = false;
      std::cout << "[INFO] ⍰ Head RGBD depth image unsubscribed" << std::endl;
    } else {
      sensor_controller_.SubscribeHeadRgbdDepthImage([](const std::shared_ptr<Image>&␣
↪img) {
        int count = ++head_rgbd_depth_counter;
        if (count % 15 == 0) {
          std::cout << "========== Head RGBD Depth Image ==========" << std::endl;
          std::cout << "Counter: " << count << std::endl;
          std::cout << "Size: " << img->data.size() << " bytes" << std::endl;
          std::cout << "Resolution: " << img->width << "x" << img->height <<␣
↪std::endl;
          std::cout << "Encoding: " << img->encoding << std::endl;
          std::cout << "=========================================" << std::endl;
        }
      });
      subscriptions_["head_rgbd_depth_image"] = true;
      std::cout << "[INFO] ✓ Head RGBD depth image subscribed" << std::endl;
    }
  }

  void ToggleHeadRgbdCameraInfoSubscription() {
    if (subscriptions_["head_rgbd_camera_info"]) {
      sensor_controller_.UnsubscribeHeadRgbdCameraInfo();
      subscriptions_["head_rgbd_camera_info"] = false;
      std::cout << "[INFO] ⍰ Head RGBD camera info unsubscribed" << std::endl;
    } else {
      sensor_controller_.SubscribeHeadRgbdCameraInfo([](const std::shared_ptr
↪<CameraInfo>& info) {
        int count = ++head_rgbd_camera_info_counter;
        if (count % 30 == 0) {
```

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```
          std::cout << "========== Head RGBD Camera Info ==========" << std::endl;
          std::cout << "Counter: " << count << std::endl;
          std::cout << "Resolution: " << info->width << "x" << info->height <<␣
↪std::endl;
          std::cout << "Distortion model: " << info->distortion_model << std::endl;
          std::cout << "========================================" << std::endl;
        }
      });
      subscriptions_["head_rgbd_camera_info"] = true;
      std::cout << "[INFO] ✓ Head RGBD camera info subscribed" << std::endl;
    }
  }

  // === Binocular Camera Subscribe Methods ===
  void ToggleBinocularImageSubscription() {
    if (subscriptions_["binocular_image"]) {
      sensor_controller_.UnsubscribeBinocularImage();
      subscriptions_["binocular_image"] = false;
      std::cout << "[INFO] ⍰ Binocular image unsubscribed" << std::endl;
    } else {
      sensor_controller_.SubscribeBinocularImage([](const std::shared_ptr
↪<BinocularCameraFrame>& frame) {
        int count = ++binocular_image_counter;
        if (count % 15 == 0) {
          std::cout << "========== Binocular Camera Image ==========" << std::endl;
          std::cout << "Counter: " << count << std::endl;
          std::cout << "Timestamp: " << frame->header.stamp << std::endl;
          std::cout << "Frame ID: " << frame->header.frame_id << std::endl;
          std::cout << "Format: " << frame->format << std::endl;
          std::cout << "Data size: " << frame->data.size() << " bytes (left+right␣
↪concatenated)" << std::endl;
          std::cout << "========================================" << std::endl;
        }
      });
      subscriptions_["binocular_image"] = true;
      std::cout << "[INFO] ✓ Binocular image subscribed" << std::endl;
    }
  }

  void ShowStatus() const {
```

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```
    std::cout << "\n"
              << std::string(80, '=') << std::endl;
    std::cout << "MAGICBOT Z1 SENSOR STATUS" << std::endl;
    std::cout << std::string(80, '=') << std::endl;
    std::cout << "LiDAR:                          "
              << (sensors_state_.at("lidar") ? "OPEN" : "CLOSED") << std::endl;
    std::cout << "Head RGBD Camera:               "
              << (sensors_state_.at("head_rgbd_camera") ? "OPEN" : "CLOSED") <<␣
↪std::endl;
    std::cout << "Binocular Camera:               "
              << (sensors_state_.at("binocular_camera") ? "OPEN" : "CLOSED") <<␣
↪std::endl;

    std::cout << "\nLIDAR SUBSCRIPTIONS:" << std::endl;
    std::cout << "  LiDAR IMU:                    "
              << (subscriptions_.at("lidar_imu") ? "✓ SUBSCRIBED" : "□ UNSUBSCRIBED")
↪<< std::endl;
    std::cout << "  LiDAR Point Cloud:            "
              << (subscriptions_.at("lidar_point_cloud") ? "✓ SUBSCRIBED" : "□␣
↪UNSUBSCRIBED") << std::endl;

    std::cout << "\nHEAD RGBD SUBSCRIPTIONS:" << std::endl;
    std::cout << "  Color Image:                  "
              << (subscriptions_.at("head_rgbd_color_image") ? "✓ SUBSCRIBED" : "□␣
↪UNSUBSCRIBED") << std::endl;
    std::cout << "  Depth Image:                  "
              << (subscriptions_.at("head_rgbd_depth_image") ? "✓ SUBSCRIBED" : "□␣
↪UNSUBSCRIBED") << std::endl;
    std::cout << "  Camera Info:                  "
              << (subscriptions_.at("head_rgbd_camera_info") ? "✓ SUBSCRIBED" : "□␣
↪UNSUBSCRIBED") << std::endl;

    std::cout << "\nBINOCULAR CAMERA SUBSCRIPTIONS:" << std::endl;
    std::cout << "  Binocular Image:              "
              << (subscriptions_.at("binocular_image") ? "✓ SUBSCRIBED" : "□␣
↪UNSUBSCRIBED") << std::endl;
    std::cout << std::string(80, '=') << "\n"
              << std::endl;
  }
```

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```
  // Getters for sensor states
  bool IsSensorOpen(const std::string& sensor_name) const {
    auto it = sensors_state_.find(sensor_name);
    return it != sensors_state_.end() && it->second;
  }

 private:
  sensor::SensorController& sensor_controller_;
  std::map<std::string, bool> sensors_state_;
  std::map<std::string, bool> subscriptions_;
};

void PrintMenu() {
  std::cout << "\n"
            << std::string(80, '=') << std::endl;
  std::cout << "MAGICBOT Z1 SENSOR CONTROL MENU" << std::endl;
  std::cout << std::string(80, '=') << std::endl;
  std::cout << "Sensor Open/Close:" << std::endl;
  std::cout << "  1 - Open LiDAR                    2 - Close LiDAR" << std::endl;
  std::cout << "  3 - Open Head RGBD Camera         4 - Close Head RGBD Camera" <<␣
↪std::endl;
  std::cout << "  5 - Open Binocular Camera         6 - Close Binocular Camera" <<␣
↪std::endl;
  std::cout << "\nLiDAR Subscriptions:" << std::endl;
  std::cout << "  i - Toggle LiDAR IMU              p - Toggle LiDAR Point Cloud" <<␣
↪std::endl;
  std::cout << "\nHead RGBD Camera Subscriptions:" << std::endl;
  std::cout << "  c - Toggle Head Color Image       d - Toggle Head Depth Image" <<␣
↪std::endl;
  std::cout << "  C - Toggle Head Camera Info" << std::endl;
  std::cout << "\nBinocular Camera Subscriptions:" << std::endl;
  std::cout << "  b - Toggle Binocular Image" << std::endl;
  std::cout << "\nCommands:" << std::endl;
  std::cout << "  s - Show Status                   q - Quit              ? - Help" <
↪< std::endl;
  std::cout << std::string(80, '=') << std::endl;
}

int getch() {
  struct termios oldt, newt;
```

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```
  int ch;
  tcgetattr(STDIN_FILENO, &oldt);
  newt = oldt;
  newt.c_lflag &= ~(ICANON | ECHO);
  tcsetattr(STDIN_FILENO, TCSANOW, &newt);
  ch = getchar();
  tcsetattr(STDIN_FILENO, TCSANOW, &oldt);
  return ch;
}

int main() {
  // Bind SIGINT (Ctrl+C)
  signal(SIGINT, signalHandler);

  std::cout << "\n"
            << std::string(80, '=') << std::endl;
  std::cout << "MagicBot Z1 SDK Sensor Interactive Example" << std::endl;
  std::cout << "SDK Version: " << SDK_VERSION_STRING << std::endl;
  std::cout << std::string(80, '=') << "\n"
            << std::endl;

  std::string local_ip = "192.168.54.111";

  // Initialize robot SDK
  if (!robot.Initialize(local_ip)) {
    std::cerr << "[ERROR] Failed to initialize robot SDK" << std::endl;
    robot.Shutdown();
    return -1;
  }
  std::cout << "[INFO] ✓ Robot SDK initialized successfully" << std::endl;

  // Connect to robot
  auto status = robot.Connect();
  if (status.code != ErrorCode::OK) {
    std::cerr << "[ERROR] Failed to connect to robot, code: " << status.code
              << ", message: " << status.message << std::endl;
    robot.Shutdown();
    return -1;
  }
  std::cout << "[INFO] ✓ Successfully connected to robot" << std::endl;
```

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```
// Get sensor controller
auto& sensor_controller = robot.GetSensorController();

// Initialize sensor controller
if (!sensor_controller.Initialize()) {
  std::cerr << "[ERROR] Failed to initialize sensor controller" << std::endl;
  robot.Disconnect();
  robot.Shutdown();
  return -1;
}
std::cout << "[INFO] ✓ Sensor controller initialized successfully\n"
          << std::endl;

// Create sensor manager
SensorManager sensor_manager(sensor_controller);

PrintMenu();

// Main loop
std::cout << "\nPress any key to continue..." << std::endl;

while (running) {
  int ch = getch();

  if (ch == 27 || ch == 'q' || ch == 'Q') {  // ESC or 'q'
    std::cout << "\n[INFO] Quit key pressed, exiting program..." << std::endl;
    break;
  }

  // Sensor open/close control
  switch (ch) {
    case '1':
      sensor_manager.OpenLidar();
      break;
    case '2':
      sensor_manager.CloseLidar();
      break;
    case '3':
      sensor_manager.OpenHeadRgbdCamera();
```

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```
      break;
    case '4':
      sensor_manager.CloseHeadRgbdCamera();
      break;
    case '5':
      sensor_manager.OpenBinocularCamera();
      break;
    case '6':
      sensor_manager.CloseBinocularCamera();
      break;

    // LiDAR subscriptions
    case 'i':
    case 'I':
      sensor_manager.ToggleLidarImuSubscription();
      break;
    case 'p':
    case 'P':
      sensor_manager.ToggleLidarPointCloudSubscription();
      break;

    // Head RGBD subscriptions
    case 'c':
      sensor_manager.ToggleHeadRgbdColorImageSubscription();
      break;
    case 'd':
      sensor_manager.ToggleHeadRgbdDepthImageSubscription();
      break;
    case 'C':
      sensor_manager.ToggleHeadRgbdCameraInfoSubscription();
      break;

    // Binocular camera subscriptions
    case 'b':
      sensor_manager.ToggleBinocularImageSubscription();
      break;

    // Commands
    case 's':
    case 'S':
```

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```
      sensor_manager.ShowStatus();
      break;
    case '?':
      PrintMenu();
      break;

    default:
      // Ignore unknown keys
      break;
  }
}

// Cleanup: close all sensors
std::cout << "\n"
          << std::string(80, '=') << std::endl;
std::cout << "Cleaning up resources..." << std::endl;
std::cout << std::string(80, '=') << std::endl;

if (sensor_manager.IsSensorOpen("lidar")) {
  sensor_manager.CloseLidar();
}
if (sensor_manager.IsSensorOpen("head_rgbd_camera")) {
  sensor_manager.CloseHeadRgbdCamera();
}
if (sensor_manager.IsSensorOpen("binocular_camera")) {
  sensor_manager.CloseBinocularCamera();
}

// Allow time for cleanup
usleep(500000);  // 0.5 seconds

sensor_controller.Shutdown();
std::cout << "[INFO] ✓ Sensor controller shutdown" << std::endl;

status = robot.Disconnect();
if (status.code == ErrorCode::OK) {
  std::cout << "[INFO] ✓ Robot disconnected" << std::endl;
}

robot.Shutdown();
```

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```
  std::cout << "[INFO] ✓ Robot shutdown" << std::endl;

  std::cout << std::string(80, '=') << std::endl;
  std::cout << "Cleanup complete" << std::endl;
  std::cout << std::string(80, '=') << "\n"
            << std::endl;

  return 0;
}
```

23.2 Python

Example file: `sensor_example.py`

```
#!/usr/bin/env python3
# -*- coding: utf-8 -*-

import sys
import time
import signal
import logging
from typing import Optional

import magicbot_z1_python as magicbot

# Configure logging format and level
logging.basicConfig(
    level=logging.INFO,
    format="%(asctime)s [%(levelname)s] %(message)s",
    datefmt="%Y-%m-%d %H:%M:%S",
    force=True,
)

# Global variables
robot: Optional[magicbot.MagicRobot] = None
running = True

# Counters for data reception
lidar_imu_counter = 0
lidar_pointcloud_counter = 0
```

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```
head_rgbd_color_counter = 0
head_rgbd_depth_counter = 0
head_rgbd_camera_info_counter = 0
binocular_image_counter = 0
binocular_camera_info_counter = 0


def signal_handler(signum, frame):
    """Signal handler function for graceful exit"""
    global running, robot
    logging.info("Received interrupt signal (%s), exiting...", signum)
    running = False
    if robot:
        robot.disconnect()
        logging.info("Robot disconnected")
        robot.shutdown()
        logging.info("Robot shutdown")
    exit(-1)


class SensorManager:
    """Manages sensor subscriptions for MagicBot Z1"""

    def __init__(self, sensor_controller):
        self.sensor_controller = sensor_controller
        self.sensors_state = {
            "lidar": False,
            "head_rgbd_camera": False,
            "binocular_camera": False,
        }
        self.subscriptions = {
            # LiDAR subscriptions
            "lidar_imu": False,
            "lidar_point_cloud": False,
            # Head RGBD subscriptions
            "head_rgbd_color_image": False,
            "head_rgbd_depth_image": False,
            "head_rgbd_camera_info": False,
            # Binocular camera subscriptions
            "binocular_image": False,
```

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```
            "binocular_camera_info": False,
        }

    # === LiDAR Control ===
    def open_lidar(self) -> bool:
        """Open LiDAR"""
        if self.sensors_state["lidar"]:
            logging.warning("LiDAR already opened")
            return True

        status = self.sensor_controller.open_lidar()
        if status.code != magicbot.ErrorCode.OK:
            logging.error("Failed to open LiDAR: %s", status.message)
            return False

        self.sensors_state["lidar"] = True
        logging.info("✓ LiDAR opened successfully")
        return True

    def close_lidar(self) -> bool:
        """Close LiDAR"""
        if not self.sensors_state["lidar"]:
            logging.warning("LiDAR already closed")
            return True

        status = self.sensor_controller.close_lidar()
        if status.code != magicbot.ErrorCode.OK:
            logging.error("Failed to close LiDAR: %s", status.message)
            return False

        self.sensors_state["lidar"] = False
        logging.info("✓ LiDAR closed")
        return True

    # === Head RGBD Camera Control ===
    def open_head_rgbd_camera(self) -> bool:
        """Open head RGBD camera"""
        if self.sensors_state["head_rgbd_camera"]:
            logging.warning("Head RGBD camera already opened")
            return True
```

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```
        status = self.sensor_controller.open_head_rgbd_camera()
        if status.code != magicbot.ErrorCode.OK:
            logging.error("Failed to open head RGBD camera: %s", status.message)
            return False

        self.sensors_state["head_rgbd_camera"] = True
        logging.info("✓ Head RGBD camera opened")
        return True

    def close_head_rgbd_camera(self) -> bool:
        """Close head RGBD camera"""
        if not self.sensors_state["head_rgbd_camera"]:
            logging.warning("Head RGBD camera already closed")
            return True

        status = self.sensor_controller.close_head_rgbd_camera()
        if status.code != magicbot.ErrorCode.OK:
            logging.error("Failed to close head RGBD camera: %s", status.message)
            return False

        self.sensors_state["head_rgbd_camera"] = False
        logging.info("✓ Head RGBD camera closed")
        return True

    # === Binocular Camera Control ===
    def open_binocular_camera(self) -> bool:
        """Open binocular camera"""
        if self.sensors_state["binocular_camera"]:
            logging.warning("Binocular camera already opened")
            return True

        status = self.sensor_controller.open_binocular_camera()
        if status.code != magicbot.ErrorCode.OK:
            logging.error("Failed to open binocular camera: %s", status.message)
            return False

        self.sensors_state["binocular_camera"] = True
        logging.info("✓ Binocular camera opened")
        return True
```

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```
    def close_binocular_camera(self) -> bool:
        """Close binocular camera"""
        if not self.sensors_state["binocular_camera"]:
            logging.warning("Binocular camera already closed")
            return True

        status = self.sensor_controller.close_binocular_camera()
        if status.code != magicbot.ErrorCode.OK:
            logging.error("Failed to close binocular camera: %s", status.message)
            return False

        self.sensors_state["binocular_camera"] = False
        logging.info("✓ Binocular camera closed")
        return True

    # === LiDAR Subscribe Methods ===
    def toggle_lidar_imu_subscription(self):
        """Toggle LiDAR IMU subscription"""
        if self.subscriptions["lidar_imu"]:
            self.sensor_controller.unsubscribe_lidar_imu()
            self.subscriptions["lidar_imu"] = False
            logging.info("□ LiDAR IMU unsubscribed")
        else:

            def lidar_imu_callback(imu):
                global lidar_imu_counter
                lidar_imu_counter += 1
                if lidar_imu_counter % 100 == 0:
                    logging.info("========== LiDAR IMU Data ==========")
                    logging.info("Counter: %d", lidar_imu_counter)
                    logging.info("Timestamp: %d", imu.timestamp)
                    logging.info(
                        "Orientation (w,x,y,z): [%.4f, %.4f, %.4f, %.4f]",
                        imu.orientation[0],
                        imu.orientation[1],
                        imu.orientation[2],
                        imu.orientation[3],
                    )
                    logging.info(
```

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```
                    "Angular velocity (x,y,z): [%.4f, %.4f, %.4f]",
                    imu.angular_velocity[0],
                    imu.angular_velocity[1],
                    imu.angular_velocity[2],
                )
                logging.info(
                    "Linear acceleration (x,y,z): [%.4f, %.4f, %.4f]",
                    imu.linear_acceleration[0],
                    imu.linear_acceleration[1],
                    imu.linear_acceleration[2],
                )
                logging.info("Temperature: %.2f", imu.temperature)
                logging.info("=" * 40)

        self.sensor_controller.subscribe_lidar_imu(lidar_imu_callback)
        self.subscriptions["lidar_imu"] = True
        logging.info("✓ LiDAR IMU subscribed")

def toggle_lidar_point_cloud_subscription(self):
    """Toggle LiDAR point cloud subscription"""
    if self.subscriptions["lidar_point_cloud"]:
        self.sensor_controller.unsubscribe_lidar_point_cloud()
        self.subscriptions["lidar_point_cloud"] = False
        logging.info("□ LiDAR point cloud unsubscribed")
    else:

        def lidar_pointcloud_callback(pointcloud):
            global lidar_pointcloud_counter
            lidar_pointcloud_counter += 1
            if lidar_pointcloud_counter % 10 == 0:
                logging.info("========== LiDAR Point Cloud ==========")
                logging.info("Counter: %d", lidar_pointcloud_counter)
                logging.info("Data size: %d bytes", len(pointcloud.data))
                logging.info("Width: %d", pointcloud.width)
                logging.info("Height: %d", pointcloud.height)
                logging.info("Is dense: %s", pointcloud.is_dense)
                logging.info("Point step: %d", pointcloud.point_step)
                logging.info("Row step: %d", pointcloud.row_step)
                logging.info("Number of fields: %d", len(pointcloud.fields))
                if pointcloud.fields:
```

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```
                        logging.info("First field name: %s", pointcloud.fields[0].
↪name)
                    logging.info("=" * 40)

            self.sensor_controller.subscribe_lidar_point_cloud(
                lidar_pointcloud_callback
            )
            self.subscriptions["lidar_point_cloud"] = True
            logging.info("✓ LiDAR point cloud subscribed")

    # === Head RGBD Subscribe Methods ===
    def toggle_head_rgbd_color_image_subscription(self):
        """Toggle head RGBD color image subscription"""
        if self.subscriptions["head_rgbd_color_image"]:
            self.sensor_controller.unsubscribe_head_rgbd_color_image()
            self.subscriptions["head_rgbd_color_image"] = False
            logging.info("□ Head RGBD color image unsubscribed")
        else:

            def head_rgbd_color_image_callback(img):
                global head_rgbd_color_counter
                head_rgbd_color_counter += 1
                if head_rgbd_color_counter % 15 == 0:
                    logging.info("========== Head RGBD Color Image ==========")
                    logging.info("Counter: %d", head_rgbd_color_counter)
                    logging.info("Size: %d bytes", len(img.data))
                    logging.info("Resolution: %dx%d", img.width, img.height)
                    logging.info("Encoding: %s", img.encoding)
                    logging.info("=" * 40)

            self.sensor_controller.subscribe_head_rgbd_color_image(
                head_rgbd_color_image_callback
            )
            self.subscriptions["head_rgbd_color_image"] = True
            logging.info("✓ Head RGBD color image subscribed")

    def toggle_head_rgbd_depth_image_subscription(self):
        """Toggle head RGBD depth image subscription"""
        if self.subscriptions["head_rgbd_depth_image"]:
            self.sensor_controller.unsubscribe_head_rgbd_depth_image()
```

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```
            self.subscriptions["head_rgbd_depth_image"] = False
            logging.info("📷 Head RGBD depth image unsubscribed")
        else:

            def head_rgbd_depth_image_callback(img):
                global head_rgbd_depth_counter
                head_rgbd_depth_counter += 1
                if head_rgbd_depth_counter % 15 == 0:
                    logging.info("========== Head RGBD Depth Image ==========")
                    logging.info("Counter: %d", head_rgbd_depth_counter)
                    logging.info("Size: %d bytes", len(img.data))
                    logging.info("Resolution: %dx%d", img.width, img.height)
                    logging.info("Encoding: %s", img.encoding)
                    logging.info("=" * 40)

            self.sensor_controller.subscribe_head_rgbd_depth_image(
                head_rgbd_depth_image_callback
            )
            self.subscriptions["head_rgbd_depth_image"] = True
            logging.info("✓ Head RGBD depth image subscribed")

    def toggle_head_rgbd_camera_info_subscription(self):
        """Toggle head RGBD camera info subscription"""
        if self.subscriptions["head_rgbd_camera_info"]:
            self.sensor_controller.unsubscribe_head_rgbd_camera_info()
            self.subscriptions["head_rgbd_camera_info"] = False
            logging.info("📷 Head RGBD camera info unsubscribed")
        else:

            def head_rgbd_camera_info_callback(info):
                global head_rgbd_camera_info_counter
                head_rgbd_camera_info_counter += 1
                logging.info("========== Head RGBD Camera Info ==========")
                logging.info("Counter: %d", head_rgbd_camera_info_counter)
                logging.info("Resolution: %dx%d", info.width, info.height)
                logging.info("Distortion model: %s", info.distortion_model)
                logging.info("=" * 40)

            self.sensor_controller.subscribe_head_rgbd_camera_info(
                head_rgbd_camera_info_callback
```

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```
            )
            self.subscriptions["head_rgbd_camera_info"] = True
            logging.info("✓ Head RGBD camera info subscribed")

    # === Binocular Camera Subscribe Methods ===
    def toggle_binocular_image_subscription(self):
        """Toggle binocular camera image subscription"""
        if self.subscriptions["binocular_image"]:
            self.sensor_controller.unsubscribe_binocular_image()
            self.subscriptions["binocular_image"] = False
            logging.info("🔕 Binocular image unsubscribed")
        else:

            def binocular_image_callback(frame):
                global binocular_image_counter
                binocular_image_counter += 1
                if binocular_image_counter % 15 == 0:
                    logging.info("========== Binocular Camera Image ==========")
                    logging.info("Counter: %d", binocular_image_counter)
                    logging.info("Timestamp: %d", frame.header.stamp)
                    logging.info("Frame ID: %s", frame.header.frame_id)
                    logging.info("Format: %s", frame.format)
                    logging.info(
                        "Data size: %d bytes (left+right concatenated)",
                        len(frame.data),
                    )
                    logging.info("=" * 40)

            self.sensor_controller.subscribe_binocular_image(binocular_image_callback)
            self.subscriptions["binocular_image"] = True
            logging.info("✓ Binocular image subscribed")

    def toggle_binocular_camera_info_subscription(self):
        """Toggle binocular camera info subscription"""
        if self.subscriptions["binocular_camera_info"]:
            self.sensor_controller.unsubscribe_binocular_camera_info()
            self.subscriptions["binocular_camera_info"] = False
            logging.info("🔕 Binocular camera info unsubscribed")
        else:
```

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```
            def binocular_camera_info_callback(info):
                global binocular_camera_info_counter
                binocular_camera_info_counter += 1
                logging.info("========== Binocular Camera Info ==========")
                logging.info("Counter: %d", binocular_camera_info_counter)
                logging.info("Resolution: %dx%d", info.width, info.height)
                logging.info("Distortion model: %s", info.distortion_model)
                logging.info("=" * 40)

            self.sensor_controller.subscribe_binocular_camera_info(
                binocular_camera_info_callback
            )
            self.subscriptions["binocular_camera_info"] = True
            logging.info("✓ Binocular camera info subscribed")

    def show_status(self):
        """Display current sensor status"""
        logging.info("\n" + "=" * 80)
        logging.info("MAGICBOT Z1 SENSOR STATUS")
        logging.info("=" * 80)
        logging.info(
            "LiDAR:                          %s",
            "OPEN" if self.sensors_state["lidar"] else "CLOSED",
        )
        logging.info(
            "Head RGBD Camera:               %s",
            "OPEN" if self.sensors_state["head_rgbd_camera"] else "CLOSED",
        )
        logging.info(
            "Binocular Camera:               %s",
            "OPEN" if self.sensors_state["binocular_camera"] else "CLOSED",
        )
        logging.info("\nLIDAR SUBSCRIPTIONS:")
        logging.info(
            "  LiDAR IMU:                    %s",
            "✓ SUBSCRIBED" if self.subscriptions["lidar_imu"] else "❌ UNSUBSCRIBED",
        )
        logging.info(
            "  LiDAR Point Cloud:            %s",
            (
```

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```
                "✓ SUBSCRIBED"
                if self.subscriptions["lidar_point_cloud"]
                else "✗ UNSUBSCRIBED"
            ),
        )
        logging.info("\nHEAD RGBD SUBSCRIPTIONS:")
        logging.info(
            "  Color Image:                %s",
            (
                "✓ SUBSCRIBED"
                if self.subscriptions["head_rgbd_color_image"]
                else "✗ UNSUBSCRIBED"
            ),
        )
        logging.info(
            "  Depth Image:                %s",
            (
                "✓ SUBSCRIBED"
                if self.subscriptions["head_rgbd_depth_image"]
                else "✗ UNSUBSCRIBED"
            ),
        )
        logging.info(
            "  Camera Info:                %s",
            (
                "✓ SUBSCRIBED"
                if self.subscriptions["head_rgbd_camera_info"]
                else "✗ UNSUBSCRIBED"
            ),
        )
        logging.info("\nBINOCULAR CAMERA SUBSCRIPTIONS:")
        logging.info(
            "  Binocular Image:            %s",
            (
                "✓ SUBSCRIBED"
                if self.subscriptions["binocular_image"]
                else "✗ UNSUBSCRIBED"
            ),
        )
        logging.info(
```

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```
            "  Camera Info:                %s",
            (
                "✓ SUBSCRIBED"
                if self.subscriptions["binocular_camera_info"]
                else "✗ UNSUBSCRIBED"
            ),
        )
        logging.info("=" * 80 + "\n")


def print_menu():
    """Print interactive menu"""
    logging.info("\n" + "=" * 80)
    logging.info("MAGICBOT Z1 SENSOR CONTROL MENU")
    logging.info("=" * 80)
    logging.info("Sensor Open/Close:")
    logging.info("  1 - Open LiDAR                    2 - Close LiDAR")
    logging.info("  3 - Open Head RGBD Camera         4 - Close Head RGBD Camera")
    logging.info("  5 - Open Binocular Camera         6 - Close Binocular Camera")
    logging.info("\nLiDAR Subscriptions:")
    logging.info("  i - Toggle LiDAR IMU              p - Toggle LiDAR Point Cloud")
    logging.info("\nHead RGBD Camera Subscriptions:")
    logging.info("  c - Toggle Head Color Image       d - Toggle Head Depth Image")
    logging.info("  C - Toggle Head Camera Info")
    logging.info("\nBinocular Camera Subscriptions:")
    logging.info(
        "  b - Toggle Binocular Image        B - Toggle Binocular Camera Info"
    )
    logging.info("\nCommands:")
    logging.info(
        "  s - Show Status                   ESC - Quit              ? - Help"
    )
    logging.info("=" * 80)


def main():
    """Main function"""
    global robot, running

    # Bind signal handler
```

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```
    signal.signal(signal.SIGINT, signal_handler)

    logging.info("\n" + "=" * 80)
    logging.info("MagicBot Z1 SDK Sensor Interactive Example")
    logging.info("Robot Model: %s", magicbot.get_robot_model())

    # Create robot instance
    robot = magicbot.MagicRobot()
    logging.info("SDK Version: %s", robot.get_sdk_version())
    logging.info("=" * 80 + "\n")

    try:
        # Configure local IP address for direct network connection and initialize SDK
        local_ip = "192.168.54.111"
        if not robot.initialize(local_ip):
            logging.error("Failed to initialize robot SDK")
            robot.shutdown()
            return -1

        logging.info("✓ Robot SDK initialized successfully")

        # Connect to robot
        status = robot.connect()
        if status.code != magicbot.ErrorCode.OK:
            logging.error(
                "Failed to connect to robot, code: %s, message: %s",
                status.code,
                status.message,
            )
            robot.shutdown()
            return -1

        logging.info("✓ Successfully connected to robot")

        # Get sensor controller
        sensor_controller = robot.get_sensor_controller()

        # Initialize sensor controller
        if not sensor_controller.initialize():
            logging.error("Failed to initialize sensor controller")
```

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```
            robot.disconnect()
            robot.shutdown()
            return -1

        logging.info("✓ Sensor controller initialized successfully\n")

        sensor_manager = SensorManager(sensor_controller)

        print_menu()

        while running:
            try:
                choice = input("\nEnter your choice: ").strip()

                if choice == "\x1b" or choice.lower() == "esc":  # ESC key
                    logging.info("ESC key pressed, exiting program...")
                    break

                # Sensor open/close control
                if choice == "1":
                    sensor_manager.open_lidar()
                elif choice == "2":
                    sensor_manager.close_lidar()
                elif choice == "3":
                    sensor_manager.open_head_rgbd_camera()
                elif choice == "4":
                    sensor_manager.close_head_rgbd_camera()
                elif choice == "5":
                    sensor_manager.open_binocular_camera()
                elif choice == "6":
                    sensor_manager.close_binocular_camera()

                # LiDAR subscriptions
                elif choice == "i":
                    sensor_manager.toggle_lidar_imu_subscription()
                elif choice == "p":
                    sensor_manager.toggle_lidar_point_cloud_subscription()

                # Head RGBD subscriptions
                elif choice == "c":
```

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```
                    sensor_manager.toggle_head_rgbd_color_image_subscription()
                elif choice == "d":
                    sensor_manager.toggle_head_rgbd_depth_image_subscription()
                elif choice == "C":
                    sensor_manager.toggle_head_rgbd_camera_info_subscription()

                # Binocular camera subscriptions
                elif choice == "b":
                    sensor_manager.toggle_binocular_image_subscription()
                elif choice == "B":
                    sensor_manager.toggle_binocular_camera_info_subscription()
                # Commands
                elif choice.lower() == "s":
                    sensor_manager.show_status()
                elif choice == "?" or choice.lower() == "help":
                    print_menu()
                elif choice == "":
                    continue
                else:
                    logging.warning("Invalid choice: '%s'. Press '?' for help.",␣
↪choice)

            except KeyboardInterrupt:
                logging.info("\nReceived keyboard interrupt, shutting down...")
                break
            except EOFError:
                logging.info("\nReceived EOF, shutting down...")
                break
            except Exception as e:
                logging.error("Error occurred while processing input: %s", e)

    except Exception as e:
        logging.error("Exception occurred during program execution: %s", e)
        import traceback

        traceback.print_exc()
        return -1

    finally:
        # Cleanup: close all sensors
```

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```
        logging.info("\n" + "=" * 80)
        logging.info("Cleaning up resources...")
        logging.info("=" * 80)

        try:
            # Close all sensors
            if sensor_manager.sensors_state["lidar"]:
                sensor_manager.close_lidar()
            if sensor_manager.sensors_state["head_rgbd_camera"]:
                sensor_manager.close_head_rgbd_camera()
            if sensor_manager.sensors_state["binocular_camera"]:
                sensor_manager.close_binocular_camera()

            # Allow time for cleanup
            time.sleep(0.5)

            sensor_controller.shutdown()
            logging.info("✓ Sensor controller shutdown")

            robot.disconnect()
            logging.info("✓ Robot disconnected")

            robot.shutdown()
            logging.info("✓ Robot shutdown")

            logging.info("=" * 80)
            logging.info("Cleanup complete")
            logging.info("=" * 80 + "\n")

        except Exception as e:
            logging.error("Exception occurred while cleaning up resources: %s", e)

    return 0


if __name__ == "__main__":
    sys.exit(main())
```

23.3 Running Instructions

23.3.1 Environment Setup

```
export PYTHONPATH=/opt/magic_robotics/magicbot_z1_sdk/lib:$PYTHONPATH
export LD_LIBRARY_PATH=/opt/magic_robotics/magicbot_z1_sdk/lib:$LD_LIBRARY_PATH
```

23.3.2 Run Example

```
# C++
./sensor_example
# Python
python3 sensor_example.py
```

23.3.3 Control Instructions

- Sensor On/Off Control:
  - `1` - Open LiDAR
  - `2` - Close LiDAR
  - `3` - Open head RGBD camera
  - `4` - Close head RGBD camera
  - `5` - Open binocular camera
  - `6` - Close binocular camera
- LiDAR Data Subscription:
  - `i` - Toggle IMU data subscription
  - `p` - Toggle point cloud data subscription
- Head RGBD Camera Data Subscription:
  - `c` - Toggle color image subscription
  - `C` - Toggle color camera parameters subscription
  - `d` - Toggle depth image subscription
  - `D` - Toggle depth camera parameters subscription
- Binocular Camera Data Subscription:
  - `b` - Toggle image subscription
- Other Commands:

  - `s` - Show current status
  - `?` - Show help menu

23.3.4 Stop Program

- Press `ESC` to safely stop the program
- The program will automatically clean up all resources

CHAPTER 24

Audio Control Example

This example demonstrates how to use the Magicbot-Z1 SDK for initialization, robot connection, audio control (get volume, set volume, TTS playback, audio stream subscription), and other basic operations.

24.1 C++

Example file: `audio_example.cpp`

```cpp
#include "magic_robot.h"
#include "magic_sdk_version.h"

#include <termios.h>
#include <unistd.h>
#include <csignal>

#include <iostream>

using namespace magic::z1;

magic::z1::MagicRobot robot;

void signalHandler(int signum) {
  std::cout << "Interrupt signal (" << signum << ") received.\n";
```

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```
  robot.Shutdown();
  // Exit process
  exit(signum);
}

void print_help() {
  std::cout << "Key Function Description:\n";
  std::cout << "  Audio Functions:\n";
  std::cout << "  1        Function 1: Get volume\n";
  std::cout << "  2        Function 2: Set volume\n";
  std::cout << "  3        Function 3: Play TTS\n";
  std::cout << "  4        Function 4: Stop playback\n";
  std::cout << "  Audio stream Functions:\n";
  std::cout << "  5        Function 5: Open audio stream\n";
  std::cout << "  6        Function 6: Close audio stream\n";
  std::cout << "  7        Function 7: Subscribe to audio stream\n";
  std::cout << "  8        Function 8: Unsubscribe to audio stream\n";
  std::cout << "  Wakeup Status Functions:\n";
  std::cout << "  q        Function q: Open wakeup status stream\n";
  std::cout << "  w        Function w: Close wakeup status stream\n";
  std::cout << "  e        Function e: Subscribe to wakeup status\n";
  std::cout << "  r        Function r: Unsubscribe to wakeup status\n";
  std::cout << "\n";
  std::cout << "  ?        Function ?: Print help\n";
  std::cout << "  ESC      Exit program\n";
}

int getch() {
  struct termios oldt, newt;
  int ch;
  tcgetattr(STDIN_FILENO, &oldt);  // Get current terminal settings
  newt = oldt;
  newt.c_lflag &= ~(ICANON | ECHO);  // Disable buffering and echo
  tcsetattr(STDIN_FILENO, TCSANOW, &newt);
  ch = getchar();                            // Read key press
  tcsetattr(STDIN_FILENO, TCSANOW, &oldt);  // Restore settings
  return ch;
}
```

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```
void GetVolume() {
  // Get audio controller
  auto& controller = robot.GetAudioController();

  // Get volume
  int get_volume = 0;
  auto status = controller.GetVolume(get_volume);
  if (status.code != ErrorCode::OK) {
    std::cerr << "get volume failed"
              << ", code: " << status.code
              << ", message: " << status.message << std::endl;
    return;
  }
  std::cout << "get volume success, volume: " << std::to_string(get_volume) <<␣
↪std::endl;
}

void SetVolume() {
  // Get audio controller
  auto& controller = robot.GetAudioController();
  // Set volume
  auto status = controller.SetVolume(50);
  if (status.code != ErrorCode::OK) {
    std::cerr << "set volume failed"
              << ", code: " << status.code
              << ", message: " << status.message << std::endl;
    return;
  }
  std::cout << "set volume success" << std::endl;
}

void PlayTts() {
  // Get audio controller
  auto& controller = robot.GetAudioController();
  // Play speech
  TtsCommand tts;
  tts.id = "100000000001";
  tts.content = "How's the weather today!";
  tts.priority = TtsPriority::HIGH;
  tts.mode = TtsMode::CLEARTOP;
```

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```
  auto status = controller.Play(tts);
  if (status.code != ErrorCode::OK) {
    std::cerr << "play tts failed"
              << ", code: " << status.code
              << ", message: " << status.message << std::endl;
    return;
  }
  std::cout << "play tts success" << std::endl;
}

void StopTts() {
  // Get audio controller
  auto& controller = robot.GetAudioController();
  // Stop speech playback
  auto status = controller.Stop();
  if (status.code != ErrorCode::OK) {
    std::cerr << "stop tts failed"
              << ", code: " << status.code
              << ", message: " << status.message << std::endl;
    return;
  }
  std::cout << "stop tts success" << std::endl;
}

void OpenAudioStream() {
  // Get audio controller
  auto& controller = robot.GetAudioController();
  // Open audio stream
  auto status = controller.OpenAudioStream();
  if (status.code != ErrorCode::OK) {
    std::cerr << "open audio stream failed"
              << ", code: " << status.code
              << ", message: " << status.message << std::endl;
    return;
  }
  std::cout << "open audio stream success" << std::endl;
}

void CloseAudioStream() {
  // Get audio controller
```

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```
  auto& controller = robot.GetAudioController();
  // Close audio stream
  auto status = controller.CloseAudioStream();
  if (status.code != ErrorCode::OK) {
    std::cerr << "close audio stream failed"
              << ", code: " << status.code
              << ", message: " << status.message << std::endl;
    return;
  }
  std::cout << "close audio stream success" << std::endl;
}

void SubscribeAudioStream() {
  // Get audio controller
  auto& controller = robot.GetAudioController();

  // Subscribe to audio streams
  controller.SubscribeOriginAudioStream([](const std::shared_ptr<AudioStream> data) {
    static int32_t counter = 0;
    if (counter++ % 30 == 0) {
      std::cout << "Received origin audio stream data, size: " << data->data_length <
↪< std::endl;
    }
  });

  controller.SubscribeBfAudioStream([](const std::shared_ptr<AudioStream> data) {
    static int32_t counter = 0;
    if (counter++ % 30 == 0) {
      std::cout << "Received bf audio stream data, size: " << data->data_length <<␣
↪std::endl;
    }
  });
  std::cout << "Subscribed to audio streams" << std::endl;
}

void UnsubscribeAudioStream() {
  // Get audio controller
  auto& controller = robot.GetAudioController();
  // Unsubscribe from audio streams
  controller.UnsubscribeOriginAudioStream();
```

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```
  controller.UnsubscribeBfAudioStream();
  std::cout << "Unsubscribed from audio streams" << std::endl;
}

void OpenWakeupStatusStream() {
  // Get audio controller
  auto& controller = robot.GetAudioController();
  // Open wakeup status stream
  auto status = controller.OpenWakeupStatusStream();
}

void CloseWakeupStatusStream() {
  // Get audio controller
  auto& controller = robot.GetAudioController();
  // Close wakeup status stream
  auto status = controller.CloseWakeupStatusStream();
}

void SubscribeWakeupStatus() {
  // Get audio controller
  auto& controller = robot.GetAudioController();
  // Subscribe to wakeup status
  controller.SubscribeWakeupStatus([](const std::shared_ptr<WakeupStatus> data) {
    static int32_t counter = 0;
    if (data->is_wakeup) {
      if (data->enable_wakeup_orientation) {
        std::cout << "Received wakeup status data, is_wakeup: " << data->is_wakeup <<
↪", enable_wakeup_orientation: " << data->enable_wakeup_orientation << ", wakeup_
↪orientation: " << data->wakeup_orientation << std::endl;
      } else {
        std::cout << "Received wakeup status data, is_wakeup: " << data->is_wakeup <<␣
↪std::endl;
      }
    } else {
      std::cout << "Received wakeup status data, is_wakeup: " << data->is_wakeup <<␣
↪std::endl;
    }
  });
}
```

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```cpp
void UnsubscribeWakeupStatus() {
  // Get audio controller
  auto& controller = robot.GetAudioController();
  // Unsubscribe from wakeup status
  controller.UnsubscribeWakeupStatus();
}

int main(int argc, char* argv[]) {
  // Bind SIGINT (Ctrl+C)
  signal(SIGINT, signalHandler);

  std::cout << "SDK Version: " << SDK_VERSION_STRING << std::endl;

  print_help();

  std::string local_ip = "192.168.54.111";
  // Configure local IP address for direct network connection and initialize SDK
  if (!robot.Initialize(local_ip)) {
    std::cerr << "robot sdk initialize failed." << std::endl;
    robot.Shutdown();
    return -1;
  }

  // Connect to robot
  auto status = robot.Connect();
  if (status.code != ErrorCode::OK) {
    std::cerr << "connect robot failed"
              << ", code: " << status.code
              << ", message: " << status.message << std::endl;
    robot.Shutdown();
    return -1;
  }
  std::cout << "Press any key to continue (ESC to exit)..."
            << std::endl;

  // Wait for user input
  while (1) {
    int key = getch();
    if (key == 27)
      break;  // ESC key ASCII code is 27
```

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```
    std::cout << "Key ASCII: " << key << ", Character: " << static_cast<char>(key) <<␣
↪std::endl;
    switch (key) {
      // 1. Audio Functions
      case '1': {
        // Get volume
        GetVolume();
        break;
      }
      case '2': {
        // Set volume
        SetVolume();
        break;
      }
      case '3': {
        PlayTts();
        break;
      }
      case '4': {
        StopTts();
        break;
      }
      // 2. Audio stream Functions
      case '5': {
        OpenAudioStream();
        break;
      }
      case '6': {
        CloseAudioStream();
        break;
      }
      case '7': {
        SubscribeAudioStream();
        break;
      }
      case '8': {
        UnsubscribeAudioStream();
        break;
      }
```

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```
    // 3. Wakeup Status Functions
    case 'Q':
    case 'q': {
      OpenWakeupStatusStream();
      break;
    }
    case 'W':
    case 'w': {
      CloseWakeupStatusStream();
      break;
    }
    case 'E':
    case 'e': {
      SubscribeWakeupStatus();
      break;
    }
    case 'R':
    case 'r': {
      UnsubscribeWakeupStatus();
      break;
    }
    case '?': {
      print_help();
      break;
    }
    default:
      std::cout << "Unknown key: " << key << std::endl;
      break;
  }
  usleep(10000);
}

// Disconnect from robot
status = robot.Disconnect();
if (status.code != ErrorCode::OK) {
  std::cerr << "disconnect robot failed"
            << ", code: " << status.code
            << ", message: " << status.message << std::endl;
  robot.Shutdown();
  return -1;
```

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```
  }

  robot.Shutdown();

  return 0;
}
```

24.2 Python

Example file: `audio_example.py`

```python
#!/usr/bin/env python3
# -*- coding: utf-8 -*-

import sys
import time
import signal
import threading
import logging
from typing import Optional

import magicbot_z1_python as magicbot

# Configure logging format and level
logging.basicConfig(
    level=logging.INFO,  # Minimum log level
    format="%(asctime)s [%(levelname)s] %(message)s",
    datefmt="%Y-%m-%d %H:%M:%S",
)

# Global variables
robot: Optional[magicbot.MagicRobot] = None
running = True


def signal_handler(signum, frame):
    """Signal handler function for graceful exit"""
    global running, robot
    logging.info("Received interrupt signal (%s), exiting...", signum)
    running = False
```

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```
    if robot:
        robot.shutdown()
        logging.info("Robot shutdown")
    exit(-1)


def print_help():
    """Print help information"""
    logging.info("Key Function Demo Program")
    logging.info("")
    logging.info("Audio Functions:")
    logging.info("  1        Function 1: Get volume")
    logging.info("  2        Function 2: Set volume")
    logging.info("  3        Function 3: Play TTS")
    logging.info("  4        Function 4: Stop playback")
    logging.info("")
    logging.info("Audio stream Functions:")
    logging.info("  5        Function 5: Open audio stream")
    logging.info("  6        Function 6: Close audio stream")
    logging.info("  7        Function 7: Subscribe to audio stream")
    logging.info("  8        Function 8: Unsubscribe to audio stream")
    logging.info("")
    logging.info("Wakeup Status Functions:")
    logging.info("  Q        Function Q: Open wakeup status stream")
    logging.info("  W        Function W: Close wakeup status stream")
    logging.info("  E        Function E: Subscribe to wakeup status")
    logging.info("  R        Function R: Unsubscribe to wakeup status")
    logging.info("")
    logging.info("  ?        Function ?: Print help")
    logging.info("  ESC      Exit program")


def get_volume():
    """Get volume"""
    global robot
    try:
        # Get audio controller
        controller = robot.get_audio_controller()

        # Get volume
```

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```
        status, volume = controller.get_volume()
        if status.code != magicbot.ErrorCode.OK:
            logging.error(
                "Failed to get volume, code: %s, message: %s",
                status.code,
                status.message,
            )
            return

        logging.info("Successfully got volume, volume: %s", volume)
    except Exception as e:
        logging.error("Exception occurred while getting volume: %s", e)


def set_volume(volume):
    """Set volume"""
    global robot
    try:
        # Get audio controller
        controller = robot.get_audio_controller()

        # Set volume to 7
        status = controller.set_volume(volume)
        if status.code != magicbot.ErrorCode.OK:
            logging.error(
                "Failed to set volume, code: %s, message: %s",
                status.code,
                status.message,
            )
            return

        logging.info("Successfully set volume")
    except Exception as e:
        logging.error("Exception occurred while setting volume: %s", e)


def play_tts(content):
    """Play TTS speech"""
    global robot
    try:
```

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```
        # Get audio controller
        controller = robot.get_audio_controller()

        # Create TTS command
        tts = magicbot.TtsCommand()
        tts.id = "100000000001"
        tts.content = content
        tts.priority = magicbot.TtsPriority.HIGH
        tts.mode = magicbot.TtsMode.CLEARTOP

        # Play speech
        status = controller.play(tts)
        if status.code != magicbot.ErrorCode.OK:
            logging.error(
                "Failed to play TTS, code: %s, message: %s", status.code, status.
↪message
            )
            return

        logging.info("Successfully played TTS")
    except Exception as e:
        logging.error("Exception occurred while playing TTS: %s", e)


def stop_tts():
    """Stop TTS playback"""
    global robot
    try:
        # Get audio controller
        controller = robot.get_audio_controller()

        # Stop speech playback
        status = controller.stop()
        if status.code != magicbot.ErrorCode.OK:
            logging.error(
                "Failed to stop TTS, code: %s, message: %s", status.code, status.
↪message
            )
            return
```

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```
        logging.info("Successfully stopped TTS")
    except Exception as e:
        logging.error("Exception occurred while stopping TTS: %s", e)


def open_audio_stream():
    """Open audio stream"""
    global robot
    try:
        # Get audio controller
        controller = robot.get_audio_controller()

        # Open audio stream
        status = controller.open_audio_stream()
        if status.code != magicbot.ErrorCode.OK:
            logging.error(
                "Failed to open audio stream, code: %s, message: %s",
                status.code,
                status.message,
            )
            return

        logging.info("Successfully opened audio stream")
    except Exception as e:
        logging.error("Exception occurred while opening audio stream: %s", e)


def close_audio_stream():
    """Close audio stream"""
    global robot
    try:
        # Get audio controller
        controller = robot.get_audio_controller()

        # Close audio stream
        status = controller.close_audio_stream()
        if status.code != magicbot.ErrorCode.OK:
            logging.error(
                "Failed to close audio stream, code: %s, message: %s",
                status.code,
```

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```
                status.message,
            )
            return

        logging.info("Successfully closed audio stream")
    except Exception as e:
        logging.error("Exception occurred while closing audio stream: %s", e)


def subscribe_audio_stream():
    """Subscribe to audio stream"""
    global robot
    try:
        # Get audio controller
        controller = robot.get_audio_controller()

        # Audio stream counters
        origin_counter = 0
        bf_counter = 0

        def origin_audio_callback(audio_stream):
            """Original audio stream callback function"""
            nonlocal origin_counter
            if origin_counter % 30 == 0:
                logging.info(
                    "Received original audio stream data, size: %d",
                    audio_stream.data_length,
                )
                sys.stdout.write("\r")
                sys.stdout.flush()
            origin_counter += 1

        def bf_audio_callback(audio_stream):
            """BF audio stream callback function"""
            nonlocal bf_counter
            if bf_counter % 30 == 0:
                logging.info(
                    "Received BF audio stream data, size: %d", audio_stream.data_
↪length
                )
```

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```
                sys.stdout.write("\r")
                sys.stdout.flush()
            bf_counter += 1

        # Subscribe to audio streams
        controller.subscribe_origin_audio_stream(origin_audio_callback)
        controller.subscribe_bf_audio_stream(bf_audio_callback)

        logging.info("Subscribed to audio streams")
    except Exception as e:
        logging.error("Exception occurred while subscribing to audio stream: %s", e)


def unsubscribe_audio_stream():
    """Unsubscribe to audio stream"""
    global robot
    try:
        # Get audio controller
        controller = robot.get_audio_controller()

        # Unsubscribe to audio stream
        controller.unsubscribe_bf_audio_stream()
        controller.unsubscribe_origin_audio_stream()

        logging.info("Unsubscribed to audio stream")
    except Exception as e:
        logging.error("Exception occurred while unsubscribing to audio stream: %s", e)


def open_wakeup_status_stream():
    """Open wakeup status stream"""
    global robot
    try:
        # Get audio controller
        controller = robot.get_audio_controller()

        # Open wakeup status stream
        status = controller.open_wakeup_status_stream()
        if status.code != magicbot.ErrorCode.OK:
            logging.error(
```

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```
                "Failed to open wakeup status stream, code: %s, message: %s",
                status.code,
                status.message,
            )
            return

        logging.info("Successfully opened wakeup status stream")
    except Exception as e:
        logging.error("Exception occurred while opening wakeup status stream: %s", e)


def close_wakeup_status_stream():
    """Close wakeup status stream"""
    global robot
    try:
        # Get audio controller
        controller = robot.get_audio_controller()

        # Close wakeup status stream
        status = controller.close_wakeup_status_stream()
        if status.code != magicbot.ErrorCode.OK:
            logging.error(
                "Failed to close wakeup status stream, code: %s, message: %s",
                status.code,
                status.message,
            )
            return

        logging.info("Successfully closed wakeup status stream")
    except Exception as e:
        logging.error("Exception occurred while closing wakeup status stream: %s", e)


def unsubscribe_wakeup_status():
    """Unsubscribe to wakeup status"""
    global robot
    try:
        # Get audio controller
        controller = robot.get_audio_controller()
```

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```
        # Unsubscribe to wakeup status
        controller.unsubscribe_wakeup_status()

        logging.info("Unsubscribed to wakeup status")
    except Exception as e:
        logging.error("Exception occurred while unsubscribing to wakeup status: %s",␣
↪e)


def subscribe_wakeup_status():
    """Subscribe to wakeup status"""
    global robot
    try:
        # Get audio controller
        controller = robot.get_audio_controller()

        # Wakeup status counter
        wakeup_counter = 0

        def wakeup_status_callback(wakeup_status):
            """Wakeup status callback function"""
            nonlocal wakeup_counter
            if wakeup_status.is_wakeup:
                if wakeup_status.enable_wakeup_orientation:
                    logging.info(
                        "Voice wakeup detected! Orientation: %.2f radians (%.1f␣
↪degrees)",
                        wakeup_status.wakeup_orientation,
                        wakeup_status.wakeup_orientation * 180.0 / 3.14159,
                    )
                else:
                    logging.info("Voice wakeup detected!")
                sys.stdout.write("\r")
                sys.stdout.flush()
            else:
                if wakeup_counter % 10 == 0:  # Log every 50th non-wakeup status
                    logging.info(
                        "Wakeup status: sleeping, enable_wakeup_orientation: %s,␣
↪orientation: %.2f radians",
                        wakeup_status.enable_wakeup_orientation,
```

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```
                        wakeup_status.wakeup_orientation * 180.0 / 3.14159,
                    )
                    sys.stdout.write("\r")
                    sys.stdout.flush()
            wakeup_counter += 1

        # Subscribe to wakeup status
        controller.subscribe_wakeup_status(wakeup_status_callback)

        logging.info("Subscribed to wakeup status stream")
    except Exception as e:
        logging.error("Exception occurred while subscribing to wakeup status: %s", e)


def get_user_input():
    """Get user input - Read a single line of data"""
    try:
        # Method 1: Read a line using input() (recommended)
        return input("Enter command: ").strip()
    except (EOFError, KeyboardInterrupt):
        return ""


def main():
    """Main function"""
    global robot, running

    # Bind signal handler
    signal.signal(signal.SIGINT, signal_handler)

    logging.info("Robot model: %s", magicbot.get_robot_model())

    # Create robot instance
    robot = magicbot.MagicRobot()

    try:
        # Configure local IP address for direct network connection and initialize SDK
        local_ip = "192.168.54.111"
        if not robot.initialize(local_ip):
            logging.error("Failed to initialize robot SDK")
```

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```
            robot.shutdown()
            return -1

        # Connect to robot
        status = robot.connect()
        if status.code != magicbot.ErrorCode.OK:
            logging.error(
                "Failed to connect to robot, code: %s, message: %s",
                status.code,
                status.message,
            )
            robot.shutdown()
            return -1

        logging.info("Successfully connected to robot")

        # Initialize audio controller
        audio_controller = robot.get_audio_controller()
        if not audio_controller.initialize():
            logging.error("Failed to initialize audio controller")
            robot.disconnect()
            robot.shutdown()
            return -1

        logging.info("Successfully initialized audio controller")
        print_help()
        logging.info("Press any key to continue (ESC to exit)...")

        # Main loop
        while running:
            try:
                str_input = get_user_input()

                # Split input parameters by space
                parts = str_input.strip().split()

                if not parts:
                    time.sleep(0.01)  # Brief delay
                    continue
```

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```
            # Parse parameters
            key = parts[0]
            args = parts[1:] if len(parts) > 1 else []
            if key == "\x1b":  # ESC key
                break
            # 1. Audio Functions
            # 1.1 Get volume
            if key == "1":
                get_volume()
            # 1.2 Set volume
            elif key == "2":
                volume = args[0] if args else 50
                set_volume(volume)
            # 1.3 Play TTS
            elif key == "3":
                content = args[0] if args else "How's the weather today!"
                play_tts(content)
            # 1.4 Stop TTS
            elif key == "4":
                stop_tts()
            # 2. Audio Stream Functions
            # 2.1 Open audio stream
            elif key == "5":
                open_audio_stream()
            # 2.2 Close audio stream
            elif key == "6":
                close_audio_stream()
            # 2.3 Subscribe to audio stream
            elif key == "7":
                subscribe_audio_stream()
            # 2.4 Unsubscribe from audio stream
            elif key.upper() == "8":
                unsubscribe_audio_stream()
            # 3. Wakeup Status Functions
            # 3.1 Open wakeup status stream
            elif key.upper() == "Q":
                open_wakeup_status_stream()
            # 3.2 Close wakeup status stream
            elif key.upper() == "W":
                close_wakeup_status_stream()
```

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```
                # 3.3 Subscribe to wakeup status stream
                elif key.upper() == "E":
                    subscribe_wakeup_status()
                # 3.4 Unsubscribe from wakeup status stream
                elif key.upper() == "R":
                    unsubscribe_wakeup_status()
                # 4. Print help information
                elif key.upper() == "?":
                    print_help()
                else:
                    logging.warning("Unknown key: %s", key)

                time.sleep(0.01)  # Brief delay

            except KeyboardInterrupt:
                break
            except Exception as e:
                logging.error("Exception occurred while processing user input: %s", e)
    except Exception as e:
        logging.error("Exception occurred during program execution: %s", e)
        return -1

    finally:
        # Clean up resources
        try:
            logging.info("Clean up resources")
            # Close sensor controller
            audio_controller = robot.get_audio_controller()
            audio_controller.shutdown()
            logging.info("Audio controller closed")

            # Disconnect
            robot.disconnect()
            logging.info("Robot connection disconnected")

            # Shutdown robot
            robot.shutdown()
            logging.info("Robot shutdown")

        except Exception as e:
```

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```
            logging.error("Exception occurred while cleaning up resources: %s", e)


if __name__ == "__main__":
    sys.exit(main())
```

24.3 Running Instructions

24.3.1 Environment Setup

```
export PYTHONPATH=/opt/magic_robotics/magicbot_z1_sdk/lib:$PYTHONPATH
export LD_LIBRARY_PATH=/opt/magic_robotics/magicbot_z1_sdk/lib:$LD_LIBRARY_PATH
```

24.3.2 Run Example

```
# C++
./audio_example
# Python
python3 audio_example.py
```

24.3.3 Control Instructions

- `1`: Get current volume
- `2`: Set volume
- `3`: Play TTS speech
- `4`: Stop TTS playback
- `5`: Open audio stream
- `6`: Close audio stream
- `7`: Subscribe to audio stream data
- `8`: Unsubscribe from audio stream data
- `Q`: Open voice wakeup status stream
- `W`: Close voice wakeup status stream
- `E`: Subscribe to voice wakeup status
- `R`: Unsubscribe from voice wakeup status
- `?`: Print help information

24.3.4 Stop Program

- Press `ESC` to safely stop the program
- The program will automatically clean up all resources

CHAPTER 25

State Monitor Example

This example demonstrates how to use the Magicbot-Z1 SDK for initialization, robot connection, robot status monitoring (faults, BMS), and other basic operations.

25.1 C++

Example file: `monitor_example.cpp`

```cpp
#include "magic_robot.h"
#include "magic_sdk_version.h"

#include <unistd.h>
#include <csignal>

#include <iostream>

using namespace magic::z1;

magic::z1::MagicRobot robot;

void signalHandler(int signum) {
  std::cout << "Interrupt signal (" << signum << ") received.\n";
```

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```
  robot.Shutdown();
  // Exit process
  exit(signum);
}

int main() {
  // Bind SIGINT (Ctrl+C)
  signal(SIGINT, signalHandler);

  std::cout << "SDK Version: " << SDK_VERSION_STRING << std::endl;

  std::string local_ip = "192.168.54.111";
  // Configure local IP address for direct ethernet connection to robot and␣
↪initialize SDK
  if (!robot.Initialize(local_ip)) {
    std::cerr << "robot sdk initialize failed." << std::endl;
    robot.Shutdown();
    return -1;
  }

  // Connect to robot
  auto status = robot.Connect();
  if (status.code != ErrorCode::OK) {
    std::cerr << "connect robot failed"
              << ", code: " << status.code
              << ", message: " << status.message << std::endl;
    robot.Shutdown();
    return -1;
  }
  // Wait for 5 seconds
  usleep(5000000);

  auto& monitor = robot.GetStateMonitor();

  RobotState state;
  status = monitor.GetCurrentState(state);
  if (status.code != ErrorCode::OK) {
    std::cerr << "get robot state failed"
              << ", code: " << status.code
              << ", message: " << status.message << std::endl;
```

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```
    robot.Shutdown();
    return -1;
  }

  std::cout << "health: " << state.bms_data.battery_health
            << ", percentage: " << state.bms_data.battery_percentage
            << ", state: " << std::to_string((int8_t)state.bms_data.battery_state)
            << ", power_supply_status: " << std::to_string((int8_t)state.bms_data.
↪power_supply_status)
            << std::endl;

  auto& faults = state.faults;
  for (auto& [code, msg] : faults) {
    std::cout << "code: " << std::to_string(code)
              << ", message: " << msg << std::endl;
  }

  // Disconnect from robot
  status = robot.Disconnect();
  if (status.code != ErrorCode::OK) {
    std::cerr << "disconnect robot failed"
              << ", code: " << status.code
              << ", message: " << status.message << std::endl;
    robot.Shutdown();
    return -1;
  }

  robot.Shutdown();

  return 0;
}
```

25.2 Python

Example file: `monitor_example.py`

```
#!/usr/bin/env python3

import sys
import time
```

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```
import signal
import logging
from typing import Optional

import magicbot_z1_python as magicbot

# Configure logging format and level
logging.basicConfig(
    level=logging.INFO,  # Minimum log level
    format="%(asctime)s [%(levelname)s] %(message)s",
    datefmt="%Y-%m-%d %H:%M:%S",
)


# Global variables
robot: Optional[magicbot.MagicRobot] = None


def signal_handler(signum, frame):
    """Signal handler function for graceful exit"""
    global robot
    logging.info("Received interrupt signal (%s), exiting...", signum)
    if robot:
        robot.disconnect()
        logging.info("Robot disconnected")
        robot.shutdown()
        logging.info("Robot shutdown")
    exit(-1)


def main():
    """Main function"""
    global robot

    # Bind signal handler
    signal.signal(signal.SIGINT, signal_handler)

    logging.info("Robot model: %s", magicbot.get_robot_model())

    # Create robot instance
```

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```
    robot = magicbot.MagicRobot()

    try:
        # Configure local IP address for direct network connection and initialize SDK
        local_ip = "192.168.54.111"
        if not robot.initialize(local_ip):
            logging.error("Failed to initialize robot SDK")
            robot.shutdown()
            return -1

        # Connect to robot
        status = robot.connect()
        if status.code != magicbot.ErrorCode.OK:
            logging.error(
                "Failed to connect to robot, code: %s, message: %s",
                status.code,
                status.message,
            )
            robot.shutdown()
            return -1

        logging.info("Successfully connected to robot")

        # Wait 5 seconds
        logging.info("Waiting 5 seconds...")
        time.sleep(5)

        # Get state monitor
        monitor = robot.get_state_monitor()

        # Get current state
        state = monitor.get_current_state()

        # Print battery information
        logging.info("Battery health: %s", state.bms_data.battery_health)
        logging.info("Battery percentage: %s%%", state.bms_data.battery_percentage)
        logging.info("Battery state: %s", state.bms_data.battery_state)
        logging.info("Power supply status: %s", state.bms_data.power_supply_status)

        # Print fault information
```

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```
        faults = state.faults
        for fault in faults:
            logging.info(
                "Error code: %s, Error message: %s",
                fault.error_code,
                fault.error_message,
            )

    except Exception as e:
        logging.error("Exception occurred during program execution: %s", e)
        return -1

    finally:
        # Clean up resources
        try:
            logging.info("Clean up resources")
            # Close state monitor
            monitor = robot.get_state_monitor()
            monitor.shutdown()

            # Disconnect
            robot.disconnect()
            logging.info("Robot connection disconnected")

            # Shutdown robot
            robot.shutdown()
            logging.info("Robot shutdown")

        except Exception as e:
            logging.error("Exception occurred while cleaning up resources: %s", e)


if __name__ == "__main__":
    sys.exit(main())
```

25.3 Running Instructions

25.3.1 Environment Setup

```
export PYTHONPATH=/opt/magic_robotics/magicbot_z1_sdk/lib:$PYTHONPATH
export LD_LIBRARY_PATH=/opt/magic_robotics/magicbot_z1_sdk/lib:$LD_LIBRARY_PATH
```

25.3.2 Run Example

```
# C++
./monitor_example
# Python
python3 monitor_example.py
```

25.3.3 Stop Program

- Press `Ctrl+C` to safely stop the program
- The program will automatically clean up all resources

CHAPTER 26

SLAM Navigation Example

This example demonstrates how to use the Magicbot-Z1 SDK for SLAM mapping, localization, navigation and other operations, including map management, pose acquisition and other functions.

26.1 C++

Example files:

- `slam_example.cpp`
- `navigation_example.cpp`

Reference documentation:

- `C++ API/slam_navigation_reference.md`

26.1.1 Mapping Example

```
#include "magic_robot.h"
#include "magic_sdk_version.h"

#include <termios.h>
#include <unistd.h>
#include <csignal>
#include <ctime>
```

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```
#include <fstream>
#include <iostream>
#include <string>

using namespace magic::z1;

magic::z1::MagicRobot robot;
bool running = true;
SlamMode current_slam_mode = SlamMode::IDLE;

void SignalHandler(int signum) {
  std::cout << "Received interrupt signal (" << signum << "), exiting..." <<␣
↪std::endl;
  running = false;
  robot.Shutdown();
  exit(signum);
}

void PrintHelp() {
  std::cout << "\n========================================" << std::endl;
  std::cout << "SLAM and Navigation Function Demo Program" << std::endl;
  std::cout << "========================================" << std::endl;
  std::cout << "preparation Functions:" << std::endl;
  std::cout << "  0        Function 0: Recovery stand" << std::endl;
  std::cout << "SLAM Functions:" << std::endl;
  std::cout << "  1        Function 1: Switch to mapping mode" << std::endl;
  std::cout << "  2        Function 2: Start mapping" << std::endl;
  std::cout << "  3        Function 3: Cancel mapping" << std::endl;
  std::cout << "  4        Function 4: Save map" << std::endl;
  std::cout << "  5        Function 5: Load map (input map name after pressing 5)" <<␣
↪std::endl;
  std::cout << "  6        Function 6: Delete map (input map name after pressing 6)" <
↪< std::endl;
  std::cout << "  7        Function 7: Get all map information and save map image as␣
↪PGM file" << std::endl;
  std::cout << "  8        Function 8: Get map path (input map name)" << std::endl;
  std::cout << "  9        Function 9: Get SLAM mapping point cloud map" << std::endl;
  std::cout << "Close Functions:" << std::endl;
  std::cout << "  P        Function P: Close SLAM" << std::endl;
  std::cout << "\n  ?        Function ?: Print help" << std::endl;
```

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```
  std::cout << "  ESC      Exit program" << std::endl;
  std::cout << "======================================\n"
            << std::endl;
}

int getch() {
  struct termios oldt, newt;
  int ch;
  tcgetattr(STDIN_FILENO, &oldt);
  newt = oldt;
  newt.c_lflag &= ~(ICANON | ECHO);
  tcsetattr(STDIN_FILENO, TCSANOW, &newt);
  ch = getchar();
  tcsetattr(STDIN_FILENO, TCSANOW, &oldt);
  return ch;
}

std::string GetUserInput(const std::string& prompt) {
  std::cout << prompt;
  std::string input;
  std::getline(std::cin, input);
  return input;
}

void RecoveryStand() {
  std::cout << "=== Executing Recovery Stand ===" << std::endl;
  auto& controller = robot.GetHighLevelMotionController();

  auto status = controller.SetGait(GaitMode::GAIT_RECOVERY_STAND, 10000);
  if (status.code != ErrorCode::OK) {
    std::cerr << "Failed to set robot gait, code: " << status.code
              << ", message: " << status.message << std::endl;
    return;
  }
  std::cout << "Successfully executed recovery stand" << std::endl;
}

void SwitchToMappingMode() {
  auto& controller = robot.GetSlamNavController();
```

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```
  auto status = controller.ActivateSlamMode(SlamMode::MAPPING, "", 10000);
  if (status.code != ErrorCode::OK) {
    std::cerr << "Failed to switch to mapping mode, code: " << status.code
              << ", message: " << status.message << std::endl;
    return;
  }

  current_slam_mode = SlamMode::MAPPING;
  std::cout << "Successfully switched to mapping mode" << std::endl;
  std::cout << "Robot is now in mapping mode, ready to create new maps" << std::endl;
}

void StartMapping() {
  auto& controller = robot.GetSlamNavController();

  auto status = controller.StartMapping(10000);
  if (status.code != ErrorCode::OK) {
    std::cerr << "Failed to start mapping, code: " << status.code
              << ", message: " << status.message << std::endl;
    return;
  }

  std::cout << "Successfully started mapping" << std::endl;
}

void CancelMapping() {
  auto& controller = robot.GetSlamNavController();

  auto status = controller.CancelMapping(10000);
  if (status.code != ErrorCode::OK) {
    std::cerr << "Failed to cancel mapping, code: " << status.code
              << ", message: " << status.message << std::endl;
    return;
  }

  std::cout << "Successfully cancelled mapping" << std::endl;
}

void SaveMap() {
  auto& controller = robot.GetSlamNavController();
```

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```
  if (current_slam_mode != SlamMode::MAPPING) {
    std::cerr << "Warning: Currently not in mapping mode, may not be able to save map
↪" << std::endl;
  }

  // Generate map name with timestamp
  std::time_t now = std::time(nullptr);
  std::string map_name = "map_" + std::to_string(now);
  std::cout << "Saving map: " << map_name << std::endl;

  auto status = controller.SaveMap(map_name, 20000);
  if (status.code != ErrorCode::OK) {
    std::cerr << "Failed to save map, code: " << status.code
              << ", message: " << status.message << std::endl;
    return;
  }

  std::cout << "Successfully saved map: " << map_name << std::endl;
}

void LoadMap(const std::string& map_name) {
  if (map_name.empty()) {
    std::cerr << "Map to load is not provided" << std::endl;
    return;
  }

  auto& controller = robot.GetSlamNavController();

  std::cout << "Loading map: " << map_name << std::endl;
  auto status = controller.LoadMap(map_name, 10000);
  if (status.code != ErrorCode::OK) {
    std::cerr << "Failed to load map, code: " << status.code
              << ", message: " << status.message << std::endl;
    return;
  }

  std::cout << "Successfully loaded map: " << map_name << std::endl;
}
```

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```
void DeleteMap(const std::string& map_name) {
  if (map_name.empty()) {
    std::cerr << "Map to delete is not provided" << std::endl;
    return;
  }

  auto& controller = robot.GetSlamNavController();

  std::cout << "Deleting map: " << map_name << std::endl;
  auto status = controller.DeleteMap(map_name, 10000);
  if (status.code != ErrorCode::OK) {
    std::cerr << "Failed to delete map, code: " << status.code
              << ", message: " << status.message << std::endl;
    return;
  }

  std::cout << "Successfully deleted map: " << map_name << std::endl;
}

void SaveMapImageToFile(const MapInfo& map_info) {
  try {
    const auto& map_data = map_info.map_meta_data.map_image_data;
    uint32_t width = map_data.width;
    uint32_t height = map_data.height;
    uint32_t max_gray_value = map_data.max_gray_value;
    const auto& image_bytes = map_data.image;

    std::cout << "Saving map image: " << width << "x" << height
              << ", max_gray: " << max_gray_value << std::endl;

    // Check image data size
    if (image_bytes.size() != width * height) {
      std::cerr << "Image data size mismatch: expected " << (width * height)
                << ", got " << image_bytes.size() << std::endl;
      return;
    }

    // Generate filename based on map name
    std::string safe_filename = map_info.map_name;
    // Remove invalid characters
```

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```
    safe_filename.erase(
        std::remove_if(safe_filename.begin(), safe_filename.end(),
                       [](char c) { return !std::isalnum(c) && c != '_' && c != '-'; }
↪),
        safe_filename.end());

    if (safe_filename.empty()) {
      safe_filename = "map_" + std::to_string(std::time(nullptr));
    }

    // Save as PGM format
    std::string pgm_filename = "build/" + safe_filename + ".pgm";
    std::ofstream pgm_file(pgm_filename, std::ios::binary);
    if (!pgm_file.is_open()) {
      std::cerr << "Failed to open file for writing: " << pgm_filename << std::endl;
      return;
    }

    // Write PGM header
    pgm_file << "P5\n"
             << width << " " << height << "\n"
             << max_gray_value << "\n";

    // Write image data
    pgm_file.write(reinterpret_cast<const char*>(image_bytes.data()), image_bytes.
↪size());
    pgm_file.close();

    std::cout << "Map image saved successfully as PGM: " << pgm_filename << std::endl;

  } catch (const std::exception& e) {
    std::cerr << "Exception occurred while saving map image: " << e.what() <<␣
↪std::endl;
  }
}

void GetAllMapInfo() {
  auto& controller = robot.GetSlamNavController();

  AllMapInfo all_map_info;
```

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```
  auto status = controller.GetAllMapInfo(all_map_info, 10000);
  if (status.code != ErrorCode::OK) {
    std::cerr << "Failed to get map information, code: " << status.code
              << ", message: " << status.message << std::endl;
    return;
  }

  std::cout << "Successfully retrieved map information" << std::endl;
  std::cout << "Current map: " << all_map_info.current_map_name << std::endl;
  std::cout << "Total maps: " << all_map_info.map_infos.size() << std::endl;

  if (!all_map_info.map_infos.empty()) {
    std::cout << "Map details:" << std::endl;
    for (size_t i = 0; i < all_map_info.map_infos.size(); ++i) {
      const auto& map_info = all_map_info.map_infos[i];
      std::cout << "  Map " << (i + 1) << ": " << map_info.map_name << std::endl;
      std::cout << "    Origin: [" << map_info.map_meta_data.origin.position[0] << ",
↪"
                << map_info.map_meta_data.origin.position[1] << ", "
                << map_info.map_meta_data.origin.position[2] << "]" << std::endl;
      std::cout << "    Orientation: [" << map_info.map_meta_data.origin.
↪orientation[0] << ", "
                << map_info.map_meta_data.origin.orientation[1] << ", "
                << map_info.map_meta_data.origin.orientation[2] << "]" << std::endl;
      std::cout << "    Resolution: " << map_info.map_meta_data.resolution << " m/
↪pixel" << std::endl;
      std::cout << "    Size: " << map_info.map_meta_data.map_image_data.width << " x
↪"
                << map_info.map_meta_data.map_image_data.height << std::endl;
      std::cout << "    Max gray value: " << map_info.map_meta_data.map_image_data.
↪max_gray_value << std::endl;
      std::cout << "    Image type: " << map_info.map_meta_data.map_image_data.type <
↪< std::endl;

      SaveMapImageToFile(map_info);
    }
  } else {
    std::cout << "No available maps" << std::endl;
  }
}
```

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```
void GetMapPath(const std::string& map_name) {
  if (map_name.empty()) {
    std::cerr << "Map to get path is not provided" << std::endl;
    return;
  }

  auto& controller = robot.GetSlamNavController();

  std::vector<std::string> map_path;
  auto status = controller.GetMapPath(map_name, map_path, 10000);
  if (status.code != ErrorCode::OK) {
    std::cerr << "Failed to get map path, code: " << status.code
              << ", message: " << status.message << std::endl;
    return;
  }

  if (map_path.empty()) {
    std::cerr << "No map path found" << std::endl;
    return;
  }

  for (const auto& path : map_path) {
    std::cout << "Map path: " << path << std::endl;
  }
}

void GetPointCloudMap() {
  auto& controller = robot.GetSlamNavController();

  PointCloud2 point_cloud_map;
  auto status = controller.GetPointCloudMap(point_cloud_map, 10000);
  if (status.code != ErrorCode::OK) {
    std::cerr << "Failed to get SLAM mapping point cloud map, code: " << status.code
              << ", message: " << status.message << std::endl;
    return;
  }

  std::cout << "Successfully got SLAM mapping point cloud map" << std::endl;
  std::cout << "Point cloud map - Height: " << point_cloud_map.height
```

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```
            << ", Width: " << point_cloud_map.width << std::endl;
  std::cout << "Point cloud map data size: " << point_cloud_map.data.size() << " bytes
↪" << std::endl;
}

void CloseSlam() {
  auto& controller = robot.GetSlamNavController();

  auto status = controller.ActivateSlamMode(SlamMode::IDLE, "", 10000);
  if (status.code != ErrorCode::OK) {
    std::cerr << "Failed to close SLAM, code: " << status.code
              << ", message: " << status.message << std::endl;
    return;
  }

  current_slam_mode = SlamMode::IDLE;
  std::cout << "Successfully closed SLAM system" << std::endl;
}

int main(int argc, char* argv[]) {
  // Bind signal handler
  signal(SIGINT, SignalHandler);

  std::cout << "\n========================================" << std::endl;
  std::cout << "MagicBot Z1 SDK SLAM Example" << std::endl;
  std::cout << "SDK Version: " << SDK_VERSION_STRING << std::endl;
  std::cout << "========================================\n"
            << std::endl;

  PrintHelp();
  std::cout << "Press any key to continue (ESC to exit)..." << std::endl;

  // Configure local IP address for direct network connection and initialize SDK
  std::string local_ip = "192.168.54.111";
  if (!robot.Initialize(local_ip)) {
    std::cerr << "Failed to initialize robot SDK" << std::endl;
    robot.Shutdown();
    return -1;
  }
```

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```
// Connect to robot
auto status = robot.Connect();
if (status.code != ErrorCode::OK) {
  std::cerr << "Failed to connect to robot, code: " << status.code
            << ", message: " << status.message << std::endl;
  robot.Shutdown();
  return -1;
}
std::cout << "Successfully connected to robot" << std::endl;

// Switch motion control controller to high-level controller
status = robot.SetMotionControlLevel(ControllerLevel::HighLevel);
if (status.code != ErrorCode::OK) {
  std::cerr << "Failed to switch robot motion control level, code: " << status.code
            << ", message: " << status.message << std::endl;
  robot.Shutdown();
  return -1;
}

// Initialize SLAM navigation controller
auto& slam_nav_controller = robot.GetSlamNavController();
if (!slam_nav_controller.Initialize()) {
  std::cerr << "Failed to initialize SLAM navigation controller" << std::endl;
  robot.Disconnect();
  robot.Shutdown();
  return -1;
}
std::cout << "Successfully initialized SLAM navigation controller" << std::endl;

// Main loop
while (running) {
  int key = getch();

  if (key == 27) {  // ESC key
    std::cout << "ESC key pressed, exiting..." << std::endl;
    break;
  }

  switch (key) {
    case '0':
```

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```
        RecoveryStand();
        break;
      case '1':
        SwitchToMappingMode();
        break;
      case '2':
        StartMapping();
        break;
      case '3':
        CancelMapping();
        break;
      case '4':
        SaveMap();
        break;
      case '5': {
        std::string map_name = GetUserInput("Enter map name to load: ");
        LoadMap(map_name);
        break;
      }
      case '6': {
        std::string map_name = GetUserInput("Enter map name to delete: ");
        DeleteMap(map_name);
        break;
      }
      case '7':
        GetAllMapInfo();
        break;
      case '8': {
        std::string map_name = GetUserInput("Enter map name to get path: ");
        GetMapPath(map_name);
        break;
      }
      case '9':
        GetPointCloudMap();
        break;
      case 'p':
      case 'P':
        CloseSlam();
        break;
      case '?':
```

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```
        PrintHelp();
        break;
      default:
        std::cout << "Unknown key: " << static_cast<char>(key) << std::endl;
        break;
    }

    usleep(10000);  // 10ms delay
  }

  // Cleanup resources
  std::cout << "Clean up resources" << std::endl;

  slam_nav_controller.Shutdown();
  std::cout << "SLAM navigation controller closed" << std::endl;

  robot.Disconnect();
  std::cout << "Robot connection disconnected" << std::endl;

  robot.Shutdown();
  std::cout << "Robot shutdown" << std::endl;

  return 0;
}
```

26.1.2 Navigation Example

```
#include "magic_robot.h"
#include "magic_sdk_version.h"

#include <termios.h>
#include <unistd.h>
#include <atomic>
#include <csignal>
#include <ctime>
#include <iostream>
#include <sstream>
#include <string>

using namespace magic::z1;
```

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```
magic::z1::MagicRobot robot;
bool running = true;
SlamMode current_slam_mode = SlamMode::IDLE;
NavMode current_nav_mode = NavMode::IDLE;
std::atomic<int> odometry_counter{0};

void SignalHandler(int signum) {
  std::cout << "Received interrupt signal (" << signum << "), exiting..." <<␣
↪std::endl;
  running = false;
  robot.Shutdown();
  exit(signum);
}

void PrintHelp() {
  std::cout << "\n========================================" << std::endl;
  std::cout << "SLAM and Navigation Function Demo Program" << std::endl;
  std::cout << "========================================" << std::endl;
  std::cout << "\npreparation Functions:" << std::endl;
  std::cout << "  Q        Function Q: Recovery stand" << std::endl;
  std::cout << "  W        Function W: Balance stand" << std::endl;
  std::cout << "  E        Function E: Get map path (input map name)" << std::endl;
  std::cout << "\nLocalization Functions:" << std::endl;
  std::cout << "  1        Function 1: Switch to localization mode (input map path)" <
↪< std::endl;
  std::cout << "  2        Function 2: Initialize pose (input x y yaw)" << std::endl;
  std::cout << "  3        Function 3: Get current pose information" << std::endl;
  std::cout << "\nNavigation Functions:" << std::endl;
  std::cout << "  4        Function 4: Switch to navigation mode (input map path)" <<␣
↪std::endl;
  std::cout << "  5        Function 5: Set navigation target goal (input x y yaw)" <<␣
↪std::endl;
  std::cout << "  6        Function 6: Pause navigation" << std::endl;
  std::cout << "  7        Function 7: Resume navigation" << std::endl;
  std::cout << "  8        Function 8: Cancel navigation" << std::endl;
  std::cout << "  9        Function 9: Get navigation status" << std::endl;
  std::cout << "\nOdometry Functions:" << std::endl;
  std::cout << "  Z        Function Z: Open odometry stream" << std::endl;
  std::cout << "  X        Function X: Close odometry stream" << std::endl;
```

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```
  std::cout << "  C        Function C: Subscribe odometry stream" << std::endl;
  std::cout << "  V        Function V: Unsubscribe odometry stream" << std::endl;
  std::cout << "\nClose Functions:" << std::endl;
  std::cout << "  P        Function P: Close SLAM" << std::endl;
  std::cout << "  L        Function L: Close navigation" << std::endl;
  std::cout << "\n  ?        Function ?: Print help" << std::endl;
  std::cout << "  ESC      Exit program" << std::endl;
  std::cout << "========================================\n"
            << std::endl;
}

int getch() {
  struct termios oldt, newt;
  int ch;
  tcgetattr(STDIN_FILENO, &oldt);
  newt = oldt;
  newt.c_lflag &= ~(ICANON | ECHO);
  tcsetattr(STDIN_FILENO, TCSANOW, &newt);
  ch = getchar();
  tcsetattr(STDIN_FILENO, TCSANOW, &oldt);
  return ch;
}

std::string GetUserInput(const std::string& prompt) {
  std::cout << prompt;
  std::string input;
  std::getline(std::cin, input);
  return input;
}

void RecoveryStand() {
  std::cout << "=== Executing Recovery Stand ===" << std::endl;
  auto& controller = robot.GetHighLevelMotionController();

  auto status = controller.SetGait(GaitMode::GAIT_RECOVERY_STAND, 10000);
  if (status.code != ErrorCode::OK) {
    std::cerr << "Failed to set robot gait, code: " << status.code
              << ", message: " << status.message << std::endl;
    return;
  }
```

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```
  std::cout << "Successfully executed recovery stand" << std::endl;
}

void BalanceStand() {
  std::cout << "=== Executing Balance Stand ===" << std::endl;
  auto& controller = robot.GetHighLevelMotionController();

  auto status = controller.SetGait(GaitMode::GAIT_BALANCE_STAND, 10000);
  if (status.code != ErrorCode::OK) {
    std::cerr << "Failed to set robot gait, code: " << status.code
              << ", message: " << status.message << std::endl;
    return;
  }
  std::cout << "Successfully executed balance stand" << std::endl;
}

void GetMapPath(const std::string& map_name) {
  if (map_name.empty()) {
    std::cerr << "Map to get path is not provided" << std::endl;
    return;
  }

  auto& controller = robot.GetSlamNavController();

  std::vector<std::string> map_path;
  auto status = controller.GetMapPath(map_name, map_path, 10000);
  if (status.code != ErrorCode::OK) {
    std::cerr << "Failed to get map path, code: " << status.code
              << ", message: " << status.message << std::endl;
    return;
  }

  if (map_path.empty()) {
    std::cerr << "No map path found" << std::endl;
    return;
  }

  for (const auto& path : map_path) {
    std::cout << "Map path: " << path << std::endl;
  }
```

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```
}

void SwitchToLocalizationMode(const std::string& map_path) {
  auto& controller = robot.GetSlamNavController();

  auto status = controller.ActivateSlamMode(SlamMode::LOCALIZATION, map_path, 10000);
  if (status.code != ErrorCode::OK) {
    std::cerr << "Failed to switch to localization mode, code: " << status.code
              << ", message: " << status.message << std::endl;
    return;
  }

  current_slam_mode = SlamMode::LOCALIZATION;
  std::cout << "Successfully switched to localization mode" << std::endl;
  std::cout << "Robot is now in localization mode, ready to localize on existing maps
↪" << std::endl;
}

void InitializePose(double x, double y, double yaw) {
  auto& controller = robot.GetSlamNavController();

  Pose3DEuler initial_pose;
  initial_pose.position = {x, y, 0.0};
  initial_pose.orientation = {0.0, 0.0, yaw};

  std::cout << "Initializing robot pose to: [" << x << ", " << y << ", " << yaw << "]
↪" << std::endl;

  auto status = controller.InitPose(initial_pose, 15000);
  if (status.code != ErrorCode::OK) {
    std::cerr << "Failed to initialize pose, code: " << status.code
              << ", message: " << status.message << std::endl;
    return;
  }

  std::cout << "Successfully initialized pose" << std::endl;
  std::cout << "Robot pose has been set to [" << x << ", " << y << ", " << yaw << "]"
↪<< std::endl;
}
```

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```
void GetCurrentPoseInfo() {
  auto& controller = robot.GetSlamNavController();

  LocalizationInfo pose_info;
  auto status = controller.GetCurrentLocalizationInfo(pose_info);
  if (status.code != ErrorCode::OK) {
    std::cerr << "Failed to get current pose information, code: " << status.code
              << ", message: " << status.message << std::endl;
    return;
  }

  std::cout << "Successfully retrieved current pose information" << std::endl;
  std::cout << "Localization status: " << (pose_info.is_localization ? "Localized" :
↪"Not localized") << std::endl;
  std::cout << "Position: [" << pose_info.pose.position[0] << ", "
            << pose_info.pose.position[1] << ", "
            << pose_info.pose.position[2] << "]" << std::endl;
  std::cout << "Orientation: [" << pose_info.pose.orientation[0] << ", "
            << pose_info.pose.orientation[1] << ", "
            << pose_info.pose.orientation[2] << "]" << std::endl;
}

void SwitchToNavigationMode(const std::string& map_path) {
  auto& controller = robot.GetSlamNavController();

  auto status = controller.ActivateNavMode(NavMode::GRID_MAP, map_path, 10000);
  if (status.code != ErrorCode::OK) {
    std::cerr << "Failed to switch to navigation mode, code: " << status.code
              << ", message: " << status.message << std::endl;
    return;
  }

  current_nav_mode = NavMode::GRID_MAP;
  std::cout << "Successfully switched to navigation mode" << std::endl;
}

void SetNavigationTarget(double x, double y, double yaw) {
  auto& controller = robot.GetSlamNavController();

  NavTarget target_goal;
```

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```
  target_goal.id = 1;
  target_goal.frame_id = "map";
  target_goal.goal.position = {x, y, 0.0};
  target_goal.goal.orientation = {0.0, 0.0, yaw};

  auto status = controller.SetNavTarget(target_goal, 10000);
  if (status.code != ErrorCode::OK) {
    std::cerr << "Failed to set navigation target, code: " << status.code
              << ", message: " << status.message << std::endl;
    return;
  }

  std::cout << "Successfully set navigation target: position=(" << x << ", " << y <<
↪", 0.0), "
            << "orientation=(0.0, 0.0, " << yaw << ")" << std::endl;
}

void PauseNavigation() {
  auto& controller = robot.GetSlamNavController();

  auto status = controller.PauseNavTask();
  if (status.code != ErrorCode::OK) {
    std::cerr << "Failed to pause navigation, code: " << status.code
              << ", message: " << status.message << std::endl;
    return;
  }

  std::cout << "Successfully paused navigation" << std::endl;
}

void ResumeNavigation() {
  auto& controller = robot.GetSlamNavController();

  auto status = controller.ResumeNavTask();
  if (status.code != ErrorCode::OK) {
    std::cerr << "Failed to resume navigation, code: " << status.code
              << ", message: " << status.message << std::endl;
    return;
  }
```

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```
  std::cout << "Successfully resumed navigation" << std::endl;
}

void CancelNavigation() {
  auto& controller = robot.GetSlamNavController();

  auto status = controller.CancelNavTask();
  if (status.code != ErrorCode::OK) {
    std::cerr << "Failed to cancel navigation, code: " << status.code
              << ", message: " << status.message << std::endl;
    return;
  }

  std::cout << "Successfully cancelled navigation" << std::endl;
}

void GetNavigationStatus() {
  auto& controller = robot.GetSlamNavController();

  NavStatus nav_status;
  auto status = controller.GetNavTaskStatus(nav_status);
  if (status.code != ErrorCode::OK) {
    std::cerr << "Failed to get navigation status, code: " << status.code
              << ", message: " << status.message << std::endl;
    return;
  }

  std::cout << "=== Navigation Status ===" << std::endl;
  std::cout << "Target ID: " << nav_status.id << std::endl;
  std::cout << "Status: " << static_cast<int>(nav_status.status) << std::endl;
  std::cout << "Error code: " << nav_status.error_code << std::endl;
  std::cout << "Error description: " << nav_status.error_desc << std::endl;

  // Status interpretation
  std::string status_meaning;
  switch (nav_status.status) {
    case NavStatusType::NONE:
      status_meaning = "No navigation target set";
      break;
    case NavStatusType::RUNNING:
```

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```
      status_meaning = "Navigation is running";
      break;
    case NavStatusType::END_SUCCESS:
      status_meaning = "Navigation completed successfully";
      break;
    case NavStatusType::END_FAILED:
      status_meaning = "Navigation failed";
      break;
    case NavStatusType::PAUSE:
      status_meaning = "Navigation is paused";
      break;
    case NavStatusType::CONTINUE:
      status_meaning = "Navigation resumed from pause";
      break;
    case NavStatusType::CANCEL:
      status_meaning = "Navigation was cancelled";
      break;
    default:
      status_meaning = "Unknown status";
      break;
  }

  std::cout << "Status meaning: " << status_meaning << std::endl;
  std::cout << "========================" << std::endl;
}

void OpenOdometryStream() {
  auto& controller = robot.GetSlamNavController();

  auto status = controller.OpenOdometryStream();
  if (status.code != ErrorCode::OK) {
    std::cerr << "Failed to open odometry stream, code: " << status.code
              << ", message: " << status.message << std::endl;
    return;
  }

  std::cout << "Successfully opened odometry stream" << std::endl;
}

void CloseOdometryStream() {
```

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```
  auto& controller = robot.GetSlamNavController();

  auto status = controller.CloseOdometryStream();
  if (status.code != ErrorCode::OK) {
    std::cerr << "Failed to close odometry stream, code: " << status.code
              << ", message: " << status.message << std::endl;
    return;
  }

  std::cout << "Successfully closed odometry stream" << std::endl;
}

void SubscribeOdometryStream() {
  auto& controller = robot.GetSlamNavController();

  auto callback = [](const std::shared_ptr<Odometry> odometry) {
    if (odometry_counter % 30 == 0) {
      std::cout << "Odometry position: " << odometry->position[0] << ", "
                << odometry->position[1] << ", " << odometry->position[2] <<␣
↪std::endl;
      std::cout << "Odometry orientation: " << odometry->orientation[0] << ", "
                << odometry->orientation[1] << ", " << odometry->orientation[2] << ",
↪"
                << odometry->orientation[3] << std::endl;
      std::cout << "Odometry linear velocity: " << odometry->linear_velocity[0] << ",
↪"
                << odometry->linear_velocity[1] << ", " << odometry->linear_
↪velocity[2] << std::endl;
      std::cout << "Odometry angular velocity: " << odometry->angular_velocity[0] <<
↪", "
                << odometry->angular_velocity[1] << ", " << odometry->angular_
↪velocity[2] << std::endl;
    }
    odometry_counter++;
  };

  controller.SubscribeOdometry(callback);
  std::cout << "Successfully subscribed odometry stream" << std::endl;
}
```

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```
void UnsubscribeOdometryStream() {
  auto& controller = robot.GetSlamNavController();

  controller.UnsubscribeOdometry();
  std::cout << "Successfully unsubscribed odometry stream" << std::endl;
}

void CloseSlam() {
  auto& controller = robot.GetSlamNavController();

  auto status = controller.ActivateSlamMode(SlamMode::IDLE, "", 10000);
  if (status.code != ErrorCode::OK) {
    std::cerr << "Failed to close SLAM, code: " << status.code
              << ", message: " << status.message << std::endl;
    return;
  }

  current_slam_mode = SlamMode::IDLE;
  std::cout << "Successfully closed SLAM system" << std::endl;
}

void CloseNavigation() {
  auto& controller = robot.GetSlamNavController();

  auto status = controller.ActivateNavMode(NavMode::IDLE, "", 10000);
  if (status.code != ErrorCode::OK) {
    std::cerr << "Failed to close navigation, code: " << status.code
              << ", message: " << status.message << std::endl;
    return;
  }

  current_nav_mode = NavMode::IDLE;
  std::cout << "Successfully closed navigation system" << std::endl;
}

int main(int argc, char* argv[]) {
  // Bind signal handler
  signal(SIGINT, SignalHandler);

  std::cout << "\n========================================" << std::endl;
```

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```
  std::cout << "MagicBot Z1 SDK Navigation Example" << std::endl;
  std::cout << "SDK Version: " << SDK_VERSION_STRING << std::endl;
  std::cout << "========================================\n"
            << std::endl;

  PrintHelp();
  std::cout << "Press any key to continue (ESC to exit)..." << std::endl;

  // Configure local IP address for direct network connection and initialize SDK
  std::string local_ip = "192.168.54.111";
  if (!robot.Initialize(local_ip)) {
    std::cerr << "Failed to initialize robot SDK" << std::endl;
    robot.Shutdown();
    return -1;
  }

  // Connect to robot
  auto status = robot.Connect();
  if (status.code != ErrorCode::OK) {
    std::cerr << "Failed to connect to robot, code: " << status.code
              << ", message: " << status.message << std::endl;
    robot.Shutdown();
    return -1;
  }
  std::cout << "Successfully connected to robot" << std::endl;

  // Switch motion control controller to high-level controller
  status = robot.SetMotionControlLevel(ControllerLevel::HighLevel);
  if (status.code != ErrorCode::OK) {
    std::cerr << "Failed to switch robot motion control level, code: " << status.code
              << ", message: " << status.message << std::endl;
    robot.Shutdown();
    return -1;
  }
  std::cout << "Successfully switched robot motion control level to high-level" <<␣
↪std::endl;

  // Initialize SLAM navigation controller
  auto& slam_nav_controller = robot.GetSlamNavController();
  if (!slam_nav_controller.Initialize()) {
```

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```
    std::cerr << "Failed to initialize SLAM navigation controller" << std::endl;
    robot.Disconnect();
    robot.Shutdown();
    return -1;
}
std::cout << "Successfully initialized SLAM navigation controller" << std::endl;

// Main loop
while (running) {
    int key = getch();

    if (key == 27) {  // ESC key
        std::cout << "ESC key pressed, exiting..." << std::endl;
        break;
    }

    switch (key) {
        // 1. preparation Functions
        case 'q':
        case 'Q':
            RecoveryStand();
            break;
        case 'w':
        case 'W':
            BalanceStand();
            break;

        case 'e':
        case 'E': {
            std::string map_name = GetUserInput("Enter map name to get path: ");
            GetMapPath(map_name);
            break;
        }
        // 2. Localization Functions
        case '1': {
            std::string map_path = GetUserInput("Enter map path for localization: ");
            SwitchToLocalizationMode(map_path);
            break;
        }
        case '2': {
```

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```
        std::string input = GetUserInput("Enter pose (x y yaw): ");
        std::istringstream iss(input);
        double x = 0.0, y = 0.0, yaw = 0.0;
        iss >> x >> y >> yaw;
        std::cout << "input pose, x: " << x << ", y: " << y << ", yaw: " << yaw <<␣
↪std::endl;
        InitializePose(x, y, yaw);
        break;
      }
      case '3':
        GetCurrentPoseInfo();
        break;

      // 3. Navigation Functions
      case '4': {
        std::string map_path = GetUserInput("Enter map path for navigation: ");
        SwitchToNavigationMode(map_path);
        break;
      }
      case '5': {
        std::string input = GetUserInput("Enter target (x y yaw): ");
        std::istringstream iss(input);
        double x = 0.0, y = 0.0, yaw = 0.0;
        iss >> x >> y >> yaw;
        SetNavigationTarget(x, y, yaw);
        break;
      }
      case '6':
        PauseNavigation();
        break;
      case '7':
        ResumeNavigation();
        break;
      case '8':
        CancelNavigation();
        break;
      case '9':
        GetNavigationStatus();
        break;
      // 4. Odometry Functions
```

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```
    case 'z':
    case 'Z':
      OpenOdometryStream();
      break;
    case 'x':
    case 'X':
      CloseOdometryStream();
      break;
    case 'c':
    case 'C':
      SubscribeOdometryStream();
      break;
    case 'v':
    case 'V':
      UnsubscribeOdometryStream();
      break;
    // 5. Close Functions
    case 'l':
    case 'L':
      CloseNavigation();
      break;
    case 'p':
    case 'P':
      CloseSlam();
      break;

    case '?':
      PrintHelp();
      break;
    default:
      std::cout << "Unknown key: " << static_cast<char>(key) << std::endl;
      break;
  }

  usleep(10000);  // 10ms delay
}

// Cleanup resources
std::cout << "Clean up resources" << std::endl;
```

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```
  slam_nav_controller.Shutdown();
  std::cout << "SLAM navigation controller closed" << std::endl;

  robot.Disconnect();
  std::cout << "Robot connection disconnected" << std::endl;

  robot.Shutdown();
  std::cout << "Robot shutdown" << std::endl;

  return 0;
}
```

26.2 Python

Example files:

- `slam_example.py`
- `navigation_example.py`

Reference documentation:

- `Python API/slam_navigation_reference.md`

26.2.1 Mapping Example

```
#!/usr/bin/env python3
# -*- coding: utf-8 -*-

import sys
import time
import signal
import threading
import logging
from typing import Optional
import numpy as np
import cv2
import random
import termios
import tty

import magicbot_z1_python as magicbot
```

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```
# Configure logging format and level
logging.basicConfig(
    level=logging.INFO,  # Minimum log level
    format="%(asctime)s [%(levelname)s] %(message)s",
    datefmt="%Y-%m-%d %H:%M:%S",
)

# Global variables
robot: Optional[magicbot.MagicRobot] = None
running = True
current_slam_mode = None
current_nav_mode = magicbot.NavMode.IDLE


def signal_handler(signum, frame):
    """Signal handler function for graceful exit"""
    global running, robot
    logging.info("Received interrupt signal (%s), exiting...", signum)
    running = False
    if robot:
        robot.shutdown()
        logging.info("Robot shutdown")
    exit(-1)


def print_help():
    """Print help information"""
    logging.info("SLAM and Navigation Function Demo Program")
    logging.info("preparation Functions:")
    logging.info("  Q        Function Q: Recovery stand")
    logging.info("  E        Function E: Balance stand")
    logging.info("  W        Function W: Move forward")
    logging.info("  A        Function A: Move left")
    logging.info("  S        Function S: Move backward")
    logging.info("  D        Function D: Move right")
    logging.info("  X        Function X: Stop move")
    logging.info("  T        Function T: Turn left")
    logging.info("  G        Function G: Turn right")
    logging.info("")
```

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```
    logging.info("SLAM Functions:")
    logging.info("  1        Function 1: Switch to mapping mode")
    logging.info("  2        Function 2: Start mapping")
    logging.info("  3        Function 3: Cancel mapping")
    logging.info("  4        Function 4: Save map")
    logging.info("  5        Function 5: Load map")
    logging.info("  6        Function 6: Delete map")
    logging.info(
        "  7        Function 7: Get all map information and save map image as PGM file
↪"
    )
    logging.info("  8        Function 8: Get map path")
    logging.info("  9        Function 9: Get SLAM mapping point cloud map")
    logging.info("")
    logging.info("Close Functions:")
    logging.info("  P        Function P: Close SLAM")
    logging.info("")
    logging.info("  ?        Function ?: Print help")
    logging.info("  ESC      Exit program")


# ==================== SLAM Functions ====================


def switch_to_mapping_mode():
    """Switch to mapping mode"""
    global robot, current_slam_mode
    try:
        # Get SLAM navigation controller
        controller = robot.get_slam_nav_controller()

        # Switch to mapping mode
        status = controller.activate_slam_mode(magicbot.SlamMode.MAPPING)
        if status.code != magicbot.ErrorCode.OK:
            logging.error(
                "Failed to switch to mapping mode, code: %s, message: %s",
                status.code,
                status.message,
            )
            return
```

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```
        current_slam_mode = "MAPPING"
        logging.info("Successfully switched to mapping mode")
        logging.info("Robot is now in mapping mode, ready to create new maps")
    except Exception as e:
        logging.error("Exception occurred while switching to mapping mode: %s", e)


def load_map(map_to_load):
    """Load map"""
    global robot
    try:
        if not map_to_load:
            logging.error("Map to load is not provided")
            return
        # Get SLAM navigation controller
        controller = robot.get_slam_nav_controller()

        logging.info("Loading map: %s", map_to_load)
        controller.load_map(map_to_load)
    except Exception as e:
        logging.error("Exception occurred while loading map: %s", e)
        return

    logging.info("Successfully loaded map: %s", map_to_load)


def start_mapping():
    """Start mapping"""
    global robot
    try:
        # Get SLAM navigation controller
        controller = robot.get_slam_nav_controller()

        # Start mapping
        status = controller.start_mapping()
        if status.code != magicbot.ErrorCode.OK:
            logging.error(
                "Failed to start mapping, code: %s, message: %s",
                status.code,
```

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```
                status.message,
            )
            return

        logging.info("Successfully started mapping")
    except Exception as e:
        logging.error("Exception occurred while starting mapping: %s", e)


def cancel_mapping():
    """Cancel mapping"""
    global robot
    try:
        # Get SLAM navigation controller
        controller = robot.get_slam_nav_controller()

        # Cancel mapping
        status = controller.cancel_mapping()
        if status.code != magicbot.ErrorCode.OK:
            logging.error(
                "Failed to cancel mapping, code: %s, message: %s",
                status.code,
                status.message,
            )
            return

        logging.info("Successfully cancelled mapping")
    except Exception as e:
        logging.error("Exception occurred while cancelling mapping: %s", e)


def save_map():
    """Save map"""
    global robot, current_slam_mode
    try:
        # Get SLAM navigation controller
        controller = robot.get_slam_nav_controller()

        # Check if in mapping mode
        if current_slam_mode != "MAPPING":
```

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```
            logging.warning(
                "Warning: Currently not in mapping mode, may not be able to save map"
            )

        # Generate map name with timestamp
        map_name = f"map_{int(time.time())}"
        logging.info("Saving map: %s", map_name)

        # Save map
        status = controller.save_map(map_name, 20000)
        if status.code != magicbot.ErrorCode.OK:
            logging.error(
                "Failed to save map, code: %s, message: %s",
                status.code,
                status.message,
            )
            return

        logging.info("Successfully saved map: %s", map_name)
    except Exception as e:
        logging.error("Exception occurred while saving map: %s", e)


def delete_map(map_to_delete):
    """Delete map"""
    global robot
    try:
        if not map_to_delete:
            logging.error("Map to delete is not provided")
            return
        # Get SLAM navigation controller
        controller = robot.get_slam_nav_controller()

        # Delete the first map as an example
        logging.info("Deleting map: %s", map_to_delete)

        # Delete map
        status = controller.delete_map(map_to_delete)
        if status.code != magicbot.ErrorCode.OK:
            logging.error(
```

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```
                "Failed to delete map, code: %s, message: %s",
                status.code,
                status.message,
            )
            return

        logging.info("Successfully deleted map: %s", map_to_delete)
    except Exception as e:
        logging.error("Exception occurred while deleting map: %s", e)


def get_all_map_info():
    """Get all map information"""
    global robot
    try:
        # Get SLAM navigation controller
        controller = robot.get_slam_nav_controller()

        # Get all map information
        status, all_map_info = controller.get_all_map_info()
        if status.code != magicbot.ErrorCode.OK:
            logging.error(
                "Failed to get map information, code: %s, message: %s",
                status.code,
                status.message,
            )
            return

        logging.info("Successfully retrieved map information")
        logging.info("Current map: %s", all_map_info.current_map_name)
        logging.info("Total maps: %d", len(all_map_info.map_infos))

        if all_map_info.map_infos:
            logging.info("Map details:")
            for i, map_info in enumerate(all_map_info.map_infos):
                logging.info("  Map %d: %s", i + 1, map_info.map_name)
                logging.info(
                    "    Origin: [%f, %f, %f]",
                    map_info.map_meta_data.origin.position[0],
                    map_info.map_meta_data.origin.position[1],
```

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```
                    map_info.map_meta_data.origin.position[2],
                )
                logging.info(
                    "    Orientation: [%f, %f, %f]",
                    map_info.map_meta_data.origin.orientation[0],
                    map_info.map_meta_data.origin.orientation[1],
                    map_info.map_meta_data.origin.orientation[2],
                )
                logging.info(
                    "    Resolution: %f m/pixel", map_info.map_meta_data.resolution
                )
                logging.info(
                    "    Size: %d x %d",
                    map_info.map_meta_data.map_image_data.width,
                    map_info.map_meta_data.map_image_data.height,
                )
                logging.info(
                    "    Max gray value: %d",
                    map_info.map_meta_data.map_image_data.max_gray_value,
                )
                logging.info(
                    "    Image type: %s", map_info.map_meta_data.map_image_data.type
                )

                save_map_image_to_file(map_info)

        else:
            logging.info("No available maps")
    except Exception as e:
        logging.error("Exception occurred while getting map information: %s", e)


def save_map_image_to_file(map_info):
    """Save map image to current directory"""
    try:
        # Extract image data
        map_data = map_info.map_meta_data.map_image_data
        width = map_data.width
        height = map_data.height
        max_gray_value = map_data.max_gray_value
```

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```
        image_bytes = map_data.image

        logging.info(
            "Saving map image: %dx%d, max_gray: %d", width, height, max_gray_value
        )

        # Convert bytes to numpy array
        if len(image_bytes) != width * height:
            logging.error(
                "Image data size mismatch: expected %d, got %d",
                width * height,
                len(image_bytes),
            )
            return

        # Convert Uint8Vector to bytes for numpy processing
        try:
            # Try to convert Uint8Vector to bytes
            if hasattr(image_bytes, "__iter__") and not isinstance(
                image_bytes, (str, bytes)
            ):
                # Convert Uint8Vector or similar iterable to bytes
                image_bytes_data = bytes(image_bytes)
            else:
                image_bytes_data = image_bytes
        except Exception as e:
            logging.error("Failed to convert image data to bytes: %s", e)
            return

        # Create numpy array from image data
        image_array = np.frombuffer(image_bytes_data, dtype=np.uint8).reshape(
            (height, width)
        )

        # Generate filename based on map name
        safe_filename = "".join(
            c for c in map_info.map_name if c.isalnum() or c in (" ", "-", "_")
        ).rstrip()
        safe_filename = safe_filename.replace(" ", "_")
        if not safe_filename:
```

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```
            safe_filename = f"map_{int(time.time())}"

        # Save as PGM format using OpenCV
        pgm_filename = f"build/{safe_filename}.pgm"
        success = cv2.imwrite(pgm_filename, image_array)

        if success:
            logging.info("Map image saved successfully as PGM: %s", pgm_filename)
        else:
            logging.error("Failed to save map image as PGM: %s", pgm_filename)

    except ImportError:
        logging.error("OpenCV not available, cannot save image")
        logging.info(
            "Image data: %dx%d pixels, %d bytes", width, height, len(image_bytes)
        )
    except Exception as e:
        logging.error("Exception occurred while saving map image: %s", e)


def get_map_path(map_to_get_path):
    """Get map path"""
    global robot
    try:
        if not map_to_get_path:
            logging.error("Map to get path is not provided")
            return
        # Get SLAM navigation controller
        controller = robot.get_slam_nav_controller()

        # Get map path
        status, map_path = controller.get_map_path(map_to_get_path)
        if status.code != magicbot.ErrorCode.OK:
            logging.error(
                "Failed to get map path, code: %s, message: %s",
                status.code,
                status.message,
            )
            return
        if len(map_path) == 0:
```

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```
            logging.error("No map path found")
            return

        for path in map_path:
            logging.info("Map path: %s", path)
    except Exception as e:
        logging.error("Exception occurred while getting map path: %s", e)
        return


def get_point_cloud_map():
    """Get SLAM mapping point cloud map"""
    global robot
    try:
        # Get SLAM navigation controller
        controller = robot.get_slam_nav_controller()

        # Get SLAM mapping point cloud map
        status, point_cloud_map = controller.get_point_cloud_map()
        if status.code != magicbot.ErrorCode.OK:
            logging.error(
                "Failed to get SLAM mapping point cloud map, code: %s, message: %s",
                status.code,
                status.message,
            )
            return
        logging.info("Successfully got SLAM mapping point cloud map")

        if point_cloud_map:
            logging.info(
                "Point cloud map - Height: %d, Width: %d, Data size: %d bytes",
                point_cloud_map.height,
                point_cloud_map.width,
                len(point_cloud_map.data),
            )

    except Exception as e:
        logging.error(
            "Exception occurred while getting SLAM mapping point cloud map: %s",
            e,
```

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```
        )


def close_slam():
    """Close SLAM system"""
    global robot, current_slam_mode
    try:
        # Get SLAM navigation controller
        controller = robot.get_slam_nav_controller()

        # Switch to idle mode to close SLAM
        status = controller.activate_slam_mode(magicbot.SlamMode.IDLE)
        if status.code != magicbot.ErrorCode.OK:
            logging.error(
                "Failed to close SLAM, code: %s, message: %s",
                status.code,
                status.message,
            )
            return

        current_slam_mode = "IDLE"
        logging.info("Successfully closed SLAM system")
    except Exception as e:
        logging.error("Exception occurred while closing SLAM: %s", e)


def recovery_stand():
    """Recovery stand"""
    global robot
    try:
        logging.info("=== Executing Recovery Stand ===")
        controller = robot.get_high_level_motion_controller()
        status = controller.set_gait(magicbot.GaitMode.GAIT_RECOVERY_STAND, 10000)
        if status.code != magicbot.ErrorCode.OK:
            logging.error(
                "Failed to set robot gait, code: %s, message: %s",
                status.code,
                status.message,
            )
            return
```

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```
        logging.info("Successfully executed recovery stand")
        return
    except Exception as e:
        logging.error("Exception occurred while executing recovery stand: %s", e)
        return


def balance_stand():
    """Balance stand"""
    global robot
    try:
        logging.info("=== Executing Balance Stand ===")

        # Get high-level motion controller
        controller = robot.get_high_level_motion_controller()

        # Set gait to balance stand
        status = controller.set_gait(magicbot.GaitMode.GAIT_BALANCE_STAND, 10000)
        if status.code != magicbot.ErrorCode.OK:
            logging.error(
                "Failed to set robot gait, code: %s, message: %s",
                status.code,
                status.message,
            )
            return False

        logging.info("Robot gait set to balance stand (supports movement)")
        return True

    except Exception as e:
        logging.error("Exception occurred while executing balance stand: %s", e)
        return False


def joystick_command(left_x_axis, left_y_axis, right_x_axis, right_y_axis):
    """Send joystick control command"""
    global robot
    try:
        # Get high-level motion controller
```

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```
        controller = robot.get_high_level_motion_controller()

        # Create joystick command
        joy_command = magicbot.JoystickCommand()
        joy_command.left_x_axis = left_x_axis
        joy_command.left_y_axis = left_y_axis
        joy_command.right_x_axis = right_x_axis
        joy_command.right_y_axis = right_y_axis

        # Send joystick command
        controller.send_joystick_command(joy_command)
    except Exception as e:
        logging.error("Exception occurred while sending joystick command: %s", e)


def move_forward():
    """Move forward"""
    logging.info("=== Moving Forward ===")
    return joystick_command(0.0, 1.0, 0.0, 0.0)


def move_backward():
    """Move backward"""
    logging.info("=== Moving Backward ===")
    return joystick_command(0.0, -1.0, 0.0, 0.0)


def move_left():
    """Move left"""
    logging.info("=== Moving Left ===")
    return joystick_command(-1.0, 0.0, 0.0, 0.0)


def move_right():
    """Move right"""
    logging.info("=== Moving Right ===")
    return joystick_command(1.0, 0.0, 0.0, 0.0)


def turn_left():
```

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```
    """Turn left"""
    logging.info("=== Turning Left ===")
    return joystick_command(0.0, 0.0, -1.0, 0.0)


def turn_right():
    """Turn right"""
    logging.info("=== Turning Right ===")
    return joystick_command(0.0, 0.0, 1.0, 0.0)


def stop_move():
    """Stop move"""
    logging.info("=== Stopping Move ===")
    return joystick_command(0.0, 0.0, 0.0, 0.0)


# ==================== Utility Functions ====================


# Get single character input (no echo)
def getch():
    fd = sys.stdin.fileno()
    old_settings = termios.tcgetattr(fd)
    try:
        tty.setraw(sys.stdin.fileno())
        ch = sys.stdin.read(1)
        logging.info(f"Received character: {ch}")

        sys.stdout.write("\r")
        sys.stdout.flush()
    finally:
        termios.tcsetattr(fd, termios.TCSADRAIN, old_settings)
    return ch


def get_user_input():
    """Get user input - Read a single line of data"""
    try:
        # Method 1: Read a line using input() (recommended)
```

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```
        return input("Enter command: ").strip()
    except (EOFError, KeyboardInterrupt):
        return ""


def main():
    """Main function"""
    global robot, running

    # Bind signal handler
    signal.signal(signal.SIGINT, signal_handler)

    logging.info("Robot model: %s", magicbot.get_robot_model())

    # Create robot instance
    robot = magicbot.MagicRobot()

    print_help()
    logging.info("Press any key to continue (ESC to exit)...")

    try:
        # Configure local IP address for direct network connection and initialize SDK
        local_ip = "192.168.54.111"
        if not robot.initialize(local_ip):
            logging.error("Failed to initialize robot SDK")
            robot.shutdown()
            return -1

        # Connect to robot
        status = robot.connect()
        if status.code != magicbot.ErrorCode.OK:
            logging.error(
                "Failed to connect to robot, code: %s, message: %s",
                status.code,
                status.message,
            )
            robot.shutdown()
            return -1

        logging.info("Successfully connected to robot")
```

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```
        # Switch motion control controller to high-level controller
        status = robot.set_motion_control_level(magicbot.ControllerLevel.HighLevel)
        if status.code != magicbot.ErrorCode.OK:
            logging.error(
                "Failed to switch robot motion control level, code: %s, message: %s",
                status.code,
                status.message,
            )
            robot.shutdown()
            return -1

        # Initialize SLAM navigation controller
        slam_nav_controller = robot.get_slam_nav_controller()
        if not slam_nav_controller.initialize():
            logging.error("Failed to initialize SLAM navigation controller")
            robot.disconnect()
            robot.shutdown()
            return -1

        logging.info("Successfully initialized SLAM navigation controller")

        # Main loop
        while running:
            try:
                key = getch()
                if key == "\x1b":  # ESC key
                    break

                # 1. Preparation Functions
                # 1.1 Execute recovery stand first. Two mapping methods: 1) Suspended␣
↪in air, can push robot for mapping in recovery_stand state; 2) Switch to balance_
↪stand state for remote-controlled mapping
                if key.upper() == "Q":
                    recovery_stand()
                elif key.upper() == "E":
                    balance_stand()
                elif key.upper() == "W":
                    move_forward()
                elif key.upper() == "A":
```

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```
            move_left()
        elif key.upper() == "S":
            move_backward()
        elif key.upper() == "D":
            move_right()
        elif key.upper() == "X":
            stop_move()
        elif key.upper() == "T":
            turn_left()
        elif key.upper() == "G":
            turn_right()
        # 2. Mapping Mode
        # 2.1 Switch to mapping mode
        elif key == "1":
            switch_to_mapping_mode()
        # 2.2 Start mapping
        elif key == "2":
            start_mapping()
        # 2.3 Cancel mapping
        elif key == "3":
            cancel_mapping()
        # 2.4 Save map
        elif key == "4":
            save_map()
        # 2.5 Load map
        elif key == "5":
            str_input = get_user_input()
            # Split input parameters by space
            parts = str_input.strip().split()
            # Parse parameters
            map_to_load = parts[0] if parts else ""
            load_map(map_to_load)
        # 2.6 Delete map
        elif key == "6":
            str_input = get_user_input()
            # Split input parameters by space
            parts = str_input.strip().split()
            # Parse parameters
            map_to_delete = parts[0] if parts else ""
            delete_map(map_to_delete)
```

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```
                # 2.7 Get all map information
                elif key == "7":
                    get_all_map_info()
                # 2.8 Get map path
                elif key.upper() == "8":
                    str_input = get_user_input()
                    # Split input parameters by space
                    parts = str_input.strip().split()
                    # Parse parameters
                    map_to_get_path = parts[0] if parts else ""
                    get_map_path(map_to_get_path)
                # 2.9 Get SLAM mapping point cloud map
                elif key.upper() == "9":
                    get_point_cloud_map()
                # 3. Close Functions
                # 3.1 Close SLAM
                elif key.upper() == "P":
                    close_slam()
                elif key.upper() == "?":
                    print_help()
                else:
                    logging.warning("Unknown key: %s", key)

                time.sleep(0.01)  # Brief delay

            except KeyboardInterrupt:
                break
            except Exception as e:
                logging.error("Exception occurred while processing user input: %s", e)
    except Exception as e:
        logging.error("Exception occurred during program execution: %s", e)
        return -1

    finally:
        # Clean up resources
        try:
            logging.info("Clean up resources")
            # Close SLAM navigation controller
            slam_nav_controller = robot.get_slam_nav_controller()
            slam_nav_controller.shutdown()
```

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```
            logging.info("SLAM navigation controller closed")

            # Disconnect
            robot.disconnect()
            logging.info("Robot connection disconnected")

            # Shutdown robot
            robot.shutdown()
            logging.info("Robot shutdown")

        except Exception as e:
            logging.error("Exception occurred while cleaning up resources: %s", e)


if __name__ == "__main__":
    sys.exit(main())
```

26.2.2 Navigation Example

```
#!/usr/bin/env python3
# -*- coding: utf-8 -*-

import sys
import time
import signal
import threading
import logging
from typing import Optional
import numpy as np
import cv2
import random

import magicbot_z1_python as magicbot

# Configure logging format and level
logging.basicConfig(
    level=logging.INFO,  # Minimum log level
    format="%(asctime)s [%(levelname)s] %(message)s",
    datefmt="%Y-%m-%d %H:%M:%S",
)
```

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```
# Global variables
robot: Optional[magicbot.MagicRobot] = None
running = True
current_slam_mode = None
current_nav_mode = magicbot.NavMode.IDLE
odometry_counter = 0


def signal_handler(signum, frame):
    """Signal handler function for graceful exit"""
    global running, robot
    logging.info("Received interrupt signal (%s), exiting...", signum)
    running = False
    if robot:
        robot.shutdown()
        logging.info("Robot shutdown")
    exit(-1)


def print_help():
    """Print help information"""
    logging.info("SLAM and Navigation Function Demo Program")
    logging.info("")
    logging.info("preparation Functions:")
    logging.info("  Q        Function Q: Recovery stand")
    logging.info("  W        Function W: Balance stand")
    logging.info("  E        Function E: Get map path")
    logging.info("")
    logging.info("Localization Functions:")
    logging.info("  1        Function 1: Switch to localization mode")
    logging.info("  2        Function 2: Initialize pose")
    logging.info("  3        Function 3: Get current pose information")
    logging.info("")
    logging.info("Navigation Functions:")
    logging.info("  4        Function 4: Switch to navigation mode")
    logging.info("  5        Function 5: Set navigation target goal")
    logging.info("  6        Function 6: Pause navigation")
    logging.info("  7        Function 7: Resume navigation")
    logging.info("  8        Function 8: Cancel navigation")
```

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```
    logging.info("  9        Function 9: Get navigation status")
    logging.info("")
    logging.info("Odometry Functions:")
    logging.info("  Z        Function Z: Open odometry stream")
    logging.info("  X        Function X: Close odometry stream")
    logging.info("  C        Function C: Subscribe odometry stream")
    logging.info("  V        Function V: Unsubscribe odometry stream")
    logging.info("")
    logging.info("Close Functions:")
    logging.info("  P        Function P: Close SLAM")
    logging.info("  L        Function L: Close navigation")
    logging.info("")
    logging.info("  ?        Function ?: Print help")
    logging.info("  ESC      Exit program")


# ==================== Navigation Functions ====================
def get_map_path(map_to_get_path):
    """Get map path"""
    global robot
    try:
        if not map_to_get_path:
            logging.error("Map to get path is not provided")
            return
        # Get SLAM navigation controller
        controller = robot.get_slam_nav_controller()

        # Get map path
        status, map_path = controller.get_map_path(map_to_get_path)
        if status.code != magicbot.ErrorCode.OK:
            logging.error(
                "Failed to get map path, code: %s, message: %s",
                status.code,
                status.message,
            )
            return
        if len(map_path) == 0:
            logging.error("No map path found")
            return
```

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```
        for path in map_path:
            logging.info("Map path: %s", path)
    except Exception as e:
        logging.error("Exception occurred while getting map path: %s", e)
        return


def switch_to_localization_mode(map_path):
    """Switch to localization mode"""
    global robot, current_slam_mode
    try:
        # Get SLAM navigation controller
        controller = robot.get_slam_nav_controller()

        # Switch to localization mode
        status = controller.activate_slam_mode(magicbot.SlamMode.LOCALIZATION, map_
↪path)
        if status.code != magicbot.ErrorCode.OK:
            logging.error(
                "Failed to switch to localization mode, code: %s, message: %s",
                status.code,
                status.message,
            )
            return

        current_slam_mode = "LOCALIZATION"
        logging.info("Successfully switched to localization mode")
        logging.info(
            "Robot is now in localization mode, ready to localize on existing maps"
        )
    except Exception as e:
        logging.error("Exception occurred while switching to localization mode: %s",␣
↪e)


def initialize_pose(x, y, yaw):
    """Initialize pose"""
    global robot
    try:
        # Get SLAM navigation controller
```

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```
        controller = robot.get_slam_nav_controller()

        # Create initial pose (set to origin)
        initial_pose = magicbot.Pose3DEuler()
        initial_pose.position = [x, y, 0.0]  # x, y, z
        initial_pose.orientation = [0.0, 0.0, yaw]  # roll, pitch, yaw

        logging.info("Initializing robot pose to origin...")

        # Initialize pose
        status = controller.init_pose(initial_pose)
        if status.code != magicbot.ErrorCode.OK:
            logging.error(
                "Failed to initialize pose, code: %s, message: %s",
                status.code,
                status.message,
            )
            return

        logging.info("Successfully initialized pose")
        logging.info("Robot pose has been set to origin (0, 0, 0)")
    except Exception as e:
        logging.error("Exception occurred while initializing pose: %s", e)


def get_current_localization_info():
    """Get current pose information"""
    global robot
    try:
        # Get SLAM navigation controller
        controller = robot.get_slam_nav_controller()

        # Get current pose information
        status, pose_info = controller.get_current_localization_info()
        if status.code != magicbot.ErrorCode.OK:
            logging.error(
                "Failed to get current pose information, code: %s, message: %s",
                status.code,
                status.message,
            )
```

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```
            return

        logging.info("Successfully retrieved current pose information")
        logging.info(
            "Localization status: %s",
            "Localized" if pose_info.is_localization else "Not localized",
        )
        logging.info(
            "Position: [%.3f, %.3f, %.3f]",
            pose_info.pose.position[0],
            pose_info.pose.position[1],
            pose_info.pose.position[2],
        )
        logging.info(
            "Orientation: [%.3f, %.3f, %.3f]",
            pose_info.pose.orientation[0],
            pose_info.pose.orientation[1],
            pose_info.pose.orientation[2],
        )
    except Exception as e:
        logging.error(
            "Exception occurred while getting current pose information: %s", e
        )


def switch_to_navigation_mode(map_path):
    """Switch to navigation mode"""
    global robot, current_nav_mode
    try:
        # Get SLAM navigation controller
        controller = robot.get_slam_nav_controller()

        # Switch to navigation mode
        status = controller.activate_nav_mode(magicbot.NavMode.GRID_MAP, map_path)
        if status.code != magicbot.ErrorCode.OK:
            logging.error(
                "Failed to switch to navigation mode, code: %s, message: %s",
                status.code,
                status.message,
            )
```

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```
            return

        current_nav_mode = magicbot.NavMode.GRID_MAP
        logging.info("Successfully switched to navigation mode")
    except Exception as e:
        logging.error("Exception occurred while switching to navigation mode: %s", e)


def set_navigation_target(x, y, yaw):
    """Set navigation target goal"""
    global robot
    try:
        # Get SLAM navigation controller
        controller = robot.get_slam_nav_controller()

        # Create target goal
        target_goal = magicbot.NavTarget()
        target_goal.id = 1
        target_goal.frame_id = "map"

        # Set target pose (example: move 2 meters forward)
        target_goal.goal.position = [x, y, 0.0]
        # Set target orientation (example: no rotation)
        target_goal.goal.orientation = [0.0, 0.0, yaw]

        # Set target goal
        status = controller.set_nav_target(target_goal)
        if status.code != magicbot.ErrorCode.OK:
            logging.error(
                "Failed to set navigation target, code: %s, message: %s",
                status.code,
                status.message,
            )
            return

        logging.info(
            "Successfully set navigation target: position=(%.2f, %.2f, %.2f),␣
↪orientation=(%.2f, %.2f, %.2f)",
            target_goal.goal.position[0],
            target_goal.goal.position[1],
```

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```
            target_goal.goal.position[2],
            target_goal.goal.orientation[0],
            target_goal.goal.orientation[1],
            target_goal.goal.orientation[2],
        )
    except Exception as e:
        logging.error("Exception occurred while setting navigation target: %s", e)


def pause_navigation():
    """Pause navigation"""
    global robot
    try:
        # Get SLAM navigation controller
        controller = robot.get_slam_nav_controller()

        # Pause navigation
        status = controller.pause_nav_task()
        if status.code != magicbot.ErrorCode.OK:
            logging.error(
                "Failed to pause navigation, code: %s, message: %s",
                status.code,
                status.message,
            )
            return

        logging.info("Successfully paused navigation")
    except Exception as e:
        logging.error("Exception occurred while pausing navigation: %s", e)


def resume_navigation():
    """Resume navigation"""
    global robot
    try:
        # Get SLAM navigation controller
        controller = robot.get_slam_nav_controller()

        # Resume navigation
        status = controller.resume_nav_task()
```

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```
        if status.code != magicbot.ErrorCode.OK:
            logging.error(
                "Failed to resume navigation, code: %s, message: %s",
                status.code,
                status.message,
            )
            return

        logging.info("Successfully resumed navigation")
    except Exception as e:
        logging.error("Exception occurred while resuming navigation: %s", e)


def cancel_navigation():
    """Cancel navigation"""
    global robot
    try:
        # Get SLAM navigation controller
        controller = robot.get_slam_nav_controller()

        # Cancel navigation
        status = controller.cancel_nav_task()
        if status.code != magicbot.ErrorCode.OK:
            logging.error(
                "Failed to cancel navigation, code: %s, message: %s",
                status.code,
                status.message,
            )
            return

        logging.info("Successfully cancelled navigation")
    except Exception as e:
        logging.error("Exception occurred while cancelling navigation: %s", e)


def get_navigation_status():
    """Get current navigation status"""
    global robot
    try:
        # Get SLAM navigation controller
```

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```
        controller = robot.get_slam_nav_controller()

        # Get navigation status
        status, nav_status = controller.get_nav_task_status()
        if status.code != magicbot.ErrorCode.OK:
            logging.error(
                "Failed to get navigation status, code: %s, message: %s",
                status.code,
                status.message,
            )
            return

        # Display navigation status information
        logging.info("=== Navigation Status ===")
        logging.info("Target ID: %d", nav_status.id)
        logging.info("Status: %s", nav_status.status)
        logging.info("Error Code: %d", nav_status.error_code)
        logging.info("Error Description: %s", nav_status.error_desc)

        # Provide status interpretation
        status_meaning = {
            magicbot.NavStatusType.NONE: "No navigation target set",
            magicbot.NavStatusType.RUNNING: "Navigation is running",
            magicbot.NavStatusType.END_SUCCESS: "Navigation completed successfully",
            magicbot.NavStatusType.END_FAILED: "Navigation failed",
            magicbot.NavStatusType.PAUSE: "Navigation is paused",
            magicbot.NavStatusType.CONTINUE: "Navigation resumed from pause",
            magicbot.NavStatusType.CANCEL: "Navigation was cancelled",
        }

        if nav_status.status in status_meaning:
            logging.info("Status meaning: %s", status_meaning[nav_status.status])
        else:
            logging.warning("Unknown status value: %s", nav_status.status)

        logging.info("========================")

    except Exception as e:
        logging.error("Exception occurred while getting navigation status: %s", e)
```

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```
def close_navigation():
    """Close navigation system"""
    global robot, current_nav_mode
    try:
        # Get SLAM navigation controller
        controller = robot.get_slam_nav_controller()

        # Switch to idle mode to close navigation
        status = controller.activate_nav_mode(magicbot.NavMode.IDLE)
        if status.code != magicbot.ErrorCode.OK:
            logging.error(
                "Failed to close navigation, code: %s, message: %s",
                status.code,
                status.message,
            )
            return

        current_nav_mode = magicbot.NavMode.IDLE
        logging.info("Successfully closed navigation system")
    except Exception as e:
        logging.error("Exception occurred while closing navigation: %s", e)


def open_odometry_stream():
    """Open odometry stream"""
    global robot
    try:
        # Get SLAM navigation controller
        controller = robot.get_slam_nav_controller()

        # Open odometry stream
        status = controller.open_odometry_stream()
        if status.code != magicbot.ErrorCode.OK:
            logging.error(
                "Failed to open odometry stream, code: %s, message: %s",
                status.code,
                status.message,
            )
            return
```

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```
        logging.info("Successfully opened odometry stream")
    except Exception as e:
        logging.error("Exception occurred while opening odometry stream: %s", e)


def close_odometry_stream():
    """Close odometry stream"""
    global robot
    try:
        # Get SLAM navigation controller
        controller = robot.get_slam_nav_controller()

        # Close odometry stream
        status = controller.close_odometry_stream()
        if status.code != magicbot.ErrorCode.OK:
            logging.error(
                "Failed to close odometry stream, code: %s, message: %s",
                status.code,
                status.message,
            )
            return
        logging.info("Successfully closed odometry stream")
    except Exception as e:
        logging.error("Exception occurred while closing odometry stream: %s", e)


def subscribe_odometry_stream():
    """Subscribe odometry stream"""
    global robot
    try:
        # Get SLAM navigation controller
        controller = robot.get_slam_nav_controller()

        def callback(odometry: magicbot.Odometry):
            global odometry_counter
            if odometry_counter % 30 == 0:
                logging.info(
                    "Odometry position: %f, %f, %f",
                    odometry.position[0],
                    odometry.position[1],
```

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```
                    odometry.position[2],
                )
                logging.info(
                    "Odometry orientation: %f, %f, %f, %f",
                    odometry.orientation[0],
                    odometry.orientation[1],
                    odometry.orientation[2],
                    odometry.orientation[3],
                )
                logging.info(
                    "Odometry linear velocity: %f, %f, %f",
                    odometry.linear_velocity[0],
                    odometry.linear_velocity[1],
                    odometry.linear_velocity[2],
                )
                logging.info(
                    "Odometry angular velocity: %f, %f, %f",
                    odometry.angular_velocity[0],
                    odometry.angular_velocity[1],
                    odometry.angular_velocity[2],
                )
            odometry_counter += 1

        # Subscribe odometry stream
        controller.subscribe_odometry(callback)
        logging.info("Successfully subscribed odometry stream")
    except Exception as e:
        logging.error("Exception occurred while subscribing odometry stream: %s", e)


def unsubscribe_odometry_stream():
    """Unsubscribe odometry stream"""
    global robot
    try:
        # Get SLAM navigation controller
        controller = robot.get_slam_nav_controller()

        # Unsubscribe odometry stream
        controller.unsubscribe_odometry()
        logging.info("Successfully unsubscribed odometry stream")
```

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```
    except Exception as e:
        logging.error("Exception occurred while unsubscribing odometry stream: %s", e)


def close_slam():
    """Close SLAM system"""
    global robot, current_slam_mode
    try:
        # Get SLAM navigation controller
        controller = robot.get_slam_nav_controller()

        # Switch to idle mode to close SLAM
        status = controller.activate_slam_mode(magicbot.SlamMode.IDLE)
        if status.code != magicbot.ErrorCode.OK:
            logging.error(
                "Failed to close SLAM, code: %s, message: %s",
                status.code,
                status.message,
            )
            return

        current_slam_mode = "IDLE"
        logging.info("Successfully closed SLAM system")
    except Exception as e:
        logging.error("Exception occurred while closing SLAM: %s", e)


def recovery_stand():
    """Recovery stand"""
    global robot
    try:
        logging.info("=== Executing Recovery Stand ===")
        controller = robot.get_high_level_motion_controller()
        status = controller.set_gait(magicbot.GaitMode.GAIT_RECOVERY_STAND, 10000)
        if status.code != magicbot.ErrorCode.OK:
            logging.error(
                "Failed to set robot gait, code: %s, message: %s",
                status.code,
                status.message,
            )
```

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```
            return
        logging.info("Successfully executed recovery stand")
        return
    except Exception as e:
        logging.error("Exception occurred while executing recovery stand: %s", e)
        return


def balance_stand():
    """Balance stand"""
    global robot
    try:
        logging.info("=== Executing Balance Stand ===")
        controller = robot.get_high_level_motion_controller()
        status = controller.set_gait(magicbot.GaitMode.GAIT_BALANCE_STAND, 10000)
        if status.code != magicbot.ErrorCode.OK:
            logging.error(
                "Failed to set robot gait, code: %s, message: %s",
                status.code,
                status.message,
            )
            return
        logging.info("Successfully executed balance stand")
        return
    except Exception as e:
        logging.error("Exception occurred while executing balance stand: %s", e)
        return


# ==================== Utility Functions ====================


def get_user_input():
    """Get user input - Read a single line of data"""
    try:
        # Method 1: Read a line using input() (recommended)
        return input("Enter command: ").strip()
    except (EOFError, KeyboardInterrupt):
        return ""
```

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```
def main():
    """Main function"""
    global robot, running

    # Bind signal handler
    signal.signal(signal.SIGINT, signal_handler)

    logging.info("Robot model: %s", magicbot.get_robot_model())

    # Create robot instance
    robot = magicbot.MagicRobot()

    print_help()
    logging.info("Press any key to continue (ESC to exit)...")

    try:
        # Configure local IP address for direct network connection and initialize SDK
        local_ip = "192.168.54.111"
        if not robot.initialize(local_ip):
            logging.error("Failed to initialize robot SDK")
            robot.shutdown()
            return -1

        # Connect to robot
        status = robot.connect()
        if status.code != magicbot.ErrorCode.OK:
            logging.error(
                "Failed to connect to robot, code: %s, message: %s",
                status.code,
                status.message,
            )
            robot.shutdown()
            return -1

        logging.info("Successfully connected to robot")

        # Switch motion control controller to high-level controller
        status = robot.set_motion_control_level(magicbot.ControllerLevel.HighLevel)
        if status.code != magicbot.ErrorCode.OK:
```

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```
            logging.error(
                "Failed to switch robot motion control level, code: %s, message: %s",
                status.code,
                status.message,
            )
            robot.shutdown()
            return -1

        logging.info("Successfully switched robot motion control level to high-level")

        # Initialize SLAM navigation controller
        slam_nav_controller = robot.get_slam_nav_controller()
        if not slam_nav_controller.initialize():
            logging.error("Failed to initialize SLAM navigation controller")
            robot.disconnect()
            robot.shutdown()
            return -1

        logging.info("Successfully initialized SLAM navigation controller")

        # Main loop
        while running:
            try:
                str_input = get_user_input()

                # Split input parameters by space
                parts = str_input.strip().split()

                if not parts:
                    time.sleep(0.01)  # Brief delay
                    continue

                # Parse parameters
                key = parts[0]
                args = parts[1:] if len(parts) > 1 else []
                if key == "\x1b":  # ESC key
                    break

                # 1. Preparation
                # 1.1 Execute recovery stand first
```

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```
                if key.upper() == "Q":
                    recovery_stand()
                # 1.2 Switch to balance stand, allowing robot to transition to␣
↪walking gait
                elif key.upper() == "W":
                    balance_stand()
                # 1.3 Get current map absolute path
                elif key.upper() == "E":
                    map_to_get_path = args[0] if args else ""
                    get_map_path(map_to_get_path)
                # 2. Enable Localization Mode and Initialize Pose
                # 2.2 Based on map absolute path, enable localization mode
                elif key == "1":
                    map_path = args[0] if args else ""
                    switch_to_localization_mode(map_path)
                # 2.3 Based on current map, initialize pose
                elif key == "2":
                    x = float(args[0]) if args else 0.0
                    y = float(args[1]) if args else 0.0
                    yaw = float(args[2]) if args else 0.0
                    logging.info("input pose, x: %f, y: %f, yaw: %f", x, y, yaw)
                    initialize_pose(x, y, yaw)
                # 2.4 Get current initialized pose status, check if localization␣
↪succeeded
                elif key == "3":
                    get_current_localization_info()
                # 3. Start Navigation
                # 3.1 Based on map absolute path, enable navigation mode
                elif key.upper() == "4":
                    map_path = args[0] if args else ""
                    switch_to_navigation_mode(map_path)
                # 3.2 Input target point, start navigation task
                # Due to the lidar being installed with a -1.57rad offset relative to␣
↪the robot's front,
                # the desired yaw orientation needs to be offset by -1.57rad,␣
↪otherwise the robot's pose initialization may fail
                # Please input yaw orientation, needs to be offset by -1.57rad
                elif key.upper() == "5":
                    x = float(args[0]) if args else 0.0
                    y = float(args[1]) if args else 0.0
```

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```
            yaw = float(args[2]) if args else 0.0
            logging.info("input target, x: %f, y: %f, yaw: %f", x, y, yaw)
            set_navigation_target(x, y, yaw)
        # 3.3 Pause navigation task
        elif key.upper() == "6":
            pause_navigation()
        # 3.4 Resume navigation task
        elif key.upper() == "7":
            resume_navigation()
        # 3.5 Cancel navigation task
        elif key.upper() == "8":
            cancel_navigation()
        # 3.6 Get navigation task status
        elif key.upper() == "9":
            get_navigation_status()
        # 4. Subscribe to Odometry Data
        # 4.1 Open odometry stream
        elif key.upper() == "Z":
            open_odometry_stream()
        # 4.2 Close odometry stream
        elif key.upper() == "X":
            close_odometry_stream()
        # 4.3 Subscribe to odometry stream
        elif key.upper() == "C":
            subscribe_odometry_stream()
        # 4.4 Unsubscribe from odometry stream
        elif key.upper() == "V":
            unsubscribe_odometry_stream()
        # 5. Close SLAM and Navigation
        # 5.1 Close SLAM
        elif key.upper() == "P":
            close_slam()
        # 5.2 Close navigation
        elif key.upper() == "L":
            close_navigation()
        elif key.upper() == "?":
            print_help()
        else:
            logging.warning("Unknown key: %s", key)
```

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```
                time.sleep(0.01)  # Brief delay

            except KeyboardInterrupt:
                break
            except Exception as e:
                logging.error("Exception occurred while processing user input: %s", e)
    except Exception as e:
        logging.error("Exception occurred during program execution: %s", e)
        return -1

    finally:
        # Clean up resources
        try:
            logging.info("Clean up resources")
            # Close SLAM navigation controller
            slam_nav_controller = robot.get_slam_nav_controller()
            slam_nav_controller.shutdown()
            logging.info("SLAM navigation controller closed")

            # Disconnect
            robot.disconnect()
            logging.info("Robot connection disconnected")

            # Shutdown robot
            robot.shutdown()
            logging.info("Robot shutdown")

        except Exception as e:
            logging.error("Exception occurred while cleaning up resources: %s", e)


if __name__ == "__main__":
    sys.exit(main())
```

26.3 Running Instructions

26.3.1 Environment Setup

```
export PYTHONPATH=/opt/magic_robotics/magicbot_z1_sdk/lib:$PYTHONPATH
export LD_LIBRARY_PATH=/opt/magic_robotics/magicbot_z1_sdk/lib:$LD_LIBRARY_PATH
```

26.3.2 Run Examples

```
# C++
./slam_navigation_example
# Python
python3 slam_navigation_example.py
```

26.3.3 Control Instructions

Mapping

- Preparation Functions:
  - Press `Q` - Recovery stand
  - Press `E` - Balance stand
  - Press `W/A/S/D/X` - Forward/Left/Backward/Right/Stop
  - Press `T/G` - Turn left/Turn right
- SLAM Functions:
  - Press `1` - Switch to mapping mode
  - Press `2` - Start mapping
  - Press `3` - Cancel mapping
  - Press `4` - Save map
  - Press `5` - Load map
  - Press `6` - Delete map
  - Press `7` - Get all map information and save map image as PGM file
  - Press `8` - Get map path
  - Press `9` - Get SLAM mapping point cloud map
- Close Functions:
  - Press `P` - Close SLAM

- System Commands:
  - Press `?` - Show help information

Navigation

- Preparation Functions:
  - Press `Q` - Recovery stand
  - Press `W` - Balance stand
  - Press `E` - Get map path
- Localization Functions:
  - Press `1` - Switch to localization mode
  - Press `2` - Initialize pose
  - Press `3` - Get current position information
- Navigation Functions:
  - Press `4` - Switch to navigation mode
  - Press `5` - Set navigation target goal
  - Press `6` - Pause navigation
  - Press `7` - Resume navigation
  - Press `8` - Cancel navigation
  - Press `9` - Get navigation status
- Odometry Functions:
  - Press `Z` - Open odometry stream
  - Press `X` - Close odometry stream
  - Press `C` - Subscribe odometry stream
  - Press `V` - Unsubscribe odometry stream
- Close Functions:
  - Press `P` - Close SLAM
  - Press `L` - Close navigation
- System Commands:
  - Press `?` - Show help information

26.3.4 Stop Program

- Press `ESC` to safely stop the program
- The program will automatically clean up all resources

26.3.5 Notes

- In the mapping and navigation examples, the robot must be switched to high-level motion control mode in advance (the default control mode is high-level motion control).
- In the mapping example, the robot should be switched to Balance_stand mode in advance.
- In the mapping example, you can use `GetAllMapInfo` to get information about maps stored on the robot (including 2D map PGM, map size, resolution, etc.).
- In the mapping example, you can manage maps using `SaveMap`/`DeleteMap`. Try not to store more than 3 maps on the robot.
- In the navigation example, you need to switch the robot to Balance_stand mode first.
- In the navigation example, it's best to set navigation target points based on the current localization status and pose obtained from `GetCurrentLocalizationInfo`.
- In the navigation example, before starting navigation tasks, you need to properly switch to localization mode (`ActivateSlamMode(SlamMode::LOCALIZATION, map_path)`) and navigation mode (`ActivateNavMode(NavMode::GRID_MAP, map_path)`).
- In the navigation example, both localization mode and navigation mode switches require the absolute path of the map, which can be obtained using `GetMapPath`.
- After finishing mapping or navigation, switch SLAM to IDLE mode (`ActivateSlamMode(SlamMode::IDLE)`) and navigation to IDLE mode (`ActivateNavMode(NavMode::IDLE)`)

CHAPTER 27

FAQ

When the SDK becomes unavailable, first verify whether the SDK version meets the requirements. The SDK version tag must correspond to the robot firmware version. Refer to ChangeLog

27.1 Development Environment Preparation

Operating System: Ubuntu 22.04. For detailed setup, please refer to Quick Start.

27.2 Does Magicbot-Z1 support wireless development?

No. Magicbot-Z1 currently supports only wired connections for development.

27.3 What is the current low-level communication frequency of Magicbot-Z1?

The default reporting frequency for joint status communication at the low level is 500 Hz. The publishing frequency(Suggested frequency: 500 Hz) of joint command transmission is controlled by the user.

27.4 Unable to Subscribe and Publish Topic Data?

- Check whether the corresponding topic data stream is enabled.

  Some interfaces require calling a specific function to activate the data stream, such as calling `OpenLidar` to enable LiDAR data.

- UDP multicast configuration:

  Assuming the network interface connecting the SDK development PC and the robot is enp0s31f6, configure it as follows to ensure communication between the SDK and the robot at the low level:

```
sudo ifconfig enp0s31f6 multicast
sudo route add -net 224.0.0.0 netmask 240.0.0.0 dev enp0s31f6
```

- SDK version does not match the robot firmware version:

  The SDK version tag must correspond to the robot's firmware version. For reference, see: ChangeLog.

- Clean residual SDK configuration files:

  The SDK automatically generates its default configuration at `/tmp/magicbot_z1_mjrrt.yaml`. Under normal circumstances, this file is cleared on reboot. However, if during a single boot you first use an older version of the SDK (which generates an old configuration file in `/tmp`), and then switch to a newer SDK version, the newer SDK will still load the old configuration by default. This is because if the `magicbot_z1_mjrrt.yaml` file already exists, the SDK will not recreate it, in order to facilitate debugging. As a result, topic subscription and publication may behave incorrectly.

Finally, please note that when using subscription-type SDK interfaces such as Subscribe, avoid performing blocking operations within the callback function. Otherwise, it may lead to message backlog, processing delays, or even unexpected errors.

27.5 SDK subscription topic data rate unstable?

Check the system configuration of the socket receive buffer on the SDK host in `/etc/sysctl.conf`.Apply the changes immediately using `sysctl -p`, or reboot the host.

```
net.core.rmem_max=20971520
net.core.rmem_default=20971520
net.core.wmem_max=20971520
net.core.wmem_default=20971520
```

27.6 SDK API Call Error: Deadline Exceeded

The default timeout for internal RPC calls within the SDK APIs is 5 seconds. For certain gait or skill execution APIs, the execution time may exceed 5 seconds. If this issue occurs, you can resolve it by configuring the timeout parameter for the specific API.

27.7 How to View SDK Internal Configuration and Logs?

When the SDK program is executed, it will by default generate a configuration file at `/tmp/magicbot_z1_mjrrt.yaml` and a log file at `/tmp/logs/magicbot_z1_sdk.log`. Any internal error messages of the SDK can be checked in this log file.

27.8 Video Streaming

How to access binocular camera video stream:

```
# Wireless (requires connecting to the robot's hotspot)
ffplay rtsp://192.168.12.1:8081/
# Wired
ffplay rtsp://192.168.54.119:8081/
```

You can use ffplay for testing during demonstration. If you want to capture individual frames, you need to implement your own encoding.

27.9 SLAM Relocation Failed?

SLAM navigation via SDK differs from the App's convenient visual localization. You need to modify the SLAM configuration to fix the map orientation for easier SLAM localization:

```
# Log into the robot
ssh eame@192.168.54.119
# Modify the following configuration
# vim /opt/eame/eamegrapher_3d/share/eamegrapher_3d/config/params.yaml
align_map: false

# After modifying the yaml file for the first time, restart the SLAM module for␣
↪changes to take effect with:
sudo systemctl restart slam.service
```

27.10 SLAM Navigation Not Executing?

1. First prerequisite for SLAM navigation - enter SLAM localization mode and navigation mode:

- `ActivateSlamMode(SlamMode::LOCALIZATION, map_path)`
- `ActivateNavMode(NavMode::GRID_MAP, map_path)`

  Where map_path is the absolute path to the current map, which can be obtained via `GetMapPath`

2. Second prerequisite for SLAM navigation - successful relocation:

Use `InitPose` for relocation and call `GetCurrentLocalizationInfo` to get current relocation status. If `is_localization=true`, relocation is successful; otherwise, relocation failed - check map and relocation pose, then retry `InitPose` for localization.

3. Setting SLAM navigation target points:

Since the relocation pose set by `InitPose` is estimated, it is recommended to set target position points based on the current pose obtained from `GetCurrentLocalizationInfo`.

27.11 Runtime Error: Invalid IP address

The current robot does not support simultaneous control by an APP and SDK, nor does it support multiple SDK clients controlling the robot at the same time. If an `Invalid IP address` error occurs, please check if there are other APPs or SDK clients connected.

27.12 Log Error: `Call of pthread_setschedparam with insufficient privileges!`

The main reason for this error is that the SDK is being executed with a regular user account. This warning does not fundamentally affect program operation. To resolve this error, you need to configure the system file `/etc/security/limits.conf` for the regular user to ensure the process has permission to set thread priorities:

```
*    -   rtprio   98
```

27.13 connect Error: `Failed to connect to robot, code: ErrorCode.SERVICE_ERROR, message: failed to connect to all addresses; last error: UNKNOWN: ipv4:192.168.54.119:50051: Failed to connect to remote host: Connection refused`

1. Unable to ping `192.168.54.119`:

- Network cable connection problem, check hardware connections.
- The compute box IP configuration is not in the `192.168.54.XX` subnet.

2. Robot gateway service exception:
   - Try restarting to restore normal robot software operation.

27.14 Trick Execution Error: `Failed to execute robot trick, code: ErrorCode.SERVICE_ERROR, message:` 优先级过低

Reason 1: The trick command ID called is not within the `TrickAction` enumeration range.

Reason 2: The robot needs to be on the ground and must switch to the `balance_stand` gait.

> Note: For humanoid robots, the robot must first land on the ground in the `recovery_stand` state. After landing, switch to `balance_stand`, and then you can perform tricks and other actions.

27.15 Trick Execution Error: `Failed to execute robot trick, code: ErrorCode.SERVICE_ERROR, message:` 危险动作

The possible reason for this error may be that the robot's current initial position differs greatly from the required starting position for the trick.

Solution:

- Try executing `recovery_stand` and then `balance_stand` in order to restore and retry.

27.16 Trick Execution Error: `Failed to execute robot trick, code: ErrorCode.SERVICE_ERROR, message:` 调用 ROS2 服务失败

Possible cause: There is an exception in the internal software service of the robot.

Solution:

- Restart the robot to try to recover. If restarting does not work, please contact after-sales support.