

# Baxter TM

研究版•操作手册



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# 内容提要

Baxter 机器人是总部位于波斯顿的美国 Rethink Robotics 公司推出的一款新型协作型机器人。Baxter 配备了基于 ROS(Robot Operating System)的软件开发套件 (SDK),是一个安全、经济且强大的平台。

目前全球大多数实验室和学校都配有 Baxter,该机器人广泛应用于机械手臂运动规划、 双臂柔顺协调控制、机器视觉、人机交互等领域的科研和教学活动。

此操作手册共分三个部分,分别是 Baxter 设置,工作站设置,运行示例。

Baxter 设置部分包括:硬件配置、工作空间选择、夹持器安装等。

工作站设置包括: Ubuntu 及 ROS 安装、依赖软件包安装、SDK 安装等。

运行示例包括: 使能机器人、运行示例程序。

通过使用该手册,初学者能够快速熟悉 Baxte 的基本控制和工作流程,对其软硬件有一 定初步认识。

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# 1 Baxter 设置

# 1.1 所需硬件

- Baxter 科研版机器人本体
- 1/2 英寸扳手
- 17mm 扳手
- 27mm 扳手(用于底座安装)
- 平头螺丝刀
- 电动平行夹持器或启动夹持器
- Baxter 底座
- 内六角扳手一套
- USB 键盘
- 路由器及网线

# 1.2 选择合适的工作空间

Baxter 机器人在工作时应保留足够的空间以免机械臂碰到障碍物停止运动,Baxter 工作 空间分布参考图 1.1-图 1.4。



图 1.1 Baxter 正视图



图 1.2 Baxter 俯视图



图 1.3 Baxter 侧视图

#### Top view, arms extended





# 1.3 Baxter 安装

首先参考图 1.5 选择底座安装高度。



图 1.5 Baxter 底座安装高度

然后将 Baxter 本体吊装到底座上,如图 1.6 所示。



图 1.6 吊装 Baxter

1.4 安装夹持器

## 1.4.1 安装电动夹持器

参考图 1.7-图 1.9 所示步骤。



图 1.7 安装电动夹持器基座



图 1.8 选择不同开度的手指



图 1.9 选择指端

# 1.4.2 安装气动夹持器

参考图 1.10-图 1.3 所示步骤。



图 1.10 安装气动夹持器基座



1.11 安装电磁阀



1.12 连接夹持器地线及气管



1.13 气泵通过背部气孔向机器人提供气源

# 1.5 连接急停开关及电源

Baxter 支持通用电源接口,工作电压,90-264V AC (47-63Hz),最大功耗 720W。



图 1.14 将急停开关连接至 1/0 端口

# 1.6 打开电源

至此, Baxter 机器人硬件配置已经完成, 打开背部开关后, 约 3 分钟后会显示图 1.15 的欢迎界面。



图 1.15 Baxter 科研版开机欢迎界面

# 2 工作站设置

# 2.1 安装 Ubuntu

此手册以 Ubuntu 14.04 为例。

- A)下载 Ubuntu 镜像: http://releases.ubuntu.com/trusty/ubuntu-14.04.3-desktop-amd64.iso
- B) 创建 USB 启动盘,可使用 Unetboot 或 Rufus:
  Unetboot 下载链接: <u>http://unetbootin.github.io/</u>
  Rufus 下载链接: <u>https://rufus.akeo.ie/</u>
  下面以 Rufus 为例介绍如何制作 USB 启动盘。
  1、打开 Rufus,选择 USB 设备;

	Device		×=*
	UBUNTU (F:) [4GB]		~
	Partition scheme and target system	n type	
	MBR partition scheme for BIOS or	UEFI	~
	File system		
	FAT32		~
	Cluster size		
itu-16	4096 bytes (Default)		~
	New volume label		
	UBUNTU		
	Format Options 🔽		
	Check device for bad blocks	1 Pass	~
	Quick format		
	Create a bootable disk using	FreeDOS	~ 3
	Create extended label and ico	n files	
	READ	Y	
	About Log	Start	Close

2、选择下载的 Ubuntu 镜像;

	🖋 Open			×
	← → * ↑ 🔜 > `	This PC 🔸 Desktop	✓ Ö Search Desk	top 🔎
	Organise 👻 New fo	lder		== 🕶 🛄 📀
	📃 Desktop 🛛 💉 🖊	Name	Date modified	Туре
	🕹 Downloads 🖈	iubuntu-16.04-desktop-amd64	31/03/2016 09:06	Disc Image File
untu-16	<ul> <li>Documents *</li> <li>Pictures *</li> </ul>			
	<ul> <li>00 - Angelas Doc</li> <li>01 balance sheet</li> <li>07 resume</li> <li>08 timesheets</li> <li>Dropbox</li> <li>This PC</li> </ul>			
	<ul> <li>00 - Angelas Doc</li> <li>01 balance sheet</li> <li>07 resume</li> <li>08 timesheets</li> <li>Dropbox</li> <li>This PC</li> </ul>	v c		

3、点击"Yes"下载 Syslinux 软件;

	Partition scheme and target system type
	MBR partition scheme for BIOS or UEFI
	File system
-	FAT32
0	Cluster size Download required
tu-16	4096 bytes (Defau
	New volume label       Image uses Syslinux 6.03/20151222 but this application only includes the installation files for Syslinux 6.03/2014-10-06.         Format Options       Image uses Syslinux are not compatible with one another, and it wouldn't be possible for Rufus to include them all, two additional files must be downloaded from the Internet ('Idlinux.sys' and 'Idlinux.bss'):         Create a boot       Select 'Yes' to connect to the Internet and download these files         Create extend       Note: The files will be downloaded in the current application directory and will be reused automatically if present.
	Yes No About Log Start Close

4、 点击 "OK" 以 ISO 方式写入;

Rufus 2.8.886       Image: ubuntu-16.04-desktop-amd64.iso		
Device UBUNTU (F;) [4GB] Partition scheme and target system type MBR partition scheme for BIOS or UEFI File system File system ISOHybrid image detected The image you have selected is an 'ISOHybrid' image. This means it can be written either in ISO Image (file copy) mode or DD Image (disk image) mode. Rufus recommends using ISO Image mode, so that you always have full access to the drive after writing it. However, if you encounter issues during boot, you can try writing this image again in DD Image mode. Please select the mode that you want to use to write this image: Write in ISO Image mode (Recommended) Write in DD Image mode OK Cancel Using image: ubuntu-16.04-desktop-amd64.iso #		🖋 Rufus 2.8.886 — 🗆 🗙
UBUNTU (F:) [4GB] Partition scheme and target system type MBR partition scheme for BIOS or UEFI File system ISOHybrid image detected written either in ISO Image (file copy) mode or DD Image (disk image) mode. Rufus recommends using ISO Image mode, so that you always have full access to the drive after writing it. However, if you encounter issues during boot, you can try writing this image again in DD Image mode. Please select the mode that you want to use to write this image: Write in ISO Image mode (Recommended) Write in DD Image mode OK Cancel Using image: ubuntu-16.04-desktop-amd64.iso #		Device 😥 🕫
Partition scheme and target system type MBR partition scheme for BIOS or UEFI File system ISOHybrid image detected The image you have selected is an 'ISOHybrid' image. This means it can be written either in ISO Image (file copy) mode or DD Image (disk image) mode. Rufus recommends using ISO Image mode, so that you always have full access to the drive after writing it. However, if you encounter issues during boot, you can try writing this image again in DD Image mode. Please select the mode that you want to use to write this image: Write in ISO Image mode (Recommended) Write in DD Image mode Write in DD Image mode Using image: ubuntu-16.04-desktop-amd64.iso #		UBUNTU (F:) [4GB] V
MBR partition scheme for BIOS or UEFI File system ISOHybrid image detected JSOHybrid image detected Written either in ISO Image (file copy) mode or DD Image (disk image) mode. Rufus recommends using ISO Image mode, so that you always have full access to the drive after writing it. However, if you encounter issues during boot, you can try writing this image again in DD Image mode. Please select the mode that you want to use to write this image: Write in ISO Image mode (Recommended) Write in DD Image mode OK Cancel Using image: ubuntu-16.04-desktop-amd64.iso #		Partition scheme and target system type
File system File s		MBR partition scheme for BIOS or UEFI $\sim$
ISOHybrid image detected Ubuntu-16.  ISOHybrid image detected Ubuntu-16.  ISOHybrid image detected Using image you have selected is an 'ISOHybrid' image. This means it can be written either in ISO Image (file copy) mode or DD Image (disk image) mode. Rufus recommends using ISO Image mode, so that you always have full access to the drive after writing it. However, if you encounter issues during boot, you can try writing this image again in DD Image mode. Please select the mode that you want to use to write this image:  Write in ISO Image mode (Recommended) Write in DD Image mode  OK Cancel Using image: ubuntu-16.04-desktop-amd64.iso #		File system
Abuntu-16: The image you have selected is an 'ISOHybrid' image. This means it can be written either in ISO Image (file copy) mode or DD Image (disk image) mode. Rufus recommends using ISO Image mode, so that you always have full access to the drive after writing it. However, if you encounter issues during boot, you can try writing this image again in DD Image mode. Please select the mode that you want to use to write this image: Write in ISO Image mode (Recommended) Write in DD Image mode OK Cancel About Log Start Close Using image: ubuntu-16.04-desktop-amd64.iso #	Ізонув	rid image detected
OK Cancel           OK         Cancel           Downloading: 100.0%	ubuntu-16. 🕐	The image you have selected is an 'ISOHybrid' image. This means it can be written either in ISO Image (file copy) mode or DD Image (disk image) mode. Rufus recommends using ISO Image mode, so that you always have full access to the drive after writing it. However, if you encounter issues during boot, you can try writing this image again in DD Image mode. Please select the mode that you want to use to write this image:
Downloading: 100.0%       About       Log       Start       Close       Using image: ubuntu-16.04-desktop-amd64.iso		OK Cancel
About     Log     Start     Close       Using image: ubuntu-16.04-desktop-amd64.iso     #		Downloading: 100.0%
Using image: ubuntu-16.04-desktop-amd64.iso #		About Log Start Close
		Using image: ubuntu-16.04-desktop-amd64.iso #

5、确认 USB 设备;

	🖋 Rufus 2.8.886	-	) ×		
	Device		<b>€</b> *		
	UBUNTU (F:) [4GB]		~		
	Partition scheme and target	system type			
	MBR partition scheme for BI	IOS or UEFI	$\sim$		
	File system				
	FAT32		~		
9	Cluster size				
tu-16	4096 bytes (Default)		~		
	New volume label				
	Check device for I     Quick format     Create a bootable     Create extended I	WARNING: ALL DAT DESTROYED. To continue with th	TA ON DEVICE	UBUNTU (F:) [4GB lick OK. To quit clie OK	i]' WILL BE ck CANCEL. Cancel
	Downle	oading: 100.0%	_		
	About Log	Start	Close		
	Using image: ubuntu-16.04-d	lesktop-amd64.iso #			
	Contraction of the second s				

6、写入完成后,重启电脑,选择从U盘启动。

Device Ubuntu 16.04 LTS amd64 (F:) [4GB] Partition scheme and target system type MBR partition scheme for BIOS or UEFI File system FAT32 Cluster size Cluster size Cluster size Ubuntu 16.04 LTS amd64 Format Options C Check device for bad blocks 1 Pass		🖋 Rufus 2.8.886	( <u>111</u> )	□ ×
Ubuntu 16.04 LTS amd64 (F:) [4GB]         Partition scheme and target system type         MBR partition scheme for BIOS or UEFI         File system         FAT32         Cluster size         4096 bytes (Default)         New volume label         Ubuntu 16.04 LTS amd64         Format Options C         Check device for bad blocks         1 Pass		Device		<b>€</b> *
Partition scheme and target system type         MBR partition scheme for BIOS or UEFI         File system         FAT32         Cluster size         4096 bytes (Default)         New volume label         Ubuntu 16.04 LTS amd64         Format Options          Check device for bad blocks         1 Pass		Ubuntu 16.04 LTS amd64 (F:) [4GB]		~
MBR partition scheme for BIOS or UEFI         File system         FAT32         Cluster size         4096 bytes (Default)         New volume label         Ubuntu 16.04 LTS amd64         Format Options C         Check device for bad blocks         1 Pass		Partition scheme and target system type	2	
File system         FAT32         Cluster size         4096 bytes (Default)         New volume label         Ubuntu 16.04 LTS amd64         Format Options          Check device for bad blocks         1 Pass		MBR partition scheme for BIOS or UEFI	1	~
FAT32         Cluster size         Quiter size         4096 bytes (Default)         New volume label         Ubuntu 16.04 LTS amd64         Format Options          Check device for bad blocks         1 Pass		File system		
Cluster size 4096 bytes (Default) New volume label Ubuntu 16.04 LTS amd64 Format Options C Check device for bad blocks 1 Pass		FAT32		~
buntu-16       4096 bytes (Default)         New volume label       Ubuntu 16.04 LTS amd64         Format Options           Check device for bad blocks       1 Pass         Ouick format		Cluster size		
New volume label Ubuntu 16.04 LTS amd64 Format Options  Check device for bad blocks 1 Pass	buntu-16	4096 bytes (Default)		~
Ubuntu 16.04 LTS amd64 Format Options  C Check device for bad blocks I Pass		New volume label		
Format Options  Format Options  Format Options  Format Direct device for bad blocks		Ubuntu 16.04 LTS amd64		
Check device for bad blocks 1 Pass		Format Options 🔽		
Quick format		Check device for bad blocks	iss	~
		Quick format		
Create a bootable disk using ISO Image V		Create a bootable disk using ISO	Image	~ 3
Create extended label and icon files		Create extended label and icon file	s	
		READY		
READY		About Log	Start	Close
READY About Log Start Close				

# 2.2 安装 ROS

此手册以 ROS Indigo 为例。

## 1、配置 Ubuntu 软件仓库

配置你的 Ubuntu 软件仓库(repositories) 以允许 "restricted"、"universe" 和 "multiverse"这三种安装模式。

## 2、添加 sources.list

配置你的电脑使其能够安装来自 packages.ros.org 的软件。 ROS Indigo 仅 支持 Saucy (13.10) 和 Trusty (14.04)。

 sudo sh -c 'echo "deb http://packages.ros.org/ros/ubuntu \$(lsb\_r elease -sc) main" > /etc/apt/sources.list.d/ros-latest.list'

## 3、添加 keys

```
    sudo apt-key adv --keyserver hkp://pool.sks-keyservers.net --rec
v-key 0xB01FA116
```

4、安装

首先,确保你的 Debian 软件包索引是最新的:

• sudo apt-get update

**ROS** 中有很多各种函数库和工具,我们为你提供了四种默认安装方式,你也可以单独 安装某个指定软件包。

桌面完整版安装:(推荐)包含 ROS、rqt、rviz、通用机器人函数库、2D/3D 仿真器、导航以及 2D/3D 感知功能。

在 Trusty 中 Indigo 默认搭配使用 Gazebo2。

o sudo apt-get install ros-indigo-desktop-full

桌面版安装:包含 ROS、rqt、rviz 以及通用机器人函数库。

```
o sudo apt-get install ros-indigo-desktop
```

**基础版安装:**包含 ROS 核心软件包、构建工具以及通信相关的程序库,无 GUI 工具。

o sudo apt-get install ros-indigo-ros-base

**单个软件包安装:** 你也可以安装某个指定的 ROS 软件包(使用软件包名称替换掉下面的 PACKAGE):

o sudo apt-get install ros-indigo-PACKAGE

例如:

sudo apt-get install ros-indigo-slam-gmapping

要查找可用软件包,请运行:

apt-cache search ros-indigo

#### 5、初始化 rosdep

在开始使用 ROS 之前你还需要初始化 rosdep。rosdep 可以方便在你需要编译某些 源码的时候为其安装一些系统依赖,同时也是某些 ROS 核心功能组件所必需用到的工具。

```
sudo rosdep init
```

rosdep update

#### 6、环境设置

如果每次打开一个新的终端时 ROS 环境变量都能够自动配置好(即添加到 bash 会话中),那将会方便得多:

echo "source /opt/ros/indigo/setup.bash" >> ~/.bashrc

source ~/.bashrc

如果你安装有多个 ROS 版本, ~/. bashrc 必须只能 source 你当前使用版本所对应 的 setup. bash。

如果你只想改变当前终端下的环境变量,你可以执行命令:

source /opt/ros/indigo/setup.bash

#### 7、安装 rosinstall

rosinstall 是 ROS 中一个独立分开的常用命令行工具,它可以方便让你通过一条命令就可以给某个 ROS 软件包下载很多源码树。

要在 ubuntu 上安装这个工具,请运行:

sudo apt-get install python-rosinstall

#### 8、Build farm 状态

你所安装的各种软件包都是通过 <u>ROS build farm</u>来编译构建的。你可以在<u>这里</u>查看各种独立软件包的编译状态。

## 2.3 安装 SDK

安装完 Ubuntu 14.04 和 ROS Indigo 之后,我们将在工作站上安装 Baxter SDK。

#### 1、创建 ROS 工作空间

\$ mkdir -p ~/ros\_ws/src

#### 2、编译安装

- \$ source /opt/ros/indigo/setup.bash
- \$ cd ~/ros\_ws
- \$ catkin\_make
- \$ catkin\_make install

## 3、安装 SDK 依赖

\$ sudo apt-get update

\$ sudo apt-get install git-core python-argparse python-wstool python-vcstools python-r osdep ros-indigo-control-msgs ros-indigo-joystick-drivers

## 4、安装 Baxter 科研版 SDK

- \$ cd ~/ros\_ws/src
- \$ wstool init .

\$ wstool merge https://raw.githubusercontent.com/RethinkRobotics/baxter/master/baxter \_sdk.rosinstall

- \$ wstool update
- \$ source /opt/ros/indigo/setup.bash
- \$ cd ~/ros\_ws
- \$ catkin\_make
- \$ catkin\_make install

## 5、下载并修改 baxter.sh,配置 Baxter 通讯

- \$ wget https://github.com/RethinkRobotics/baxter/raw/master/baxter.sh
- \$ chmod u+x baxter.sh
- \$ cd ~/ros\_ws
- \$ gedit baxter.sh
- # 星号内为要修改的内容
- \*\*baxter\_hostname="baxter\_hostname.local"\*\*
- \*\*your\_ip="192.168.XXX.XXX"\*\*
- \*\*\*ros\_version="indigo"\*\*\*

## 6、保存 baxter.sh,初始化 SDK 运行环境

- \$ cd ~/ros\_ws
- \$ . baxter.sh.

- 7、验证 SDK 安装
  - \$ env | grep ROS
  - # ROS\_MASTER\_URI 应是机器人的主机名
  - # ROS\_IP 应是工作站 IP
  - # ROS\_HOSTNAME 与 ROS\_IP 选一即可,指定工作站主机名

# 3 运行 Hello Baxter 示例

## 1、设置 ROS 及 Baxter 运行环境

- \$ cd ~/ros\_ws
- \$ source /opt/ros/indigo/setup.bash
- \$ catkin\_make
- # Source baxter.sh script
- \$ . baxter.sh

## 2、验证网络连接,查看 baxter topics

- # 确定 ROS 主节点 URI
- \$ env | grep ROS\_MASTER\_URI
- # Ping ROS 主节点
- \$ ping <our ROS Master>

#如

- \$ ping 011303P0017.local
- # baxter topic 列表

#### 3、通过 SSH 从工作站登录 baxter 机器人

\$ \$ ssh ruser@<our ROS Master>

```
# 密码: rethink
# 如:
$ ssh ruser@011303P0017.local
#现在已经登录到机器人,请从机器人 ping 工作站
ruser@p99 ~ $ ping <ROS_IP/ROS_HOSTNAME>
# 如
ruser@p99 ~ $ ping 192.168.101.99
# 或使用 ROS_HOSTNAME
ruser@p99 ~ $ ping yoda
$ . baxter.sh.
```

## 4、使能机器人

- \$ cd ~/ros\_ws
- \$ . baxter.sh.

\$ rosrun baxter\_tools enable\_robot.py -e

此时机器人已经处于工作状态,按住手腕处的薄膜按钮,机器人将进入零重力模式,您 可以自由拖动机械臂。

## 5、运行示例程序

\$ rosrun baxter\_examples joint\_velocity\_wobbler.py

执行上述命令后,机器臂首先移动到中间位置,进入速度控制模式,每个关节进行随机 正弦运动。

## 6、交互式编程

打开 Python 命令窗口,可逐行输入指令。

```
$ python
# 导入必要的 python 模块
# rospy - ROS Python API
>>> import rospy
# baxter_interface - Baxter Python API
>>> import baxter_interface
# initialize our ROS node, registering it with the Master
```

```
>>> rospy.init_node('Hello_Baxter')
```

# create an instance of baxter\_interface's Limb class

```
>>> limb = baxter_interface.Limb('right')
```

# get the right limb's current joint angles

>>> angles = limb.joint\_angles()

# print the current joint angles

>>> print angles

```
# reassign new joint angles (all zeros) which we will later command to the limb
```

```
>>> angles['right_s0']=0.0
```

```
>>> angles['right_s1']=0.0
```

```
>>> angles['right_e0']=0.0
```

```
>>> angles['right_e1']=0.0
```

```
>>> angles['right_w0']=0.0
```

```
>>> angles['right_w1']=0.0
```

```
>>> angles['right_w2']=0.0
```

```
# print the joint angle command
```

```
>>> print angles
```

```
# move the right arm to those joint angles
```

```
>>> limb.move_to_joint_positions(angles)
```

```
# Baxter wants to say hello, let's wave the arm
```

```
# store the first wave position
```

```
# store the second wave position
```

# wave three times

>>> for \_move in range(3):

```
... limb.move_to_joint_positions(wave_1)
```

```
... limb.move_to_joint_positions(wave_2)
```

# quit

>>> quit()

至此您已经基本熟悉了 Baxter 的工作流程并能够使用命令控制 Baxter 的基本运动了。 关于 Baxter 工作原理的细节和应用案例,请参考配套的 Baxter 教材。