

1st Kibo Robot Programming Challenge Programming Manual



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List of Changes

All changes to paragraphs, tables, and figures in this document are shown below;

Release Date	Revision	Paragraph(s)	Rationale
November 20 th , 2019	1.0	All	-
December 25 th , 2019	2.0	All	Changed expressions and corrected typos
		2. Setting up your machine	Updated for Windows users
		3.1.1. Game APIs	Updated API details
		4.3. Upload APK and run your program 4.4. Check result	Updated contents and figures
		4.5. Run on your machine (optional)	Added
		5. Tips for programming	Added some important tips
January 29 th , 2020	2.1	3.1. Creating an Android project	Added notes
		4.4. Checking simulation while running	Moved Section from Chapter 4.5
		4.5.4. rosbag replay settings	Added
March 12 th , 2020	2.2	3.1.1. Game APIs 4.6.3. Setting up the Astrobeer Robot Software	Added notes
		4.6.1. Differences between web simulator and local simulator	Added
		6. Simulator change log	
		3.1.2 (3) Reference 4.6.5. Building the Guest Science Manager APK	Fix github URL
		4.6.9 (3) Running the Guest Science Manager APK and GS APK	Fixed gds manager path
March 30 th , 2020	2.3	3.2.3. How to change the application id (option) 5.4. About navigation error	Added
		2.2.2. Installing Android Studio	Add Android Studio version
		4.4. Checking simulation while running	Corrected simulation speed 0.5x to 1.0x(real-time)
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August 5 th , 2020	2.3.2	3.2.3. Change the application ID (optional)	Add 10 th Step
August 21 st , 2020	2.3.3	3.1.1 Game APIs	Add Flashlight Control APIs



Contents

1. Introduction	1
2. Setting up your machine.....	2
2.1. Requirements	2
2.2. Setting up Android Studio.....	2
2.2.1. Installing components (Only on Ubuntu)	2
2.2.2. Installing Android Studio.....	2
2.2.3. Downloading additional components.....	3
3. Creating your application.....	4
3.1. Creating an Android project.....	4
3.1.1. Game APIs.....	4
(1) Writing the application.....	4
(2) API details.....	6
3.1.2. Type information	14
(1) Summary	14
(2) Details.....	14
(3) Reference	16
3.2. Building your application	17
3.2.1. On Ubuntu	17
3.2.2. On Windows	17
3.2.3. Change the application ID (optional)	18
(1) On Ubuntu	21
(2) On Windows	21
4. Running your program on the simulator.....	22
4.1. Using the simulator server	22
4.2. Login.....	22
4.3. Uploading the APK and running your program	24
4.4. Checking simulation while running	25
4.5. Checking the result	26
4.5.1. Result summary	26
4.5.2. Download ZIP file.....	27
4.5.3. Check simulation after running.....	28
4.5.4. rosbag replay settings.....	29
4.5.5. rviz settings.....	30
4.6. Running on your own machine (optional).....	31
4.6.1. Differences between web simulator and local simulator	31
4.6.2. Requirements	31
4.6.3. Setting up the Astrobe Robot Software	31
4.6.4. Creating the AVD (Android Virtual Device)	33
4.6.5. Building the Guest Science Manager APK	34



4.6.6. Setting up the network	34
(1) Setting the HOST network	34
(2) Setting the environment variables	34
(3) Setting up the Android network and starting the Android Emulator	35
4.6.7. Installing APKs	35
4.6.8. Setting QR codes, an AR tag, and the target.....	35
4.6.9. Running your program	36
(1) Launching the Android Emulator	36
(2) Starting the Astrobees Simulator.....	36
(3) Running the Guest Science Manager APK and GS APK.....	37
5. Programming tips	38
5.1. Do NOT write infinite loops	38
5.2. Dealing with randomness.....	39
5.3. Camera parameters	40
5.4. About navigation error.....	40
6. Simulator change log.....	41



1. Introduction

Let's start programming!

Astrobee can be controlled with an Android application called the Guest Science APK (GS APK). First, setup your machine to build your application according to the instructions in Chapter 2. Next, read Chapter 3 and create a GS APK. This chapter explains the game APIs that operate Astrobee, such as moving Astrobee and getting camera images. Then, try running the GS APK in the simulator environment. Chapter 4 describes how to use the environment.



2. Setting up your machine

First of all, set up a machine for programming.

2.1. Requirements

The machine must meet the following requirements.

- 64-bit processor
- 4 GB RAM (8 GB RAM recommended)
- Ubuntu 16.04 (64-bit version) (<http://releases.ubuntu.com/16.04/>)
or Windows 10 (64-bit version)

NOTE: If you want to run your program on your own PC, you need 8 GB of RAM (16 GB RAM recommended) and Ubuntu 16.04. For details, please refer to 0

2.2. Setting up Android Studio

2.2.1. Installing components (Only on Ubuntu)

If you use an Ubuntu machine, you need these components.

- openJDK8
- ADB (Android Debug Bridge)
- Gradle

Please install them with the following command.

```
sudo apt-get -y install openjdk-8-jdk adb gradle
```

2.2.2. Installing Android Studio

Please download Android Studio 3.4.1 from Android Studio download archives page (<https://developer.android.com/studio/archive><https://developer.android.com/studio/index.html>) and extract it into your home directory.



2.2.3. Downloading additional components

To build the Guest Science APK, you need to download additional components as follows.

- 1) Launch Android Studio.
- 2) Select [Tools] -> [SDK Manager].
- 3) On the SDK Platforms Tab, check “show Package Details”. Select “Android SDK Platform 25” and “Android SDK Platform 26”.
- 4) On the SDK Tools Tab, check “show Package Details”. Select “25.0.3”, “26.0.2” under Android SDK Build-Tools and “Android SDK Platform-Tools”.
- 5) Click the [Apply] button to install these components.

3. Creating your application

3.1. Creating an Android project

To create your application, prepare a new project with the following steps.

- 1) Download APK template (Template APK) from the Download page on the Web site.
- 2) Extract the zip file to the directory where you want it.
- 3) Launch Android Studio.
- 4) Open the APK template folder with [File] -> [Open].
- 5) Open [app/java/jp.jaxa.iss.kibo.rpc.defaultapk /YourService.java] in Project view.
- 6) Write your code in runPlan1 – runPlan3 methods in the YourService.java file.

When you open APK template folder, “Android Gradle Plugin Update Recommended” dialog may appear. However you must not update because of dependency problem, so push “Don’t remind me again for this project”

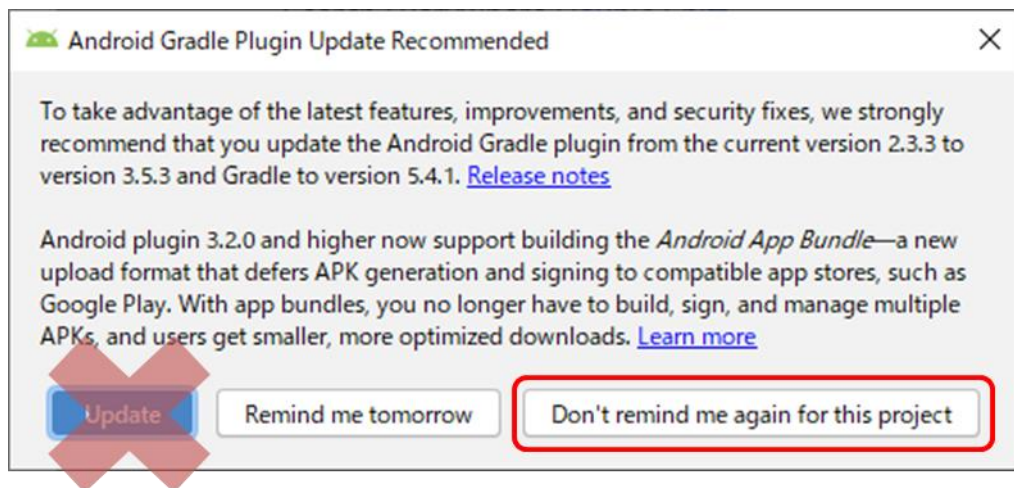


Figure 3.1-1 Android Gradle Plugin Update Recommended dialog

3.1.1. Game APIs

(1) Writing the application

You can use the game APIs shown below in the YourService.java file.

“runPlan1” is executed on the web simulator. You can choose any plan when you run the application on your own machine.

```
public class YourService extends KiboRpcService {
    // write your plan 1 here
    @Override
    protected void runPlan1(){
```




```
// start this run
api.judgeSendStart();

// move Astrobee from the starting point to P1-1
Point point = new Point(1.1, -2.2, 3.3);
Quaternion quaternion = new Quaternion(4.4, -5.5, 6.6, -7.7);
api.moveTo(point, quaternion, true);
//      :

// once Astrobee came to P1-1, get a camera image
Bitmap snapshot = api.getBitmapNavCam();
// read the QR code in the image and get the x-axis coordinate value of P3
String valueX = ...;
// send the result to scoring module
api.judgeSendDiscoveredQR(0, valueX);

// implement some other functions or repeat for P1-2, P1-3, ...
//      :

// once Astrobee came to P3, get a camera image
Bitmap snapshot = api.getBitmapNavCam();
// read the AR tag in the image
String markerId = ...;
// send the result to the scoring module
api.judgeSendDiscoveredAR(markerId);

// some other functions
//      :

// turn on the laser light,
api.laserControl(true);
// take snapshots to evaluate the accuracy of laser pointing and finish this run
api.judgeSendFinishSimulation();
sendData(MessageType.JSON, "data", "SUCCESS:defaultapk runPlan1");
}
// write your other plans here
// ...
}
```

You can find methods of the game APIs by using the code completion function of Android Studio.

Please refer to (2) for more information and you can download Sample APK from the Download page on the Web site.

(2) API details

Details of the Kibo-RPC's game APIs are listed below.

(2-1) Method Summary

Table 3-1 Method Summary

Modifier and Type	Method and Description
gov.nasa.arc.astrobeec.Result	flashlightControlFront (float brightness) Set Brightness of Front Flash Light
gov.nasa.arc.astrobeec.Result	flashlightControlBack (float brightness) Set Brightness of Back Flash Light
android.graphics.Bitmap	getBitmapDockCam () Get Bitmap image of DockCam.
android.graphics.Bitmap	getBitmapNavCam () Get Bitmap image of NavCam.
jp.jaxa.iss.kibo.rpc.api.types.ImuResult	getImu () Get IMU telemetry
static KiboRpcApi	getInstance (gov.nasa.arc.astrobeec.android.guestscience.StartGuestScienceService startGuestScienceService) Static method that provides a unique instance of this class
org.opencv.core.Mat	getMatDockCam () Get Mat image of DockCam.
org.opencv.core.Mat	getMatNavCam () Get Mat image of NavCam.
jp.jaxa.iss.kibo.rpc.api.types.PointCloud	getPointCloudHazCam () Get PointCloud data of HazCam.
jp.jaxa.iss.kibo.rpc.api.types.PointCloud	getPointCloudPerchCam () Get PointCloud data of PerchCam.
gov.nasa.arc.astrobeec.Kinematics	getTrustedRobotKinematics () Get trusted data related to positioning and orientation for Astrobee with infinite timeouts
gov.nasa.arc.astrobeec.Kinematics	getTrustedRobotKinematics (int timeout) Get trusted data related to positioning and orientation for Astrobee



Modifier and Type	Method and Description
void	judgeSendDiscoveredAR (java.lang.String id) Send an AR ID for judge.
void	judgeSendDiscoveredQR (int no, java.lang.String value) Send a QR code data for judge.
void	judgeSendFinishISS () Send finish command to do final operation at ISS.
void	judgeSendFinishSimulation () Send finish command to do final operation in simulation.
void	judgeSendStart () Send a starting time stamp for judge.
gov.nasa.arc.astrobeer.Result	moveTo (gov.nasa.arc.astrobeer.types.Point goalPoint, gov.nasa.arc.astrobeer.types.Quaternion orientation, boolean printRobotPosition) Move Astrobeer to the given point and rotate it to the given orientation.
gov.nasa.arc.astrobeer.Result	relativeMoveTo (gov.nasa.arc.astrobeer.types.Point goalPoint, gov.nasa.arc.astrobeer.types.Quaternion orientation, boolean printRobotPosition) Move Astrobeer to the given point using a relative reference and rotates it to the given orientation.
void	shutdownFactory () This method shutdown the robot factory in order to allow java to close correctly.



(2-2) Method Details

- **flashlightControlFront**

```
public gov.nasa.arc.astrobeer.Result flashlightControlFront
(float brightness)
```

Brightness of Front Flashlight

Parameters:

brightness - Brightness percentage between 0 - 1.

Returns:

A Result instance carrying data related to the execution.
Returns null if the command was NOT executed as a result of an error

- **flashlightControlBack**

```
public gov.nasa.arc.astrobeer.Result flashlightControlBack
(float brightness)
```

Brightness of Back Flashlight

Parameters:

brightness - Brightness percentage between 0 - 1.

Returns:

A Result instance carrying data related to the execution.
Returns null if the command was NOT executed as a result of an error

- **shutdownFactory**

```
public void shutdownFactory()
```

This method shuts down the robot factory in order to allow java to close correctly.

- **getInstance**

```
public
static KiboRpcApi getInstance(gov.nasa.arc.astrobeer.android.gs.Sta
rtGuestScienceService startGuestScienceService)
```

Static method that provides a unique instance of this class

Returns:

A unique instance of this class ready to use

- **getTrustedRobotKinematics**

```
public gov.nasa.arc.astrobeer.Kinematics getTrustedRobotKinematics(
int timeout)
```

Gets trusted data related to positioning and orientation for Astrobee

Parameters:

timeout - Number of seconds before canceling request

Returns:



Kinematics Trusted Kinematics, null if an internal error occurred or request timeout

- **getTrustedRobotKinematics**

```
public gov.nasa.arc.astrobee.Kinematics getTrustedRobotKinematics()  
)
```

Gets trusted data related to positioning and orientation for Astrobees with infinite timeouts

Returns:

Kinematics Trusted Kinematics, null if an internal error occurred or request timeout

- **getImu**

```
public jp.jaxa.iss.kibo.rpc.api.types.ImuResult getImu()
```

Gets IMU telemetry

Returns:

ImuResult data, null if an internal error occurred.

- **getBitmapNavCam**

```
public android.graphics.Bitmap getBitmapNavCam()
```

Gets Bitmap image of NavCam.

Returns:

Bitmap image of NavCam(1280 px x 960 px), null if an internal error occurred. Format:Bitmap.Config.ARGB_8888

- **getBitmapDockCam**

```
public android.graphics.Bitmap getBitmapDockCam()
```

Gets Bitmap image of DockCam.

Returns:

Bitmap image of DockCam(1280 px x 960 px), null if an internal error occurred. Format:Bitmap.Config.ARGB_8888

- **getMatNavCam**

```
public org.opencv.core.Mat getMatNavCam()
```

Gets Mat image of NavCam.

Returns:

Mat image of NavCam(1280 px x 960 px), null if an internal error occurred. Format:CV8UC1

- **getMatDockCam**

```
public org.opencv.core.Mat getMatDockCam()
```

Gets Mat image of DockCam.

Returns:

Mat image of DockCam(1280 px x 960 px), null if an internal error occurred. Format:CV8UC1

- **getPointCloudHazCam**

```
public jp.jaxa.iss.kibo.rpc.api.types.PointCloud getPointCloudHazCam()
```

Gets PointCloud data of HazCam.

Returns:

PointCloud data of HazCam(224 px x 171 px), null if an internal error occurred.



- **getPointCloudPerchCam**

```
public jp.jaxa.iss.kibo.rpc.api.types.PointCloud getPointCloudPerchCam()
```

Gets PointCloud data of PerchCam.

Returns:

PointCloud data of PerchCam(224 px x 171 px), null if an internal error occurred.

- **moveTo**

```
public gov.nasa.arc.astrobeer.Result moveTo(gov.nasa.arc.astrobeer.types.Point goalPoint,
gov.nasa.arc.astrobeer.types.Quaternion orientation,
boolean printRobotPosition)
```

Moves Astrobeer to the given point and rotates it to the given orientation.

Parameters:

goalPoint - Absolute cardinal point (xyz)

orientation - An instance of the Quaternion class. You may want to use CENTER_US_LAB or CENTER_JEM as an example depending on your initial position.

printRobotPosition - flag which print robot positions in log or not.

Returns:

A Result instance carrying data related to the execution. Returns null if the command was NOT executed as a result of an error

- **relativeMoveTo**

```
public gov.nasa.arc.astrobeer.Result relativeMoveTo(gov.nasa.arc.astrobeer.types.Point goalPoint,
gov.nasa.arc.astrobeer.types.Quaternion orientation,
boolean printRobotPosition)
```

Moves Astrobeer to the given point using a relative reference and rotates it to the given orientation.

Parameters:

goalPoint - The relative end point (relative to Astrobeer)

orientation - The absolute orientation

printRobotPosition - flag which print robot positions in log or not.

Returns:

A Result instance carrying data related to the execution. Returns null if the command was NOT executed as a result of an error



- **laserControl**

```
public gov.nasa.arc.astrobee.Result laserControl(boolean state)
```

Turns power on/off Laser Pointer. If it is same state as input parameter, nothing happens.

Parameters:

state - Set a laser pointer true:power on / false:power off.

Returns:

A Result instance carrying data related to the execution.
Returns null if the command was NOT executed as a result of an error

- **judgeSendStart**

```
public void judgeSendStart()
```

Sends a starting time stamp for scoring.

You should call this function before you start your mission, otherwise your score is not calculated.

- **judgeSendFinishSimulation**

```
public void judgeSendFinishSimulation()
```

Sends finish command to do final operation in simulation. When this function is called, snapshots of laser pointing accuracy are taken and they are used to scoring.

You should call this function once you have turned the laser on, otherwise your score is not calculated.

- **judgeSendFinishISS**

```
public void judgeSendFinishISS()
```

Sends finish command to do final operation at ISS. This function is for final round.



- **judgeSendDiscoveredQR**

```
public void judgeSendDiscoveredQR(int no,  
                                  java.lang.String value)
```

Sends a QR code data for scoring.

Warning:

- 1, Each pair of no and value is accepted only once. You should call this function once each QR code has been discovered, otherwise your score is not calculated.
- 2, You DO NOT change a value read from QR code, you should send a raw string you read.

Parameters:

```
no - QR code number.  
[Preliminary round, Simulation]  
0:pos_x, 1:pos_y, 2:pos_z 3:qua_x, 4:qua_y, 5:qua_z  
  
[Final round, ISS]  
0:pos_x, pos_y, pos_z  
1:qua_x, qua_y, qua_z  
  
value - string you read from QR code.  
[Preliminary round, Simulation]  
ex: pos_x, 1.23456  
  
[Final round, ISS]  
ex: pos_x, 1.23456, pos_y, 2.3456789, pos_z, 3.456
```

- **judgeSendDiscoveredAR**

```
public void judgeSendDiscoveredAR(java.lang.String id)
```

Sends an AR ID for scoring.

You should call this function once an AR tag has been discovered, otherwise your score is not calculated

Parameters:

```
id - AR code id you read.
```

3.1.2. Type information

(1) Summary

Table 3-2 Type information summary

Type	Description
jp.jaxa.iss.kibo.rpc.api.types.ImuResult	IMU telemetry data.
jp.jaxa.iss.kibo.rpc.api.types.PointCloud	Point cloud data.

(2) Details

Details of Kibo-RPC's types are bellow.

(2-1) jp.jaxa.iss.kibo.rpc.api.types.ImuResult

- **getAngularVelocity**

```
public gov.nasa.arc.astrobeer.types.Vec3d getAngularVelocity()
```

Returns:

Angular velocity data.

- **getAngularVelocityCovariance**

```
public double[] getAngularVelocityCovariance()
```

Returns:

Angular velocity Covariance data.

- **getLinearAcceleration**

```
public gov.nasa.arc.astrobeer.types.Vec3d getLinearAcceleration()
```

Returns:

Linear acceleration data.

- **getLinearAccelerationCovariance**

```
public double[] getLinearAccelerationCovariance()
```

Returns:

Linear acceleration covariance data.

- **getOrientation**

```
public gov.nasa.arc.astrobee.types.Quaternion getOrientation()
```

Returns:

Orientation data.

- **getOrientationCovariance**

```
public double[] getOrientationCovariance()
```

Returns:

Orientation covariance.

(2-2) jp.jaxa.iss.kibo.rpc.api.types.PointCloud

- **getWidth**

```
public int getWidth()
```

Returns:

Width of point cloud data.

- **getHeight**

```
public int getHeight()
```

Returns:

Height of point cloud data.

- **getPointArray**

```
public gov.nasa.arc.astrobee.types.Point[] getPointArray()
```

Returns:

Point arrays of point cloud data. It contains number of array data Width times Height.

(3) Reference

Please refer below for information about other Types.

Type	URL
gov.nasa.arc.astrobee .Kinematics	https://github.com/nasa/astrobee_android/blob/5b07e4d626781a6f7e0a9cdf4397375cbe509803/astrobee_api/api/src/main/java/gov/nasa/arc/astrobee/Kinematics.java
gov.nasa.arc.astrobee .Result	https://github.com/nasa/astrobee_android/blob/5b07e4d626781a6f7e0a9cdf4397375cbe509803/astrobee_api/api/src/main/java/gov/nasa/arc/astrobee/Result.java
gov.nasa.arc.astrobee .types.Vec3d	https://github.com/nasa/astrobee_android/blob/5b07e4d626781a6f7e0a9cdf4397375cbe509803/astrobee_api/api/src/main/java/gov/nasa/arc/astrobee/types/Vec3d.java
gov.nasa.arc.astrobee .types.Quaternion	https://github.com/nasa/astrobee_android/blob/5b07e4d626781a6f7e0a9cdf4397375cbe509803/astrobee_api/api/src/main/java/gov/nasa/arc/astrobee/types/Quaternion.java
gov.nasa.arc.astrobee .types.Point	https://github.com/nasa/astrobee_android/blob/5b07e4d626781a6f7e0a9cdf4397375cbe509803/astrobee_api/api/src/main/java/gov/nasa/arc/astrobee/types/Point.java



3.2. Building your application

3.2.1. On Ubuntu

To build your application, use the command shown below.

NOTE: DO NOT build your application using Android Studio to change the build task, as this may cause an error.

```
$ cd <YOUR_APK_PATH>
$ ANDROID_HOME=$HOME/Android/Sdk ./gradlew assembleDebug
```

You can find the APK file as "<YOUR_APK_PATH>/app/build/outputs/apk/app-debug.apk".

3.2.2. On Windows

Please build your application with the following steps.

- 1) Launch Android Studio.
- 2) Open <YOUR_APK_PATH>.
- 3) Click app on the [Project] window.
- 4) Select [Build] -> [Make Module 'app'].

If you find errors, please build an APK file on an Ubuntu machine.

You can find the APK file as "<YOUR_APK_PATH>\app\build\outputs\apk\app-debug.apk".

3.2.3. Change the application ID (optional)

You can change the application ID (*jp.jaxa.iss.kibo.rpc.sampleapk* or *jp.jaxa.iss.kibo.rpc.defaultapk* by default).

In this step, we change the application ID to “*jaxa.iss.kibo.rpc.myteam*” and APK name to “*myteam*” with the SampleAPK project.

NOTE: This instruction is for the final round. Changing application ID is not necessary and not recommended in the preliminary round.

NOTE: “*jaxa.iss.kibo.rpc*” cannot be changed.

- 1) Launch Android Studio.
- 2) Open <YOUR_APK_PATH>.
- 3) Make sure you are viewing the project in Android View.

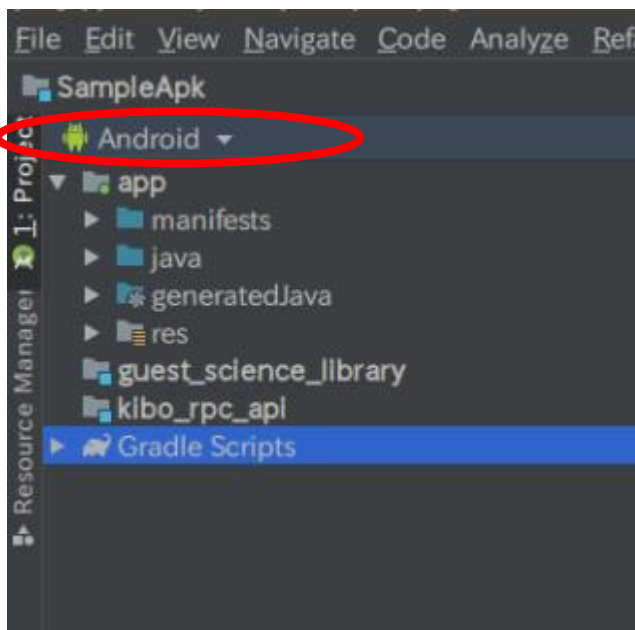


Figure 3.2-1 Android View

- 4) Click on the setting gear icon and unselect [Compact Empty Middle Package].

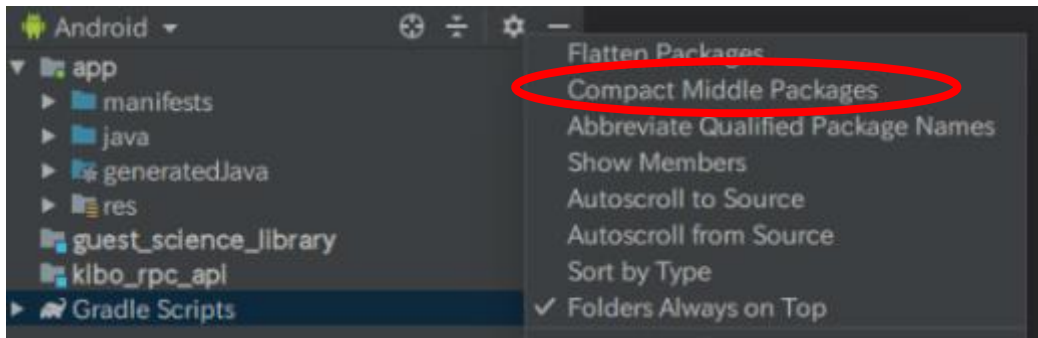


Figure 3.2-2 Unselect [Compact Empty Middle Package]

- 5) Please expand the "java" folder.

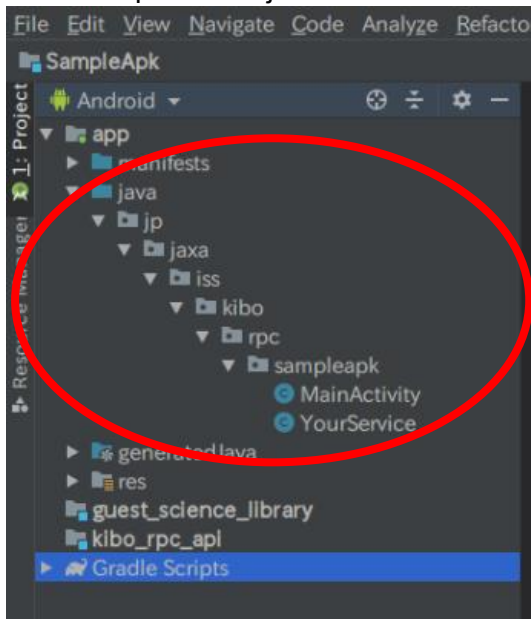


Figure 3.2-3 Expand the "java" folder

- 6) Right-click the "sampleapk" folder and select [refactor] -> [rename].

- 7) A warning will be displayed, but you go ahead and click [Rename Package]. After that, enter the APK name that you want. (In the picture, we rename to “myteam”.)

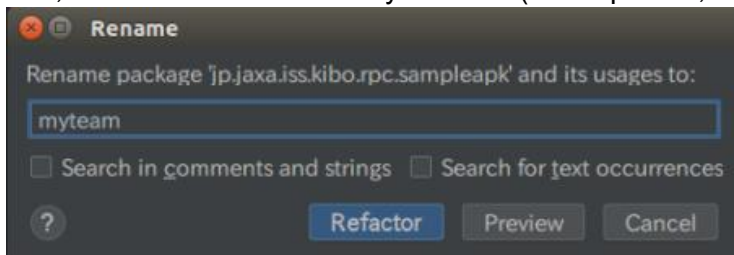


Figure 3.2-4 Rename dialog

- 8) In the bottom of Android Studio, “Refactoring Preview” will be displayed. Here, click [Do Refactor].

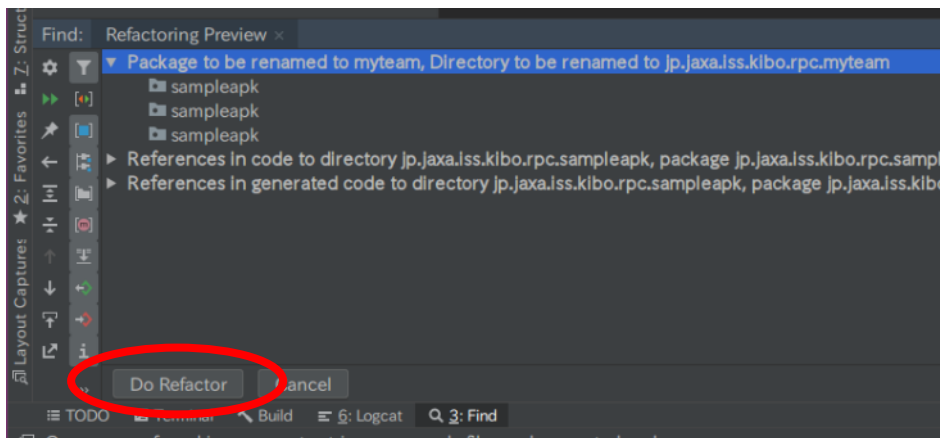


Figure 3.2-5 Refactoring Preview

- 9) Open **build.gradle (Module: app)** in Gradle Scripts on the left-side menu. Please change the application ID and click [Sync Now].

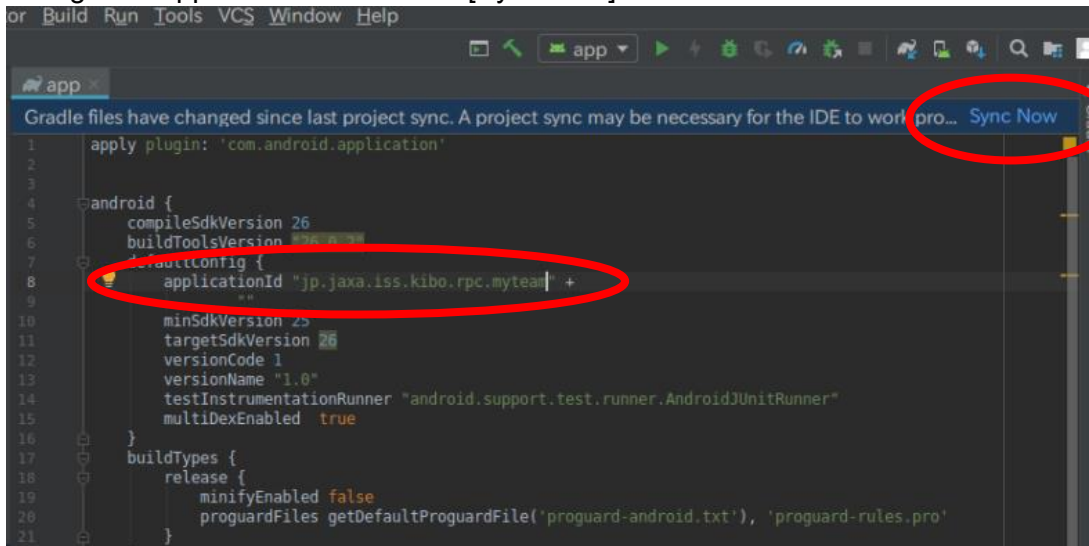


Figure 3.2-6 build.gradle (Module: app)

- 10) Open **strings.xml** in app -> res -> values on the left-side menu. Please change the APK name and save.

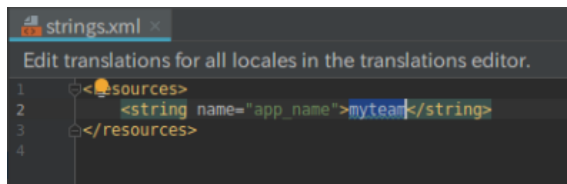


Figure 3.2-7 strings.xml

You have successfully changed the application ID in Android Studio. And if you want to change the Android project name and its directory name, follow the next steps.

(1) On Ubuntu

- 11) Close Android Studio.
- 12) Please execute the following commands.

```
cd <YOUR_APK_PATH>
cd ../
mv SampleApk <YOUR_APK_NAME>
cd <YOUR_APK_NAME>
mv SampleApk.iml <YOUR_APK_NAME>.iml
```

(2) On Windows

- 10) Close Android Studio.
- 11) Please rename a **SampleApk** folder to <YOUR_APK_NAME> with Windows Explorer.
- 12) Please rename a **SampleApk.iml** to <YOUR_APK_NAME>.iml in the **SampleApk** folder with Windows Explorer.

4. Running your program on the simulator

4.1. Using the simulator server

Once you have built your application, you can run it with the web simulator provided by JAXA. To use the simulator, you need a user account issued by the Kibo-RPC secretariat. If you don't have one, please read the Kibo-RPC Guidebook to complete your application for participation in Kibo-RPC first.

4.2. Login

Access the Kibo-RPC web site (<https://jaxa.krpc.jp/>) and click “LOGIN”.



Figure 4.2-1 LOGIN tab

On the login form, enter the ID and password for your team's account, and click the “LOGIN” button. If you have forgotten your ID or password, please contact the Kibo-RPC secretariat.



Figure 4.2-2 LOGIN button

Now, you can access the web simulator from this page.



Figure 4.2-3 Web simulator page

4.3. Uploading the APK and running your program

On the simulation page, select your APK file and the simulator version, enter a memo if desired, and click the “START SIMULATION” button.

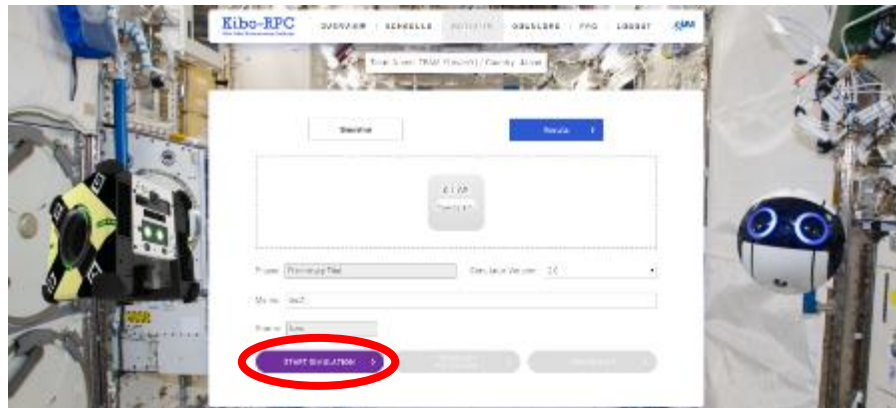


Figure 4.3-1 START SIMULATION button

A simulation may take longer than 20 minutes to run, and it does not need your attention while it runs. After starting your simulation, for example, you can log out, get a cup of coffee, then go back to the web site.

When there is a simulation running, the simulation page displays its original information, so you cannot run another simulation until it finishes.

If you want to stop your simulation, click the “TERMINATE SIMULATION” button. Note that terminating a simulation loses its game score and output files (such as rosbag and the Android Emulator’s log).

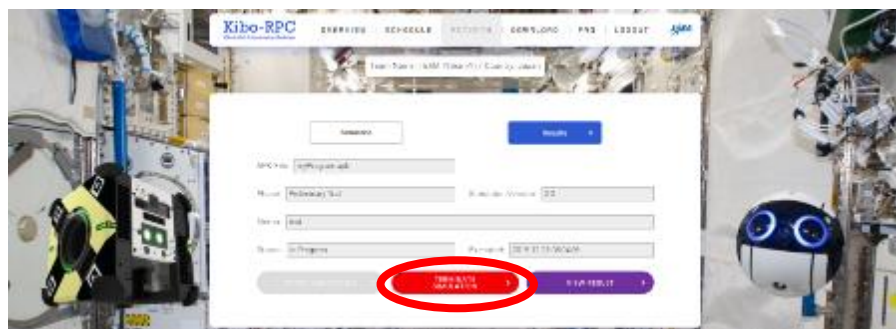


Figure 4.3-2 TERMINATE SIMULATION button

4.4. Checking simulation while running

When your simulation is running, you can log in to the simulator server (viewer) via your browser. Click the “SIMULATOR VIEWER” button to show the information for a remote connection, and open the viewer in another tab by clicking the “VIEW” button.

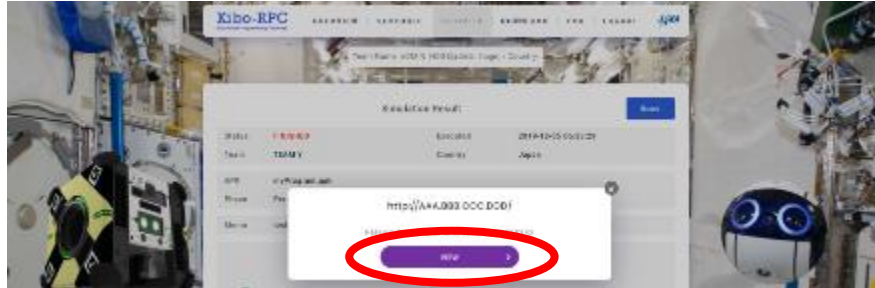


Figure 4.4-1 VIEW button

Enter the password for your remote connection to log in. Now you can use rviz to see how Astrobee moves in your simulation. This viewer is available until the simulation is finished.

The viewer displays a real-time simulation in the view-only mode for the simulation stability. You cannot operate the viewer..

4.5. Checking the result

4.5.1. Result summary

Once your simulation has started, you can check the results by clicking the “VIEW RESULT” button on the simulation page.

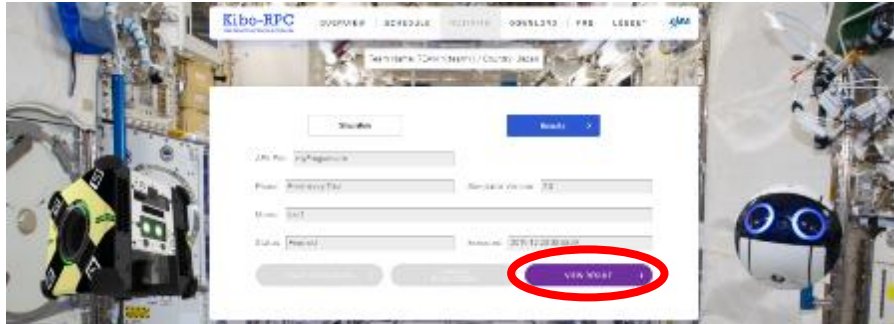


Figure 4.5-1 VIEW RESULT button

On the result page, you can see the details of your simulation, such as the game time, laser accuracy, and so on.

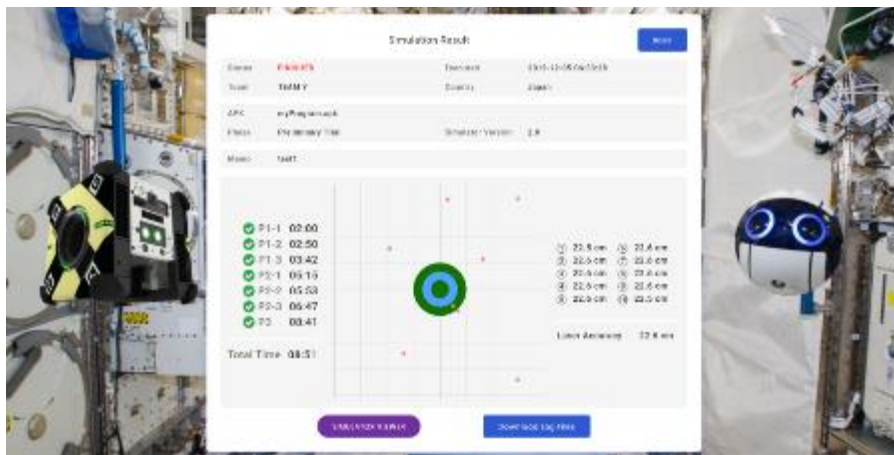


Figure 4.5-2 RESULT page

4.5.2. Download ZIP file

You can get a ZIP file by clicking the “DOWNLOAD LOG FILES” button. This ZIP file contains a game score, rosbag and the Android Emulator’s log. Note that some or all of these files will not be available unless your simulation finishes properly. Besides the result page, the game score also appears in a JSON file, which can be read using a text editor.

```
{
  "QR": {
    "0": {
      "result": true,
      "timestamp": "19700101 000423792",
      :
    },
    :
  },
  "AR": {
    "result": true,
    "timestamp": "19700101 000552624",
    :
  },
  "Approach": {
    "0": {
      "direction": true,
      "x": 1.22,
      "y": -3.44,
      "r": 4.12,
      "timestamp": "19700101 000646960",
      :
    },
    :
  },
  "Mission Time": {
    "start": "19700101 000021632",
    "finish": "19700101 000822824"
  }
}
```

“result” is true if the value of the QR code is correct.

“0”, “1”, ... and “5” correspond to P1-1, P1-2, ... and P2-3.

“result” is true if the marker ID of the AR tag near Target is correct.

“direction” is true if the laser shot is on the Target plane.

“r” is the distance between the center of Target and the laser shot.

“0”, “1”, ... and “9” correspond to the 1st, 2nd, ... and 10th snapshot.

The average distance is referred to as “Laser Accuracy”.

“Game Time” is the difference between the “start” time and the “finish” time.

4.5.3. Check simulation after running

To check previous simulations, click the “Results” button on the simulation page. The results page lists your past simulations. This list can hold up to 20 simulations.



Figure 4.5-3 Results list page

The “VIEW RESULT” button is the same as the one on the simulation page. Please be careful when you click the “REMOVE RESULT” button; it removes the output files of the selected simulation and the removed result will be lost.

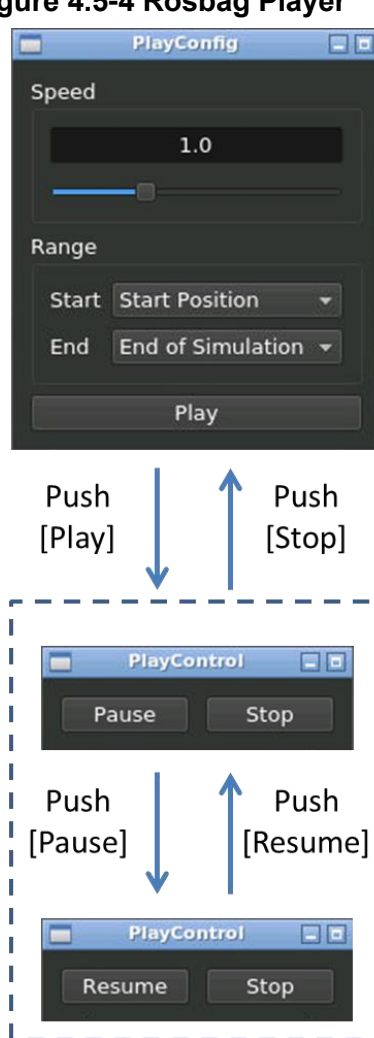
You can play the rosbag (simulation result) at 0.5x – 3x speed with the viewer. You can change rosbag replay settings and rviz settings. In detail, it is described below sections.

4.5.4. rosbag replay settings

You can change rosbag replay settings using Rosbag Player.

Figure 4.5-4 Rosbag Player

Type	Description
Speed Slider	Select replay speed.
Range Selector	Select replay range.
Play Button	Start replay and open rviz window. If rviz already has opened, it will restart.
Pause Button	Pause replay.
Resume Button	Resume replay.
Stop Button	Stop replay and back to PlayConfig window.



The diagram illustrates the interaction between the **PlayConfig** and **PlayControl** windows:

- PlayConfig** window includes:
 - Speed slider (set to 1.0)
 - Range selector (Start: Start Position, End: End of Simulation)
 - Play button
- PlayControl** window (initial state) includes:
 - Pause button
 - Stop button
- PlayControl** window (after Pause):
 - Resume button
 - Stop button

Transitions are indicated by arrows and labels:

- From **PlayConfig** to **PlayControl** (Pause/Stop state): Push [Play]
- From **PlayControl** (Pause/Stop state) to **PlayConfig**: Push [Stop]
- From **PlayControl** (Resume/Stop state) to **PlayControl** (Pause/Stop state): Push [Resume]
- From **PlayControl** (Pause/Stop state) to **PlayControl** (Resume/Stop state): Push [Pause]

4.5.5. rviz settings

You can change display settings on rviz window.

Table 4-1 rviz configuration

Item	Check box in the “Displays” tab
Planning trajectory	[Visualize]->[PlanningTrajectory]
Trajectory	[Visualize]->[Trajectory]
KeepInZone/KeepOutZone	[Visualize]->[Zones]
NavCam	[Sensors]->[NavCam]
DockCam	[Sensors]->[DockCam]
HazCam	[Sensors]->[HazCam]

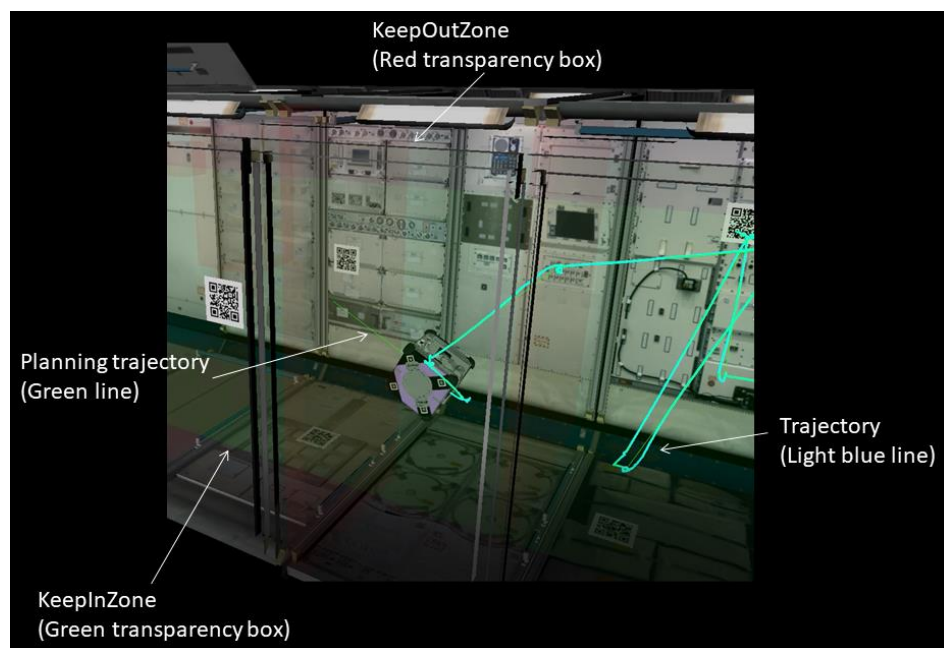


Figure 4.5-5 rviz configuration description

4.6. Running on your own machine (optional)

You can also run the program on your own machine. This chapter provides a procedure to set up the Astrobeer simulator. You get a simple simulation environment without randomness modules (Air flow simulator and Objects randomness generator) or judge module.

4.6.1. Differences between web simulator and local simulator

External Modules for Local Simulation Environment does not include random factor modules (Object position, airflow and navigation error).

You can test and debug your program using local simulator, but need to evaluate it on web simulator server in order to obtain a high score in the preliminary round.

4.6.2. Requirements

The following requirements are needed to set up a simulation environment on your machine.

- 64-bit processor
- 8 GB RAM (16 GB RAM recommended)
- Ubuntu 16.04 (64-bit version) (<http://releases.ubuntu.com/16.04/>)

4.6.3. Setting up the Astrobeer Robot Software

Clone code from GitHub (<https://github.com/nasa/astrobeer>) and install Astrobeer Robot Software according to the installation manual.

(<https://github.com/nasa/astrobeer/blob/70e3df03ff3f880d302812111d0107f3c14dccc0/INSTALL.md>)

NOTE: Since the web simulator is running Astrobeer Robot Software v0.10.2 and Android submodule v0.8.0, so please execute the following command after clone the android software repository.

```
pushd $SOURCE_PATH
git checkout 70e3df03ff3f880d302812111d0107f3c14dccc0
popd
pushd $ANDROID_PATH
git checkout 5b07e4d626781a6f7e0a9cdf4397375cbe509803
popd
```

After building the source code, execute the following commands in order.

```
pushd $BUILD_PATH
source devel/setup.bash
popd
roslaunch astrobee sim.launch dds:=false robot:=sim_pub rviz:=true
```

Is the image below displayed on your screen? If so, installation is complete!

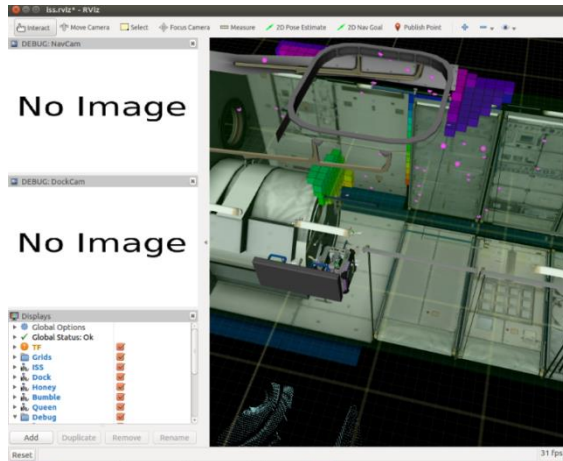


Figure 4.6-1 Setup result

4.6.4. Creating the AVD (Android Virtual Device)

Create an AVD (Android Virtual Device) as follows.

- 1) Launch Android Studio.
- 2) Select [Tools] -> [AVDManager].
- 3) In the Android Virtual Device Manager Window, click [+ Create Virtual Device ...].
- 4) Select device **Nexus 5** (Resolution 1080x1920) and click [Next].
- 5) Select the [x86 Images] tab, choose **Nougat/API Level 25/ABI x86_64/Android 7.1.1(NO Google APIs)**, then click [Next].
NOTE: Download the system image if you need it.
- 6) Set the AVD name to “AstrobeeAndroidSim”.
- 7) Click [Finish].

In the Android Virtual Device Manager window, you will see “AstrobeeAndroidSim” in the list.

Click the Play button in the Action column. If the AVD launches successfully, the following image is displayed.

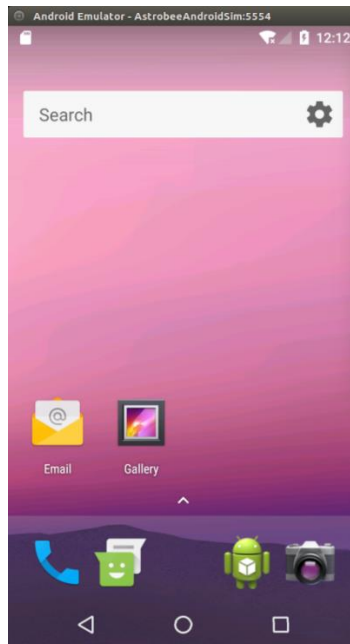


Figure 4.6-2 Android emulator screen

4.6.5. Building the Guest Science Manager APK

To run your program, you must install the Guest Science Manager APK. (Details at https://github.com/nasa/astrobee_android/blob/5b07e4d626781a6f7e0a9cdf4397375cbe509803/guest_science_readme.md)

Execute the following commands in order to build the Guest Science Manager APK.

```
cd $ANDROID_PATH/core_apks/guest_science_manager
$ ANDROID_HOME=$HOME/Android/Sdk ./gradlew assembleDebug
```

4.6.6. Setting up the network

Setup the network between the Astrobee Simulator and the Android Emulator.

(1) Setting the HOST network

Execute the following commands to open the host file.

```
sudo nano /etc/hosts
```

Add 3 lines bellow to the host file and save.

```
10.42.0.36      hlp
10.42.0.35      mlp
10.42.0.34      llp
```

(2) Setting the environment variables

Execute the following commands to set the environment variables.

```
export ANDROID_PATH="${SOURCE_PATH}_android"
export EMULATOR=$HOME/Android/Sdk/tools/emulator
export AVD=" AstrobeeAndroidSim"
```

Note that you need to execute the above commands whenever you open a terminal. If you write thees commands in your `.bashrc` file, you don't have to execute them.

(3) Setting up the Android network and starting the Android Emulator

Execute the following commands to set up the Android network and launch the Android Emulator.

```
cd $ANDROID_PATH/scripts  
./launch_emulator.sh -n
```

4.6.7. Installing APKs

If the Android Emulator is not running, execute the following commands to start it.

```
cd $ANDROID_PATH/scripts  
./launch_emulator.sh -n
```

In another terminal, execute the following commands to install the Guest Science Manger APK and your GS APK.

```
cd $ANDROID_PATH/core_apks/guest_science_manager  
adb install -g -r activity/build/outputs/apk/activity-debug.apk  
cd <YOUR_APK_PATH>  
adb install -g -r app/build/outputs/apk/app-debug.apk
```

4.6.8. Setting QR codes, an AR tag, and the target

Set QR codes, an AR tag and the target in the Astrobeer Simulator in the following steps.

- 1) Download Kibo-RPC_SimExtMod.zip from the Download page on the Web site.
- 2) Extract the zip file to directory you want.
- 3) Execute the following commands.

```
cd <SETUP MODULE DIR>  
chmod +x setup.sh  
./setup.sh
```

4.6.9. Running your program

It's time to run your program!

(1) Launching the Android Emulator

Execute the following commands to launch the Android Emulator.

```
cd $ANDROID_PATH/scripts  
./launch_emulator.sh -n
```

(2) Starting the Astrobees Simulator

Before starting the Astrobees Simulator, execute the following commands to set the ROS Environment Variables on the other terminal.

```
export ROS_IP=$(getent hosts llp | awk '{ print $1 }')  
export ROS_MASTER_URI=http://${ROS_IP}:11311
```

Execute the following command to start the Astrobees Simulator.

```
roslaunch astrobees sim.launch dds:=false robot:=sim_pub rviz:=true
```




(3) Running the Guest Science Manager APK and GS APK

Execute the following commands to set the ROS Environment Variables on the other terminal again.

```
export ROS_IP=$(getent hosts llp | awk '{ print $1 }')  
export ROS_MASTER_URI=http://${ROS_IP}:11311
```

Execute the following commands to start the Guest Science Manager APK and to launch the GDS simulator.

```
$ANDROID_PATH/scripts/gs_manager.sh start  
cd $SOURCE_PATH/tools/gds_helper/src  
python gds_simulator.py
```

Operate the GDS simulator to run your GS APK.

- 1) Press any key to grab control
- 2) Select your GS APK.
- 3) Type **b** and press **Enter** to start the GS APK.
- 4) Type **d** and press **Enter** to send a custom guest science command.

Then Astrobees starts to locate the leak!

5. Programming tips

5.1. Do NOT write infinite loops

You **must not** write any infinite loops in your code because no one can stop AstrobEE while the loop is executing.

You should use finite loops with a defined counter value as shown below.

```
// NG
while(!result.hasSucceeded()){
    // do something
}

// OK
final int LOOP_MAX = 5;
int loopCounter = 0;
while(!result.hasSucceeded() && loopCounter < LOOP_MAX){
    // do something
    ++loopCounter;
}
```



5.2. Dealing with randomness

You must consider the randomness of the environment.

When you want to move robot below...

```
// move to point 1
api.moveTo(point1, quaternion1, true);
// move to point 2
api.moveTo(point2, quaternion2, true);
// move to point 3
api.moveTo(point3, quaternion3, true);
```

If there is no randomness in the environment, this code works well.

However, Astrobees may be faced with errors such as **tolerance violations** and your code will not work.

So, you have to provide the redundant code as we see below.

Remember, **Do NOT** allow any infinite loops in your code!

```
Result result;
final int LOOP_MAX = 5;

// move to point 1(first try)
result = api.moveTo(point1, quaternion1, true);

// check result and loop while moveTo api is not succeeded.
// Do NOT write infinite loop.
int loopCounter = 0;
while(!result.hasSucceeded() && loopCounter < LOOP_MAX){

    // retry
    result = api.moveTo(point1, quaternion1, true);
    ++loopCounter;

}
// move to point 2
//...
```

5.3. Camera parameters

If you would like to use camera parameters, you can use the ones given below.

```
camera_matrix:
  rows: 3
  cols: 3
  data: [344.173397, 0.000000, 630.793795, 0.000000, 344.277922, 487.033834, 0.000000,
0.000000, 1.000000]
distortion_model: plumb_bob
distortion_coefficients:
  rows: 1
  cols: 5
  data: [-0.152963, 0.017530, -0.001107, -0.000210, 0.000000]
```

5.4. About navigation error

The real world always has uncertainties. Navigation error is one of them and Kibo-RPC simulator server simulates it.

However, modeling and simulating navigation error completely are complicated and the calculation load becomes higher, therefore random error following gaussian distribution is used generally.

Kibo-RPC simulator also implements gaussian distribution and the parameters are as follows;

```
Regarding position;
  x: mean = 0 m and 3sigma = 0.1 m
  y: mean = 0 m and 3sigma = 0.1 m
  z: mean = 0 m and 3sigma = 0.1 m
Regarding orientation;
  x: mean = 0 degree and 3sigma = 3 degree
  y: mean = 0 degree and 3sigma = 3 degree
  z: mean = 0 degree and 3sigma = 3 degree
```

You have to consider that self-position and self-orientation obtained from API (getTrustedRobotKinematics and getTrustedRobotKinematics) includes these error.



6. Simulator change log

Ver.1.0	Initial Release
Ver.2.0	Add airflow module as a disturbance element. Add Keep In Zone and Keep Out Zone. Add simulation playback function. Visualize of planned path and actual path.
Ver.2.1	Add navigation error as a random factor.

* The version which will be used in preliminary round is the latest version.