

# ROS机械臂开发：从入门到实战

—— 第9讲：“手眼”结合完成物体抓取应用






主讲人 胡春旭



机器人博客“古月居”博主  
《ROS机器人开发实践》作者  
武汉精锋微控科技有限公司 联合创始人  
华中科技大学 自动化学院 硕士



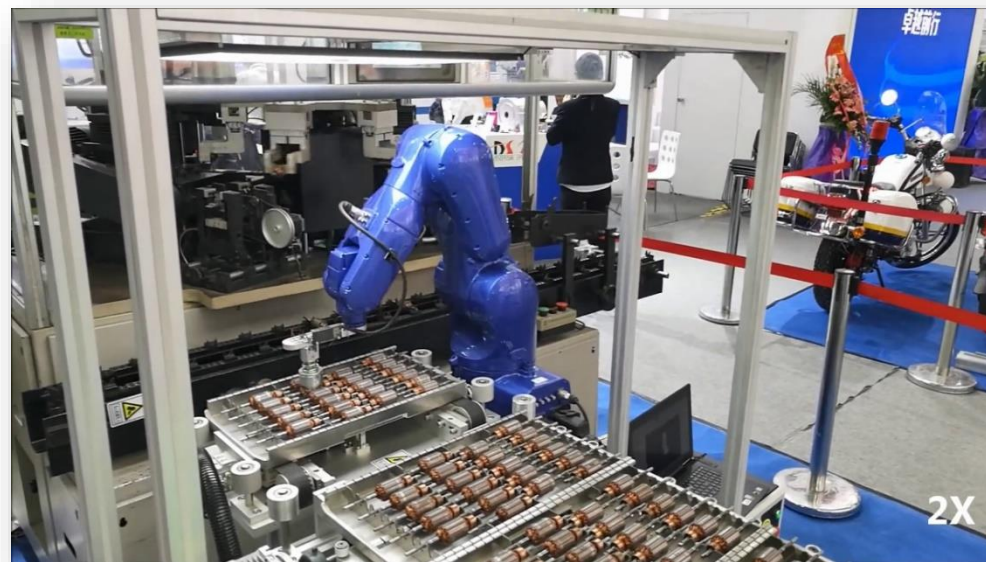
-  1. 视觉抓取中的关键技术
-  2. 手眼标定
-  3. 机械臂视觉抓取案例



# 1. 视觉抓取中的关键技术

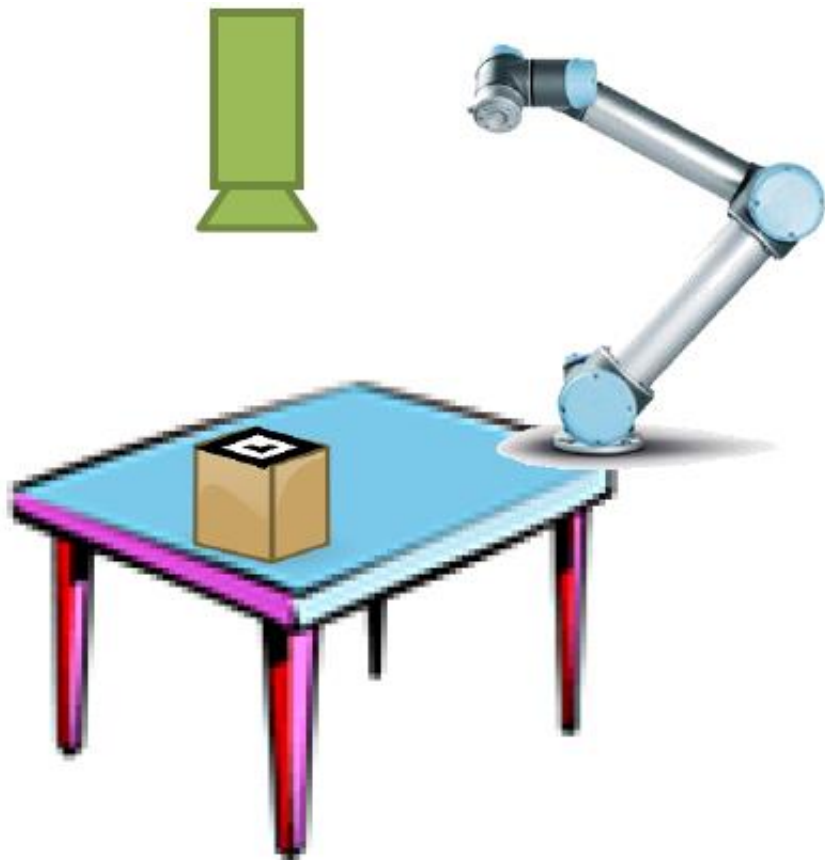


# 1. 视觉抓取中的关键技术





# 1. 视觉抓取中的关键技术



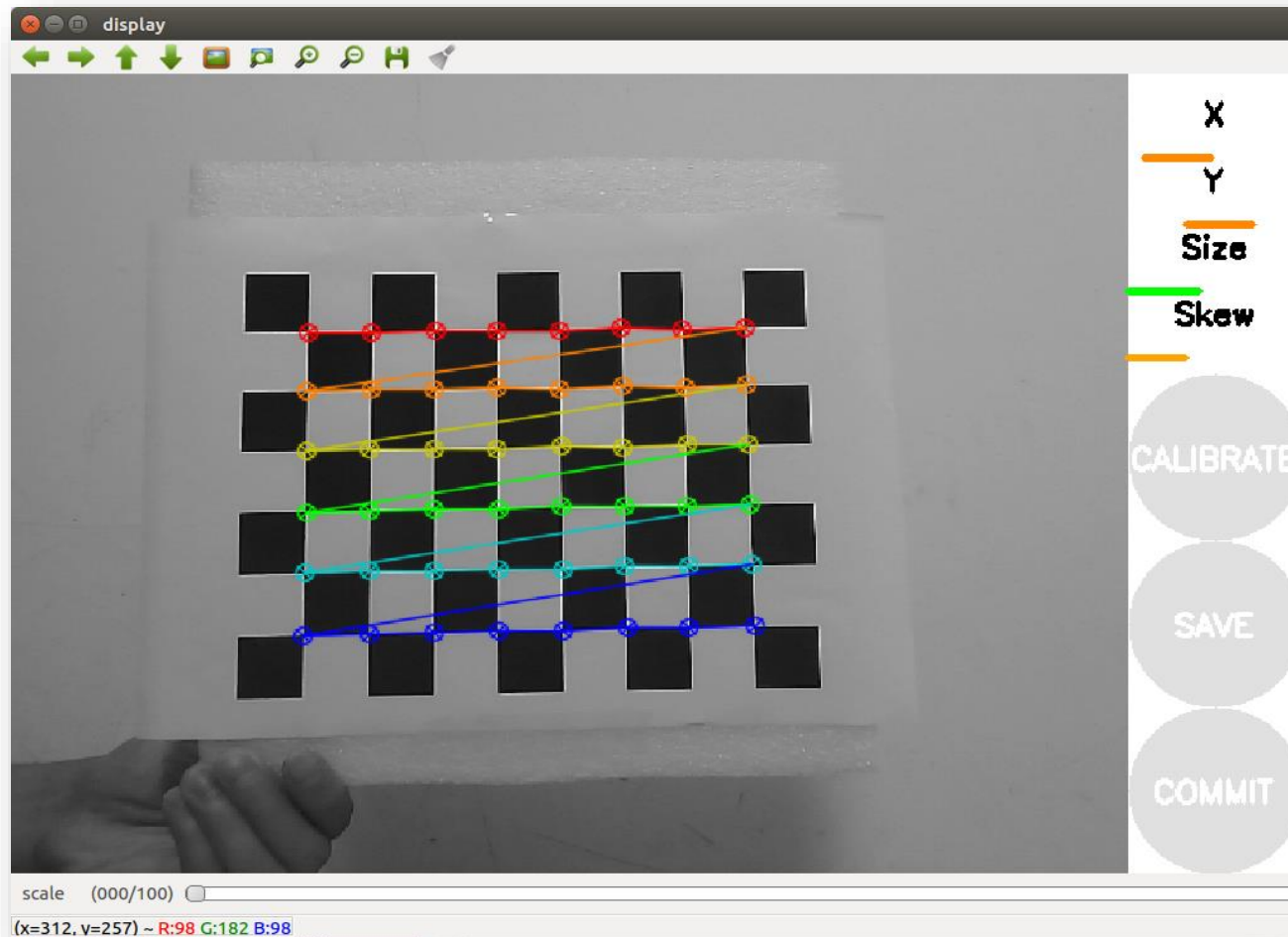
- 手眼标定（内参、外参）
- 物体识别与定位
- 抓取姿态分析
- 运动规划



# 1. 视觉抓取中的关键技术



内参标定

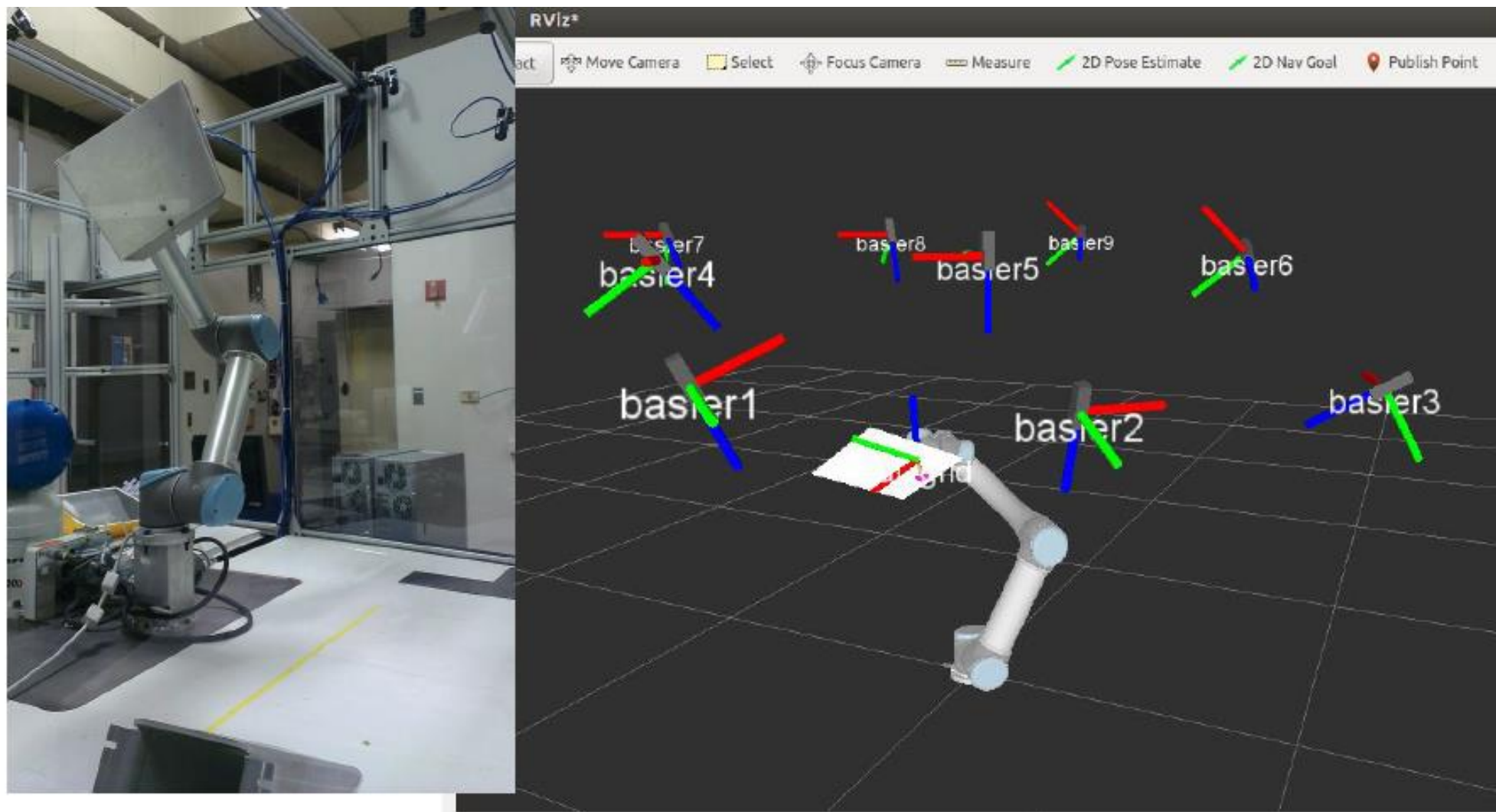


camera\_calibration: [http://wiki.ros.org/camera\\_calibration/](http://wiki.ros.org/camera_calibration/)



# 1. 视觉抓取中的关键技术

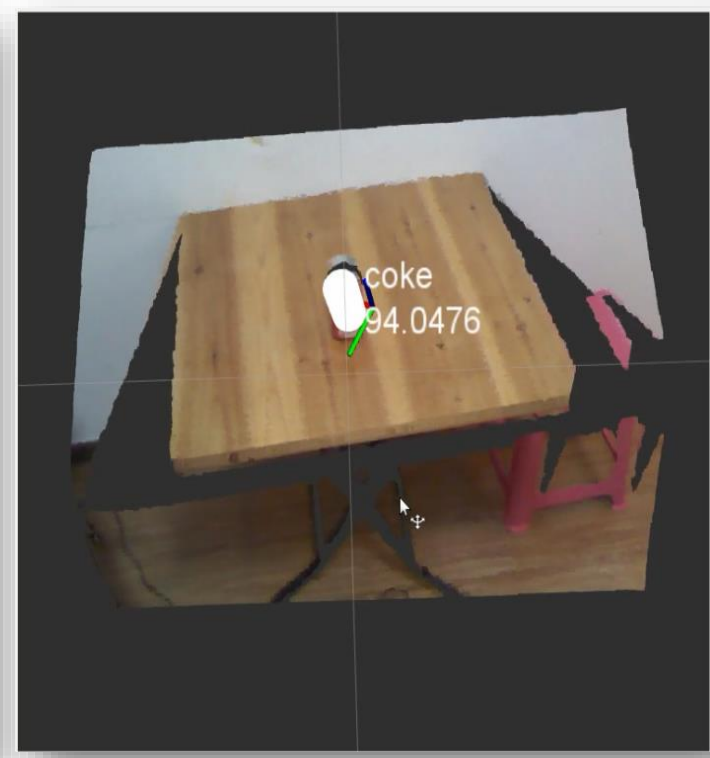
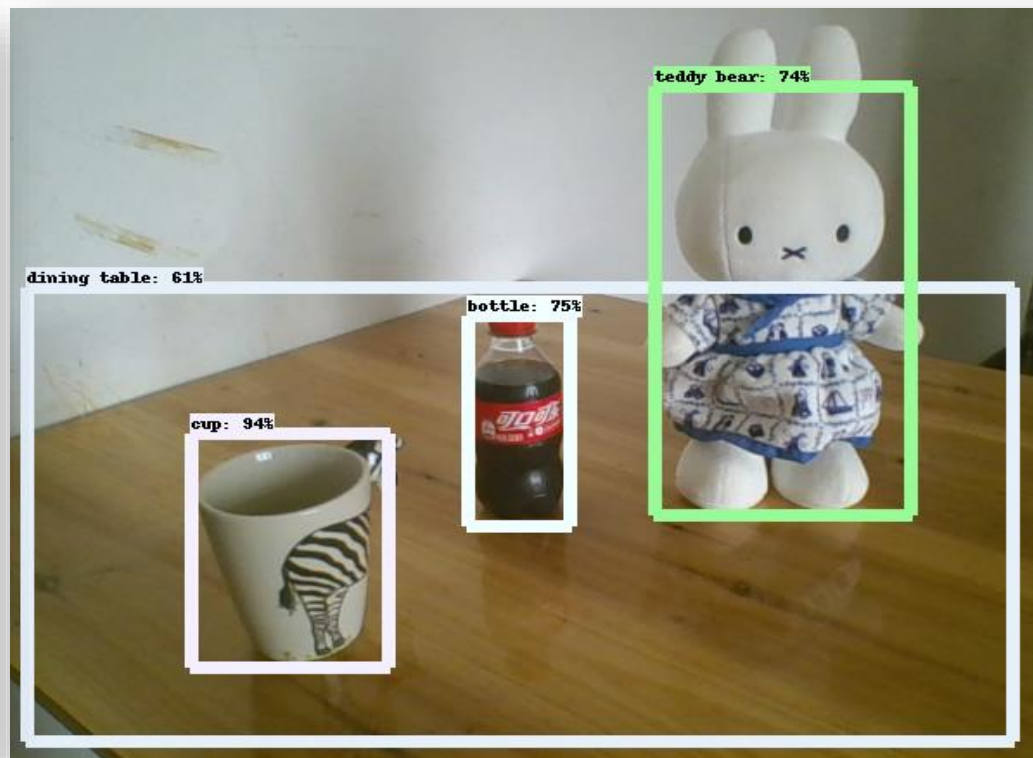
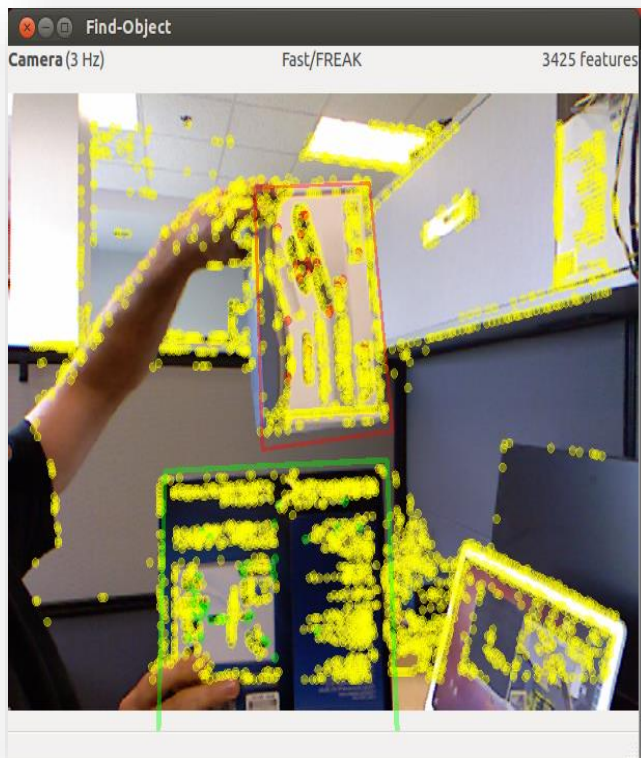
## 外参标定



visp\_hand2eye\_calibration: [http://wiki.ros.org/visp\\_hand2eye\\_calibration](http://wiki.ros.org/visp_hand2eye_calibration)  
ros\_easy\_handeye: [https://github.com/IFL-CAMP/easy\\_handeye](https://github.com/IFL-CAMP/easy_handeye)



# 1. 视觉抓取中的关键技术



## 物体识别与定位

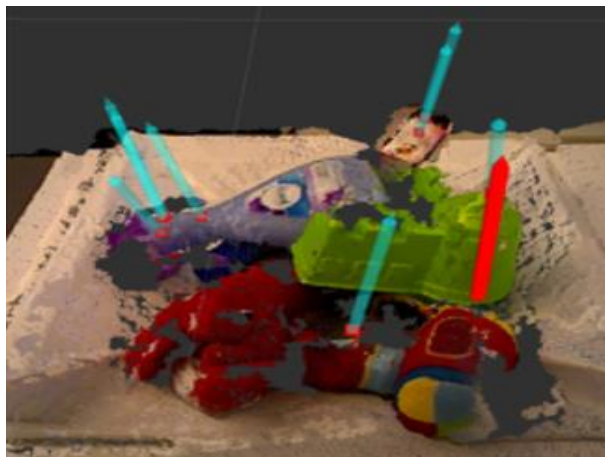
find\_object\_2d: [http://wiki.ros.org/object\\_recognition](http://wiki.ros.org/object_recognition)

Tensorflow Object Detection API: [https://github.com/tensorflow/models/tree/master/research/object\\_detection](https://github.com/tensorflow/models/tree/master/research/object_detection)

object\_recognition: [http://wiki.ros.org/object\\_recognition](http://wiki.ros.org/object_recognition)



# 1. 视觉抓取中的关键技术



抓取姿态分析

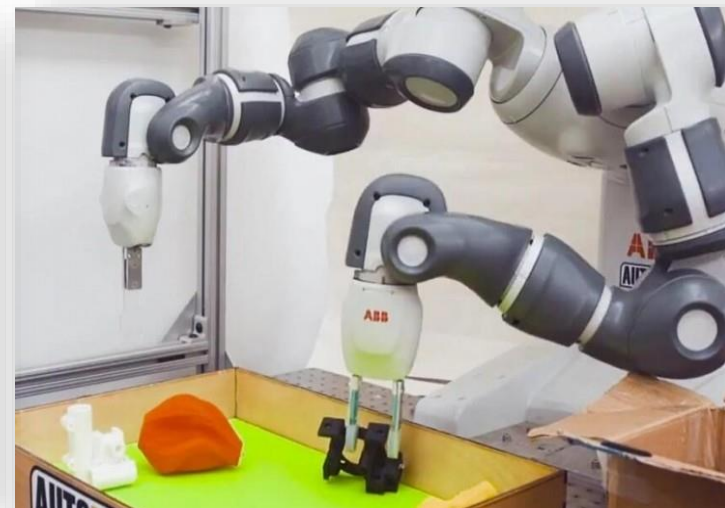
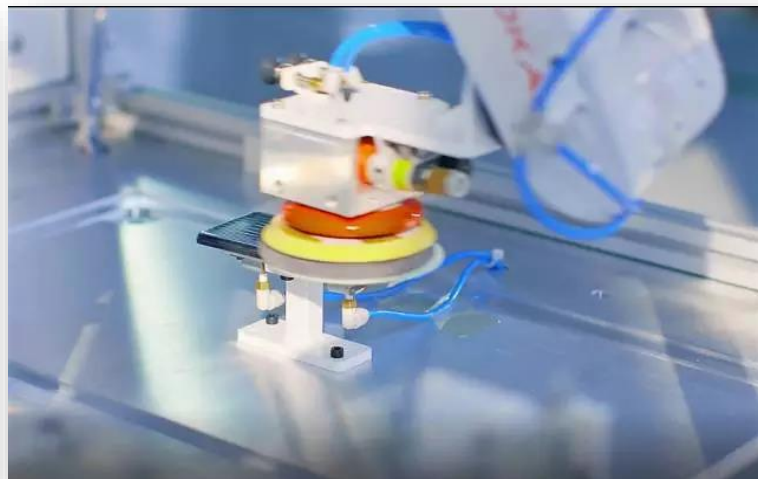
agile\_grasp: [http://wiki.ros.org/agile\\_grasp](http://wiki.ros.org/agile_grasp)

graspit: <http://wiki.ros.org/graspit>

moveit\_simple\_grasps: [http://wiki.ros.org/moveit\\_simple\\_grasps](http://wiki.ros.org/moveit_simple_grasps)



# 1. 视觉抓取中的关键技术



运动规划 (轨迹规划、运动学、动力学、避障)



## 2. 手眼标定

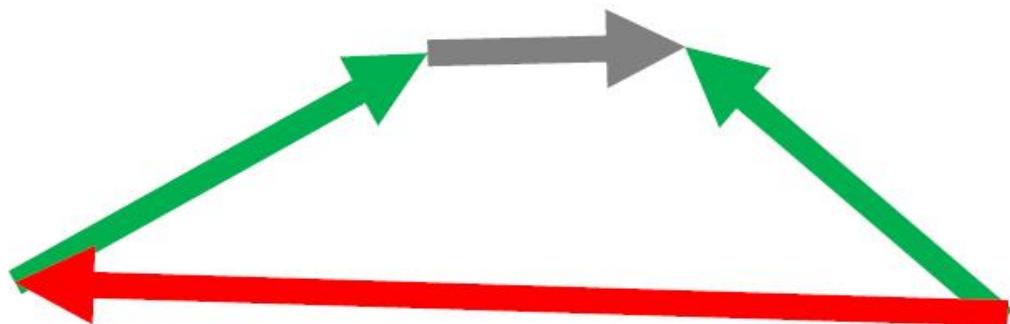


## 2. 手眼标定

eye to hand 眼在外

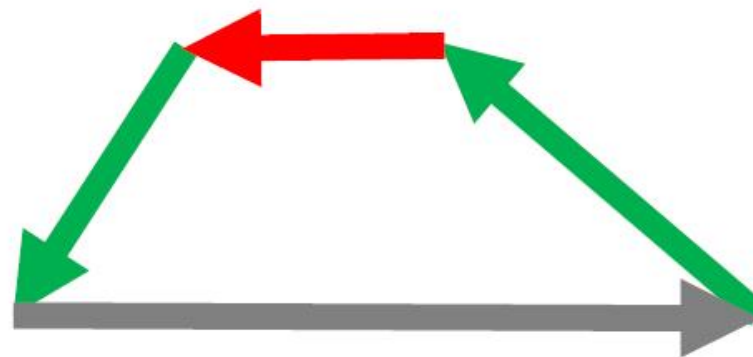


eye in hand 眼在手



Measured

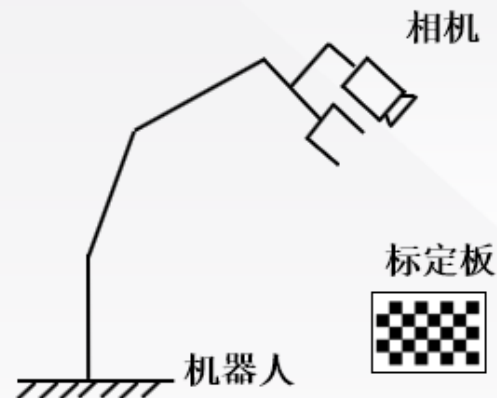
Unknown



Not used



## 2. 手眼标定



Eye In Hand

在 Eye-In-Hand 的配置方式中对于机器人移动过程中任意两个位姿，有以下公式成立：

$${}_{\text{End1}}^{\text{Robot}}T * {}_{\text{Camera1}}^{\text{End1}}T * {}_{\text{Object}}^{\text{Camera1}}T = {}_{\text{End2}}^{\text{Robot}}T * {}_{\text{Camera2}}^{\text{End2}}T * {}_{\text{Object}}^{\text{Camera2}}T$$

上式经过转换后，可得：

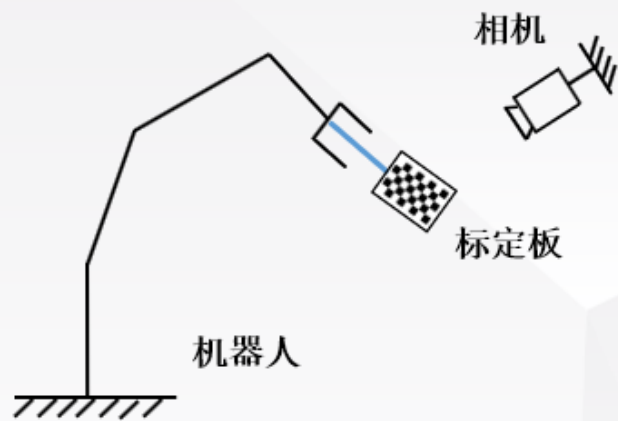
$${}_{\text{End2}}^{\text{Robot}}T^{-1} * {}_{\text{End1}}^{\text{Robot}}T * {}_{\text{Camera1}}^{\text{End1}}T = {}_{\text{Camera2}}^{\text{End2}}T * {}_{\text{object}}^{\text{Camera2}}T * {}_{\text{object}}^{\text{Camera1}}T^{-1}$$

$$\underbrace{{}_{\text{End2}}^{\text{Robot}}T^{-1} * {}_{\text{End1}}^{\text{Robot}}T}_A * \underbrace{{}_{\text{Camera1}}^{\text{End1}}T}_X = \underbrace{{}_{\text{Camera2}}^{\text{End2}}T * {}_{\text{object}}^{\text{Camera2}}T}_X * \underbrace{{}_{\text{object}}^{\text{Camera1}}T^{-1}}_B$$

\* 参考：<https://blog.csdn.net/yaked/article/details/77161160>



## 2. 手眼标定



Eye To Hand

在 Eye-To-Hand 的配置方式中对于机器人夹着标定板移动任意两个位姿，有以下公式成立：

$${}_{\text{Robot1}}^{\text{End}} T * {}_{\text{Camera1}}^{\text{Robot1}} T * {}_{\text{Object}}^{\text{Camera1}} T = {}_{\text{Robot2}}^{\text{End}} T * {}_{\text{Camera2}}^{\text{Robot2}} T * {}_{\text{Object}}^{\text{Camera2}} T$$

上式经过转换后，可得：

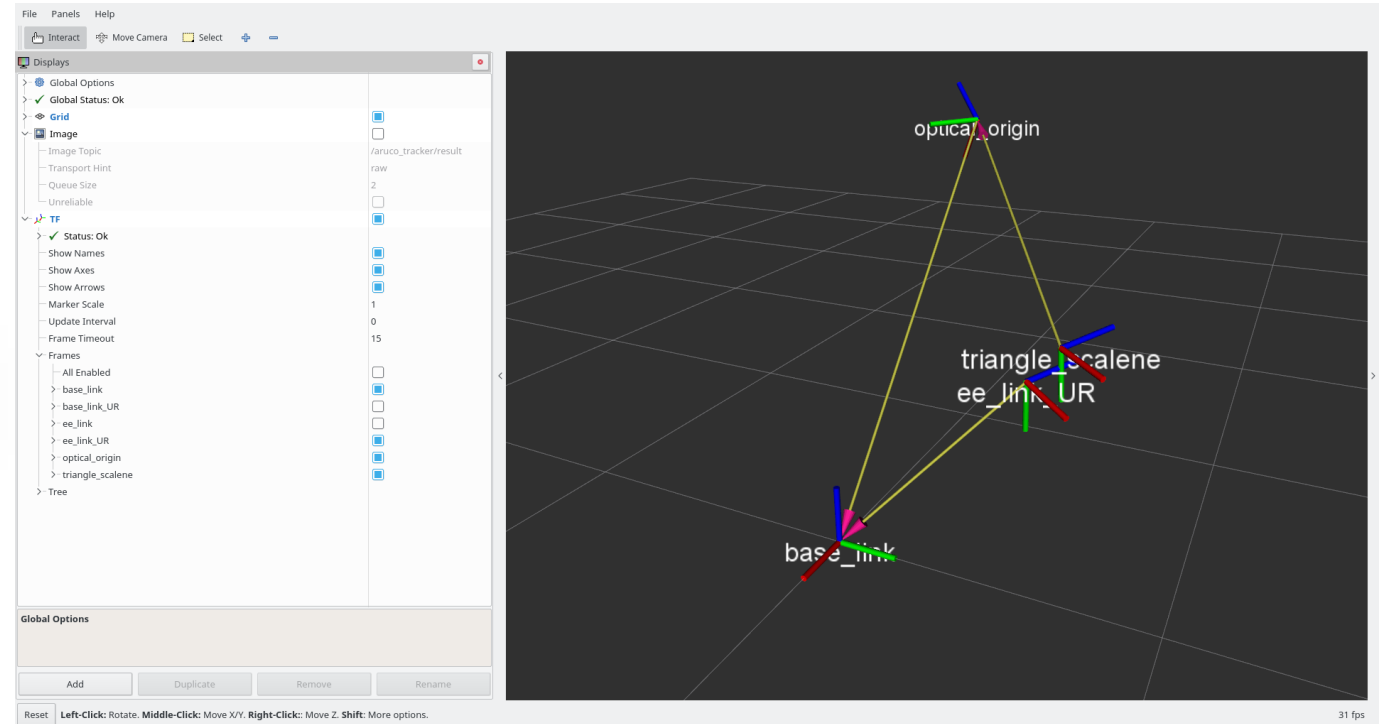
$${}_{\text{Robot2}}^{\text{End}} T^{-1} * {}_{\text{Robot1}}^{\text{End}} T * {}_{\text{Camera1}}^{\text{Robot1}} T = {}_{\text{Camera2}}^{\text{Robot2}} T * {}_{\text{Object}}^{\text{Camera2}} T * {}_{\text{Object}}^{\text{Camera1}} T^{-1}$$

$$\underbrace{{}_{\text{Robot2}}^{\text{End}} T^{-1} * {}_{\text{Robot1}}^{\text{End}} T}_A * \underbrace{{}_{\text{Camera1}}^{\text{Robot1}} T}_X = \underbrace{{}_{\text{Camera2}}^{\text{Robot2}} T}_X * \underbrace{{}_{\text{Object}}^{\text{Camera2}} T * {}_{\text{Object}}^{\text{Camera1}} T^{-1}}_B$$

\* 参考：<https://blog.csdn.net/yaked/article/details/77161160>



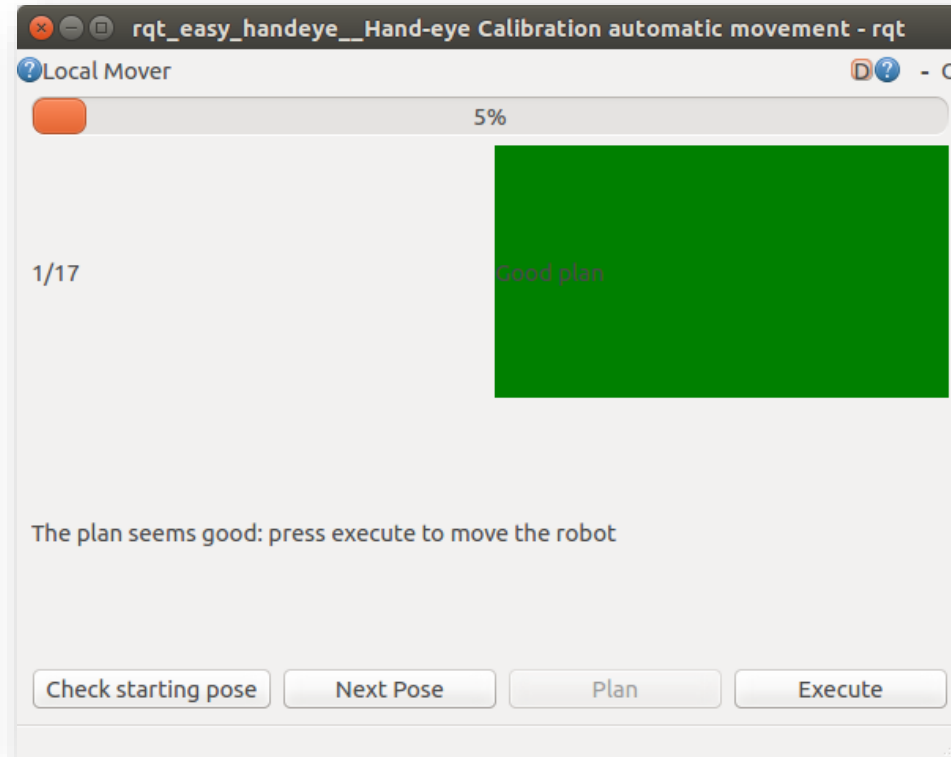
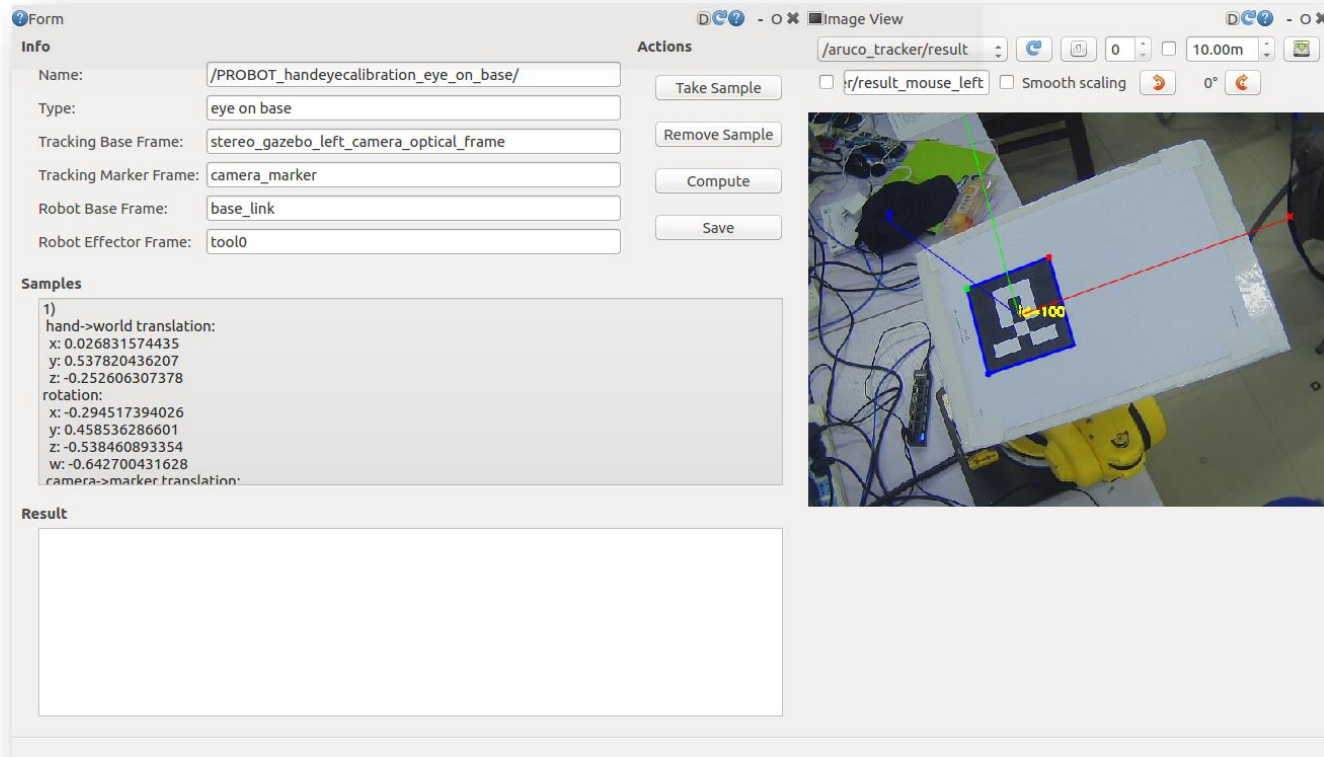
# easy\_handeye: TF / VISP Hand-Eye Calibration



[https://github.com/IFL-CAMP/easy\\_handeye](https://github.com/IFL-CAMP/easy_handeye)



## 2. 手眼标定



### easy\_handeye可视化标定过程

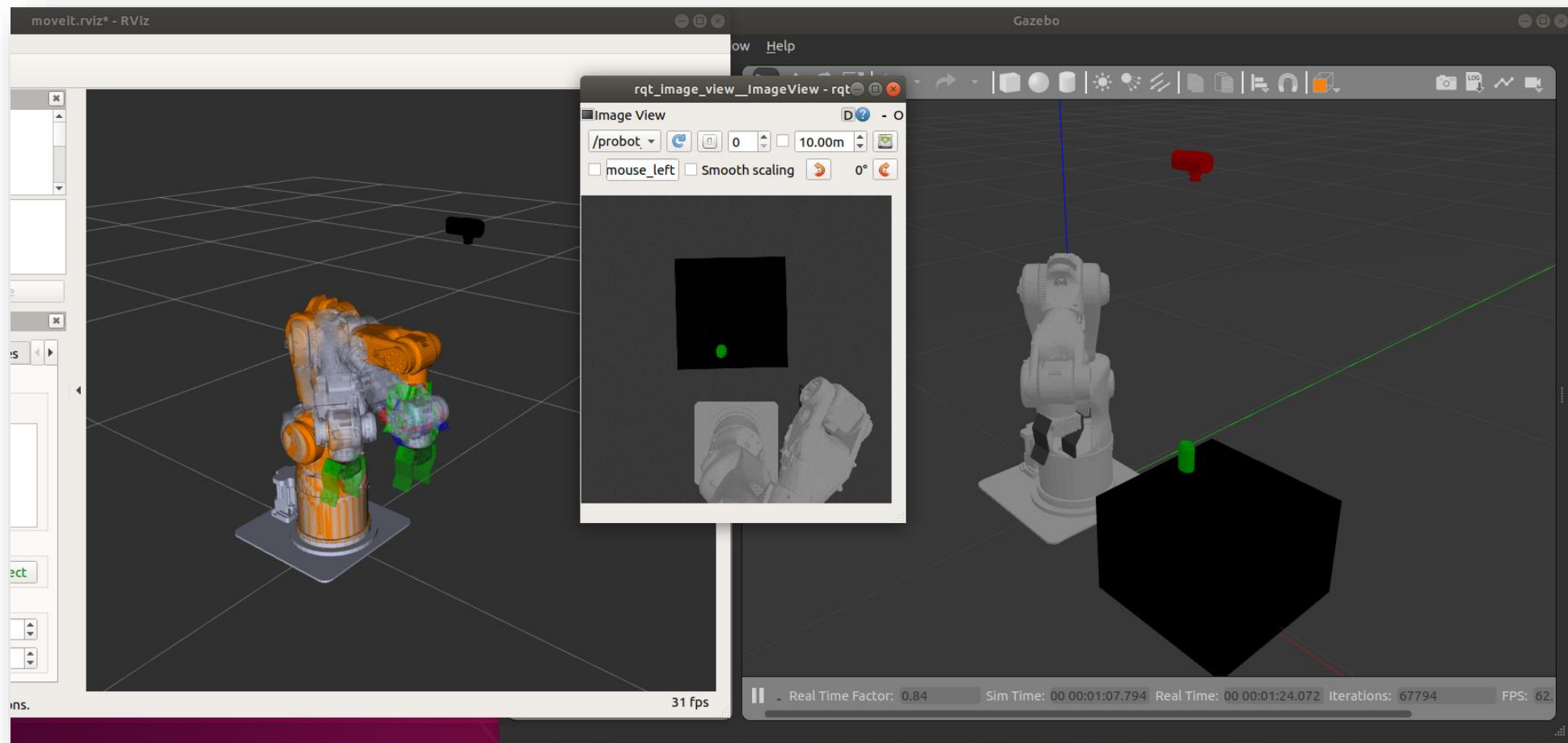
\* 参考：《PROBOT Anno手眼标定步骤（easy\_handeye-眼在外）》



## 3. 机械臂视觉抓取案例



### 3. 机械臂视觉抓取案例



视觉抓取例程

```
$ roslaunch probot_grasping probot_anno_grasping_demo.launch
```



### 3. 机械臂视觉抓取案例

```
void GraspingDemo::imageCb(const sensor_msgs::ImageConstPtr &msg)
{
    if (!grasp_running)
    {
        ROS_INFO_STREAM("Processing the Image to locate the Object...");
        try
        {
            cv_ptr = cv_bridge::toCvCopy(msg, sensor_msgs::image_encodings::BGR8);
        }
        catch (cv_bridge::Exception &e)
        {
            ROS_ERROR("cv_bridge exception: %s", e.what());
            return;
        }
    }
}
```

```
// ROS_INFO("Image Message Received");
float obj_x, obj_y;
vMng_.get2DLocation(cv_ptr->image, obj_x, obj_y);
```

获取物体在图像中的位置

```
// Temporary Debugging
std::cout<< " X-Co-ordinate in Camera Frame :" << obj_x << std::endl;
std::cout<< " Y-Co-ordinate in Camera Frame :" << obj_y << std::endl;
```

```
obj_camera_frame.setZ(-obj_y);
obj_camera_frame.setY(-obj_x);
obj_camera_frame.setX(0.45);
```

获取物体在相机坐标系下位置

```
obj_robot_frame = camera_to_robot_ * obj_camera_frame;
grasp_running = true;
```

计算物体在机器人坐标系下位置

```
// Temporary Debugging
std::cout<< " X-Co-ordinate in Robot Frame :" << obj_robot_frame.getX() << std::endl;
std::cout<< " Y-Co-ordinate in Robot Frame :" << obj_robot_frame.getY() << std::endl;
std::cout<< " Z-Co-ordinate in Robot Frame :" << obj_robot_frame.getZ() << std::endl;
```

```
}
```



### 3. 机械臂视觉抓取案例

查询是否存在机器人基坐标系与摄像头坐标系之间的坐标变换

```
try
{
    this->tf_camera_to_robot.waitForTransform("/base_link", "/camera_link", ros::Time(0), ros::Duration(50.0));
}
catch (tf::TransformException &ex)
{
    ROS_ERROR("[adventure_tf]: (wait) %s", ex.what());
    ros::Duration(1.0).sleep();
}

try
{
    this->tf_camera_to_robot.lookupTransform("/base_link", "/camera_link", ros::Time(0), (this->camera_to_robot_));
}

catch (tf::TransformException &ex)
{
    ROS_ERROR("[adventure_tf]: (lookup) %s", ex.what());
}
```

获取机器人基坐标系与摄像头坐标系之间的坐标变换矩阵



### 3. 机械臂视觉抓取案例



PROBOT Anno视觉分拣演示

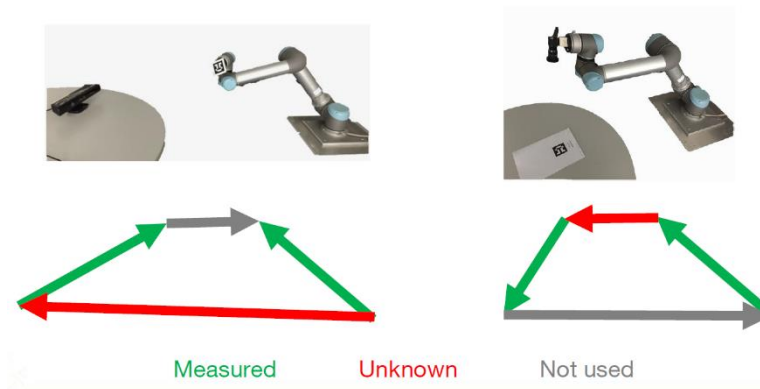


## 视觉抓取中的关键技术

- 手眼标定：相机内参、外参的标定
- 物体识别与定位：物体在什么、物体在哪里
- 抓取姿态分析：如何完成抓取动作
- 运动规划：轨迹规划、运动学、动力学、碰撞检测

## 手眼标定

- 相机位置：
  - eye to hand 眼在外
  - eye in hand 眼在手



## 机械臂视觉抓取案例

- 机器人坐标系、图像坐标系、相机坐标系、工件坐标系之间的关系
- 视觉识别与运动控制的集成

1. 查阅资料，学习“手眼标定”的理论知识；
2. 使用仿真器/真机完成物体位置的识别，并控制机械臂终端运动到物体位置。

- **easy\_handeye**

[https://github.com/IFL-CAMP/easy\\_handeye](https://github.com/IFL-CAMP/easy_handeye)

- **机器人手眼标定**

<https://blog.csdn.net/yaked/article/details/77161160>

- **find\_object\_2d**

[http://wiki.ros.org/object\\_recognition](http://wiki.ros.org/object_recognition)

- **Tensorflow Object Detection API**

[https://github.com/tensorflow/models/tree/master/research/object\\_detection](https://github.com/tensorflow/models/tree/master/research/object_detection)

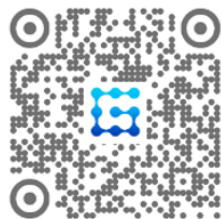
- **Robotics、 Vision and Control, Peter Corke**



# Thank You

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 古月居



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