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古月居 GYH.AI

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

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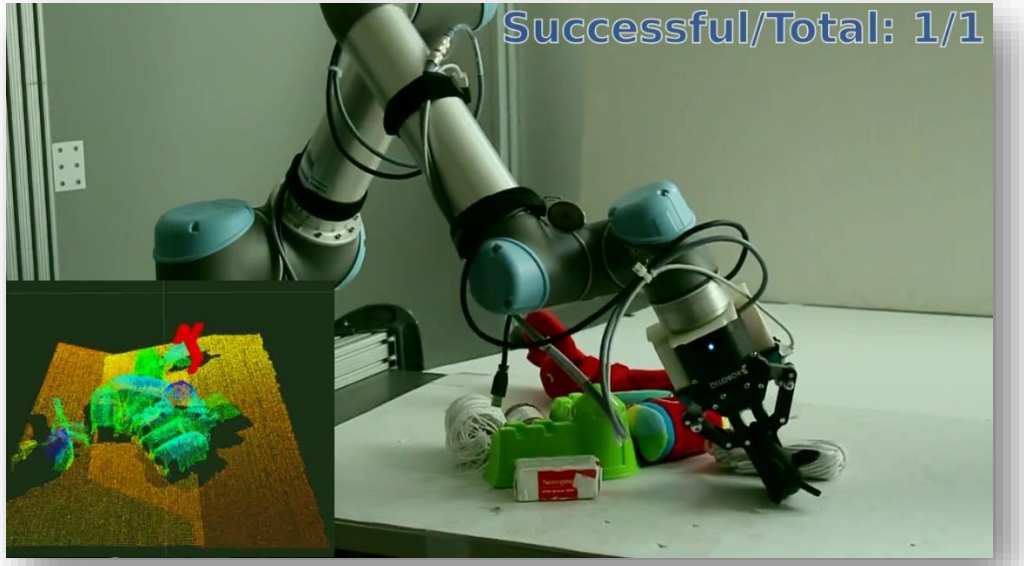
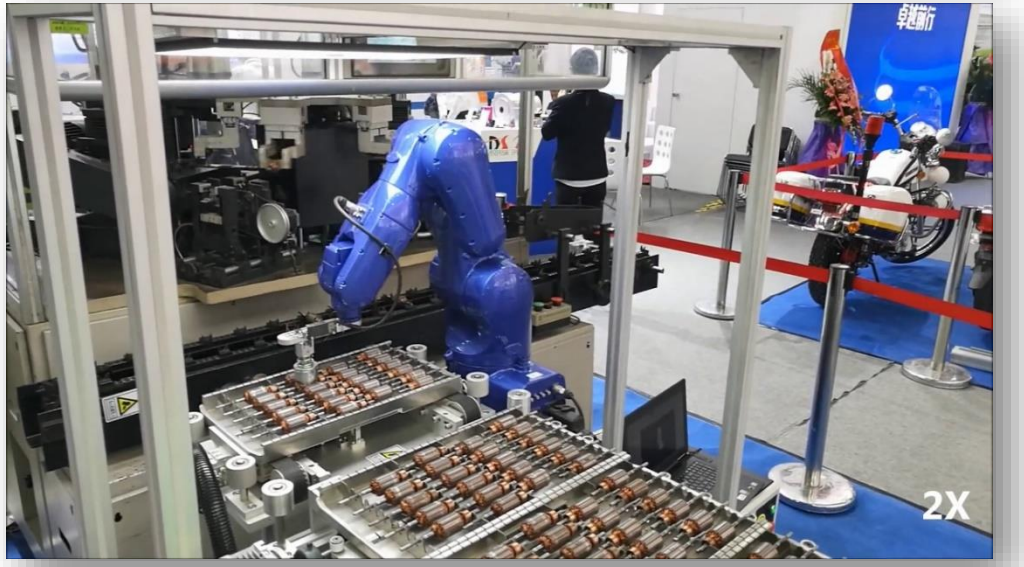
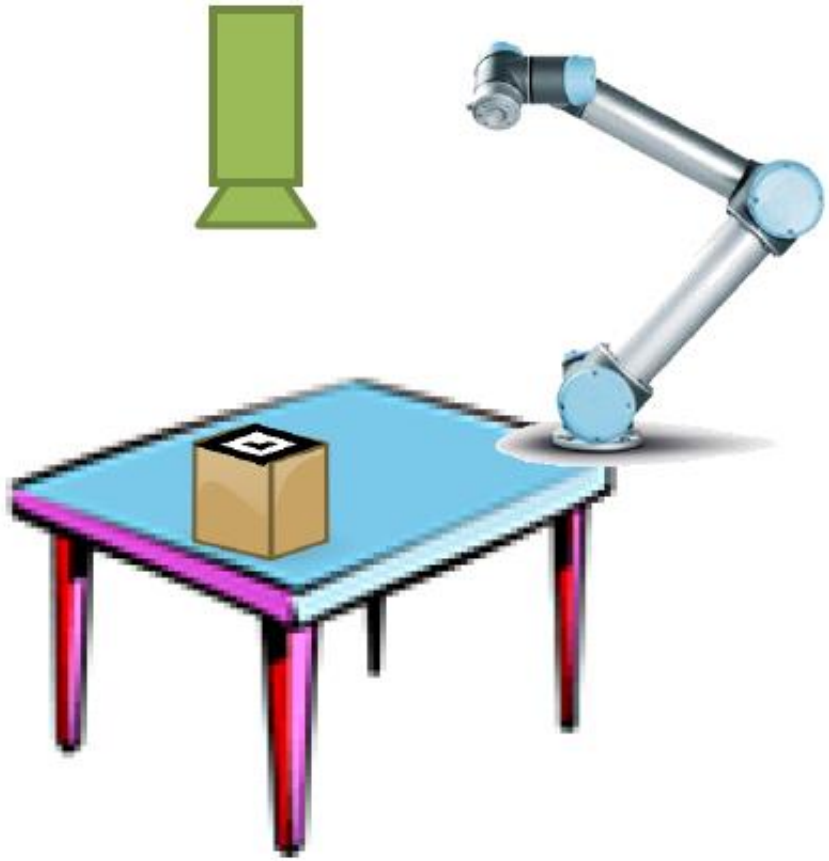
1. 视觉抓取中的关键技术

1. 视觉抓取中的关键技术



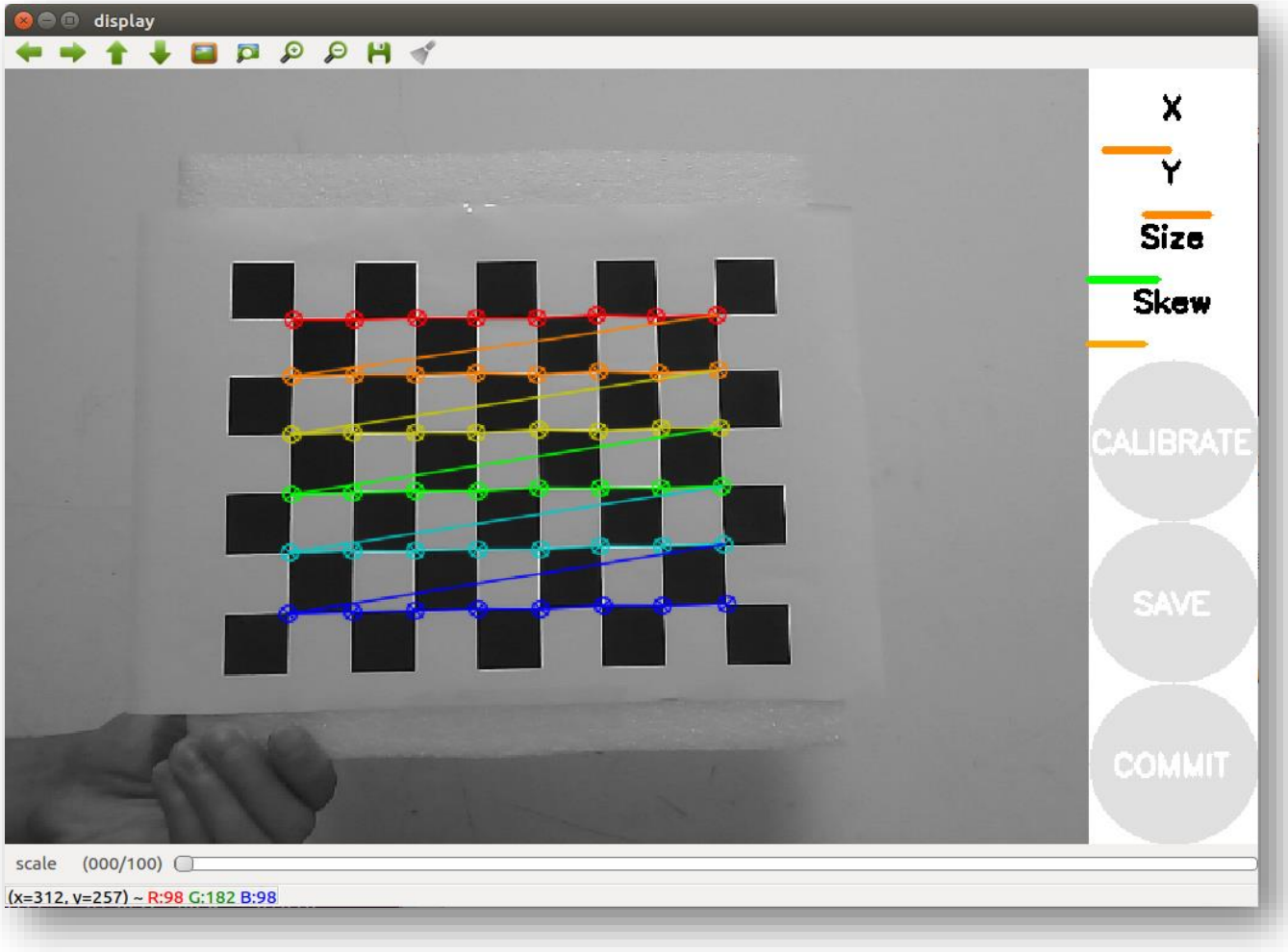


1. 视觉抓取中的关键技术



- 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

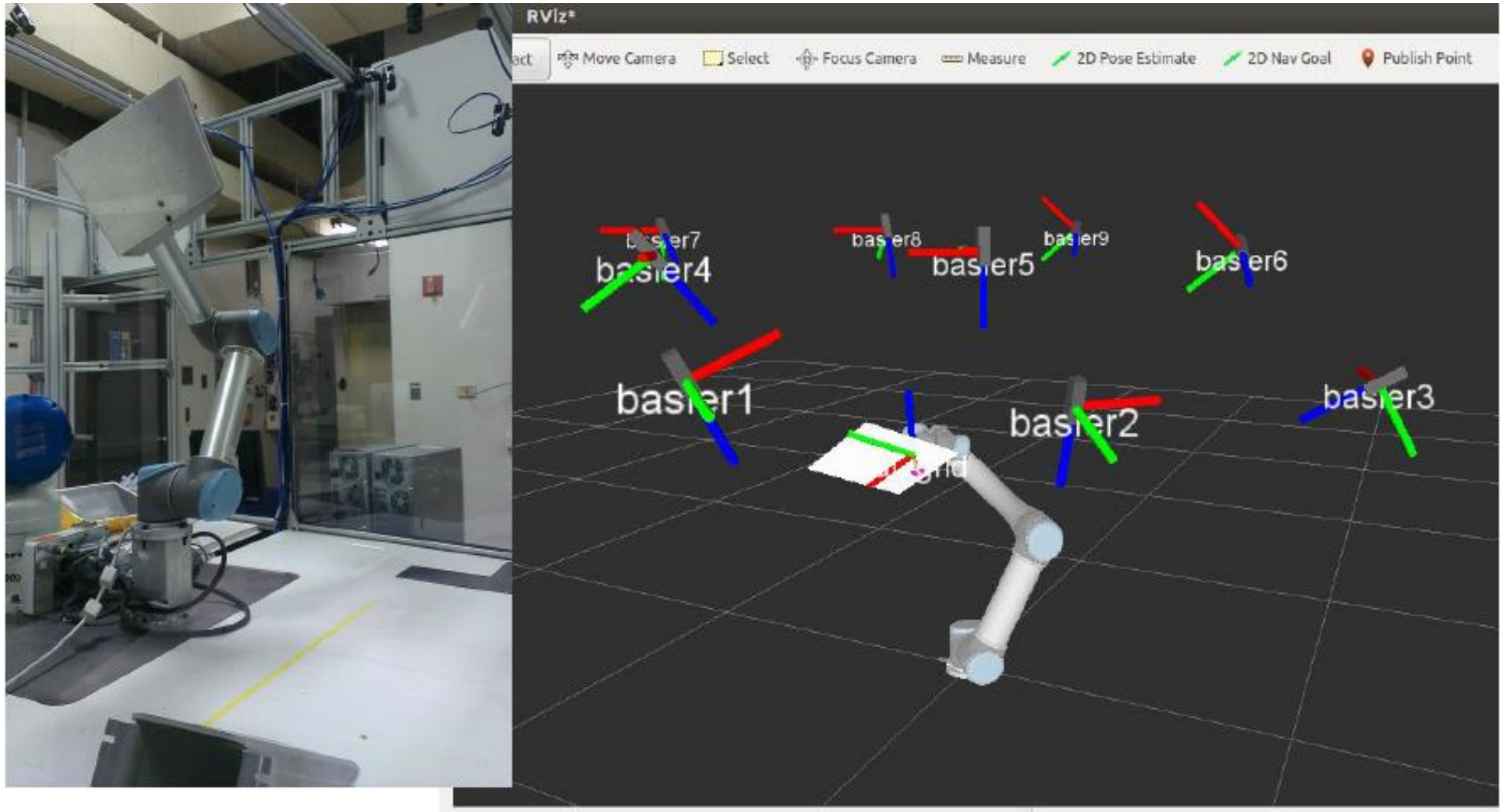
1. 视觉抓取中的关键技术



内参标定　　**camera_calibration：** http://wiki.ros.org/camera_calibration/

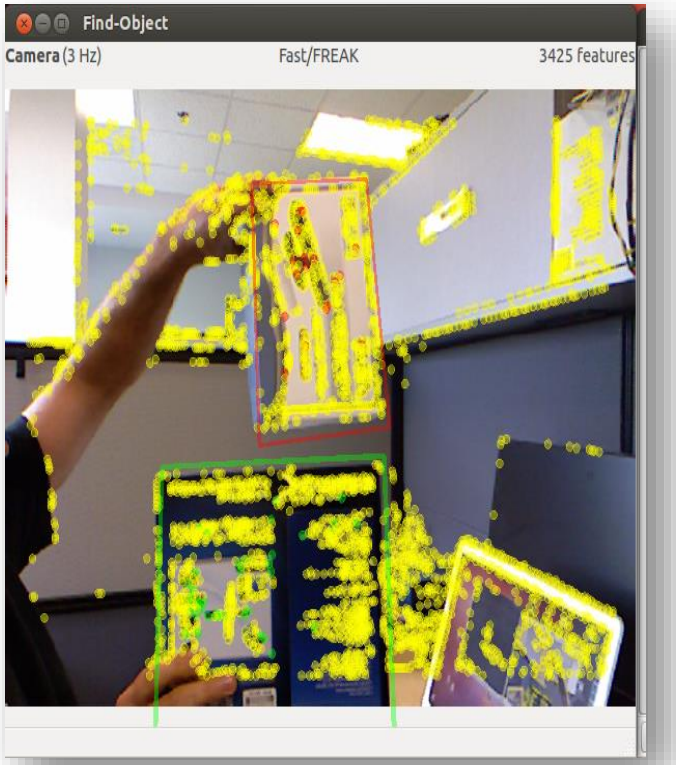
1. 视觉抓取中的关键技术

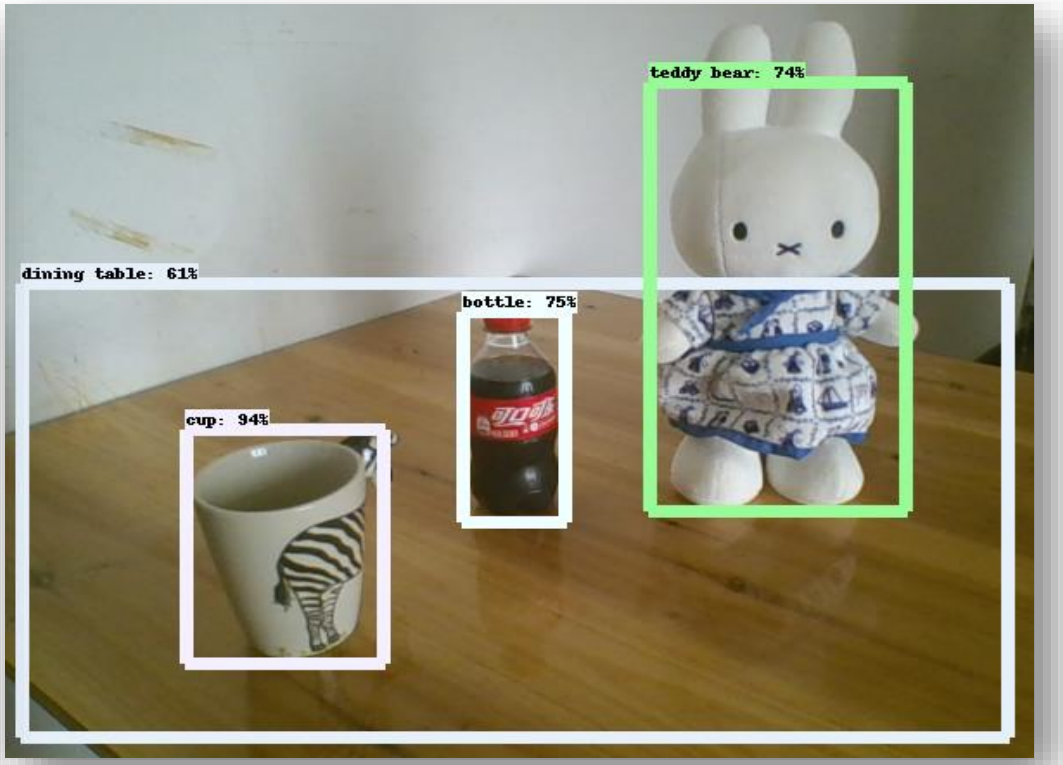
外参标定

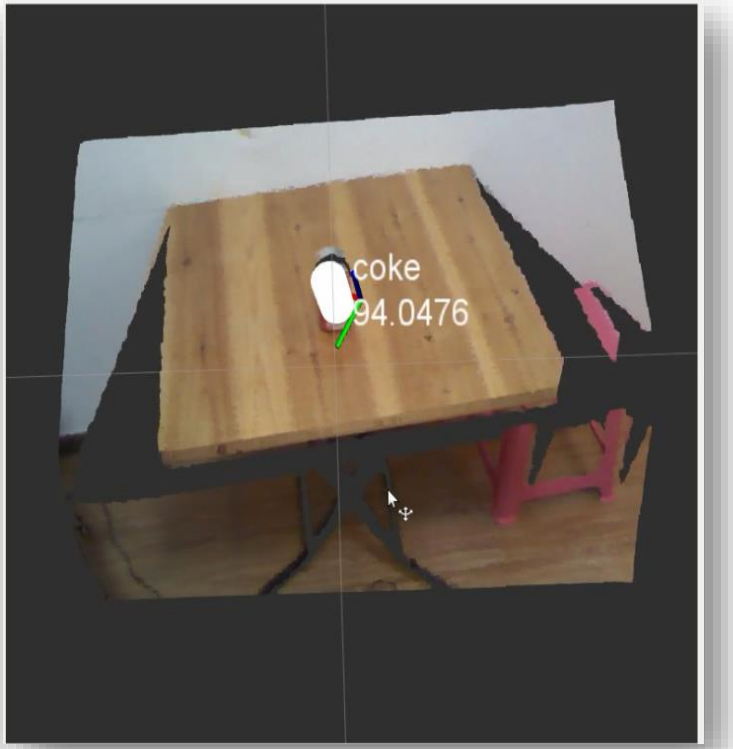


visp_hand2eye_calibration：http://wiki.ros.org/visp_hand2eye_calibration
ros easy_handeye： https://github.com/IFL-CAMP/easy_handeye

1. 视觉抓取中的关键技术



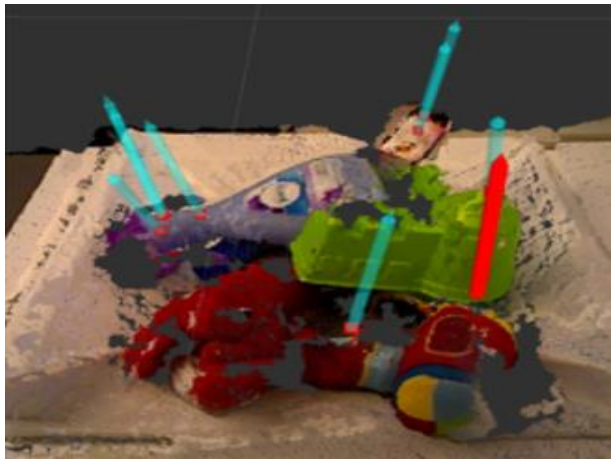


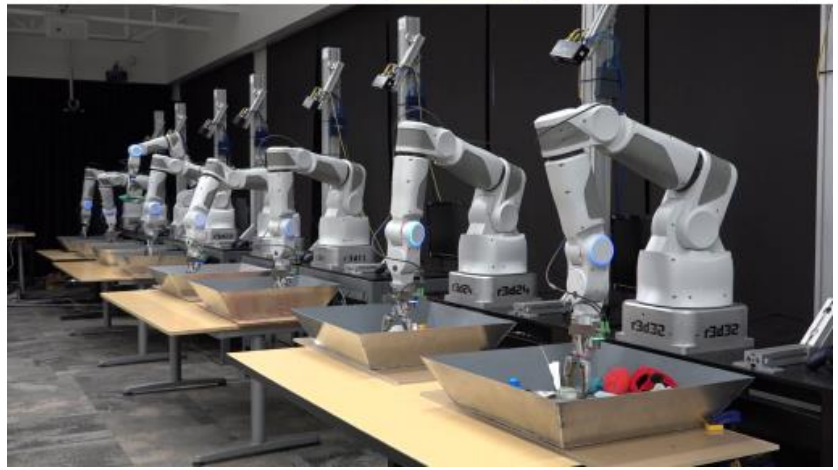


物体识别与定位

find_object_2d：http://wiki.ros.org/object_recognition
Tensorflow Object Detection API：https://github.com/tensorflow/models/tree/master/research/object_detection
object_recognition： http://wiki.ros.org/object_recognition

1. 视觉抓取中的关键技术





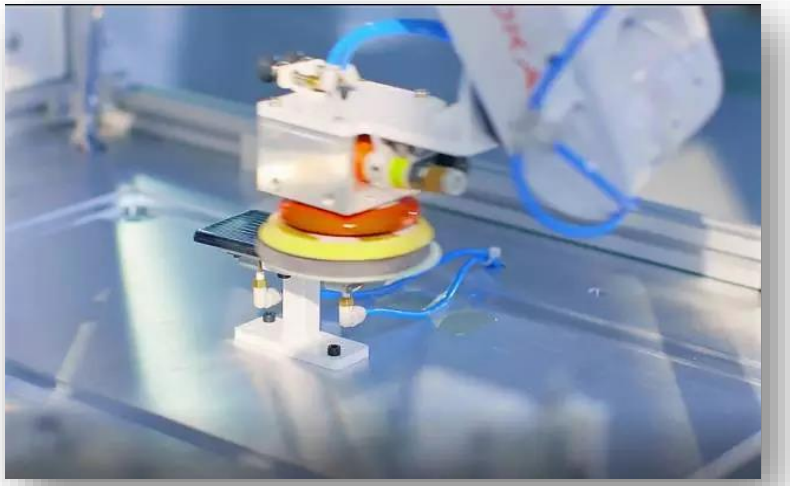
抓取姿态分析

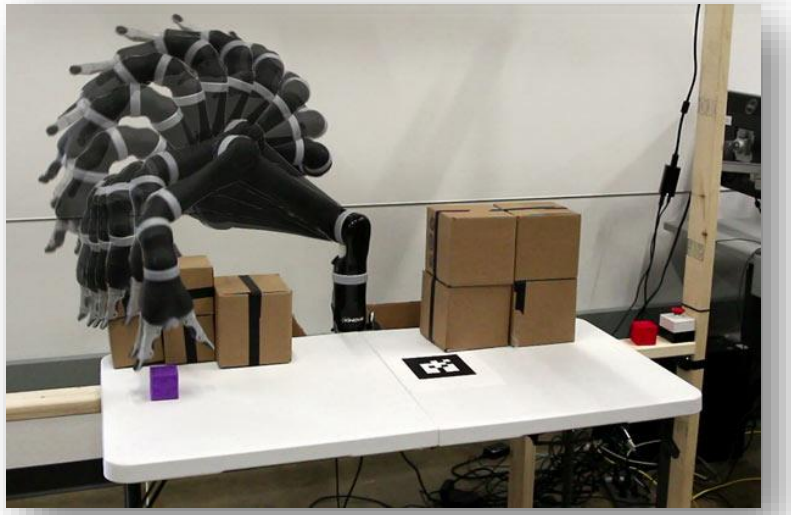
agile_grasp： http://wiki.ros.org/agile_grasp

graspit： http://wiki.ros.org/graspit

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）

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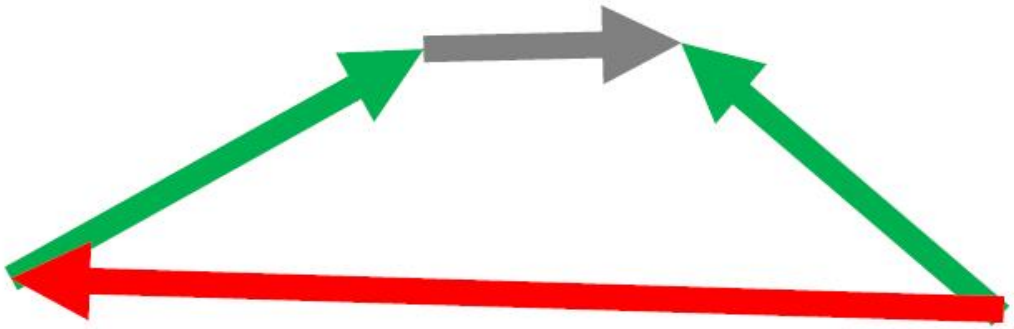
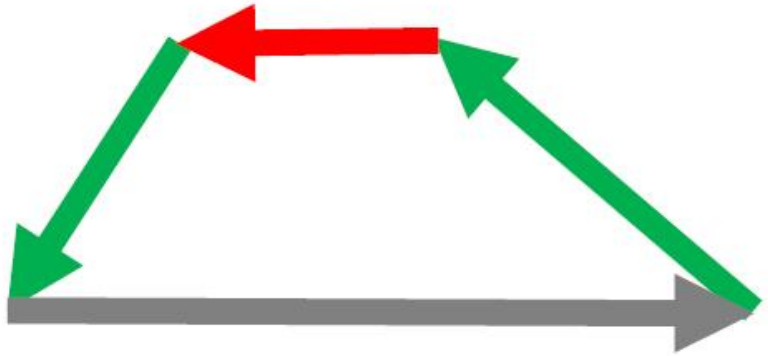
2. 手眼标定

2. 手眼标定

eye to hand 眼在外

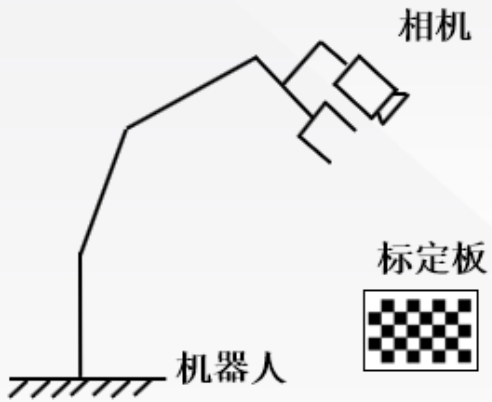


eye in hand 眼在手



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：

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

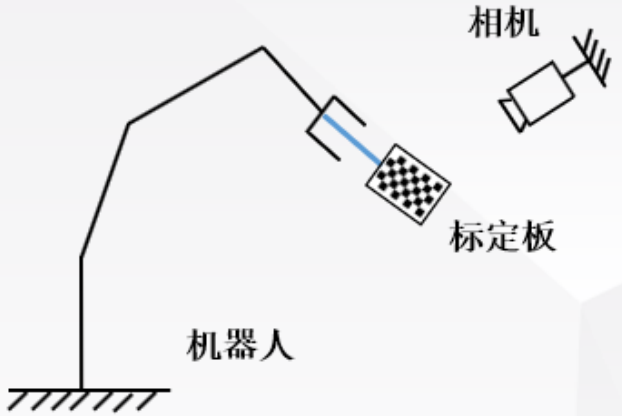
上式经过转换后，可得：

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

$$ A * X = X * B $$

* 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：

$$\underset{\text{Robot1}}{\overset{\text{End}}{T}} * \underset{\text{Camera1}}{\overset{\text{Robot1}}{T}} * \underset{\text{Object}}{\overset{\text{Camera1}}{T}} = \underset{\text{Robot2}}{\overset{\text{End}}{T}} * \underset{\text{Camera2}}{\overset{\text{Robot2}}{T}} * \underset{\text{Object}}{\overset{\text{Camera2}}{T}}$$

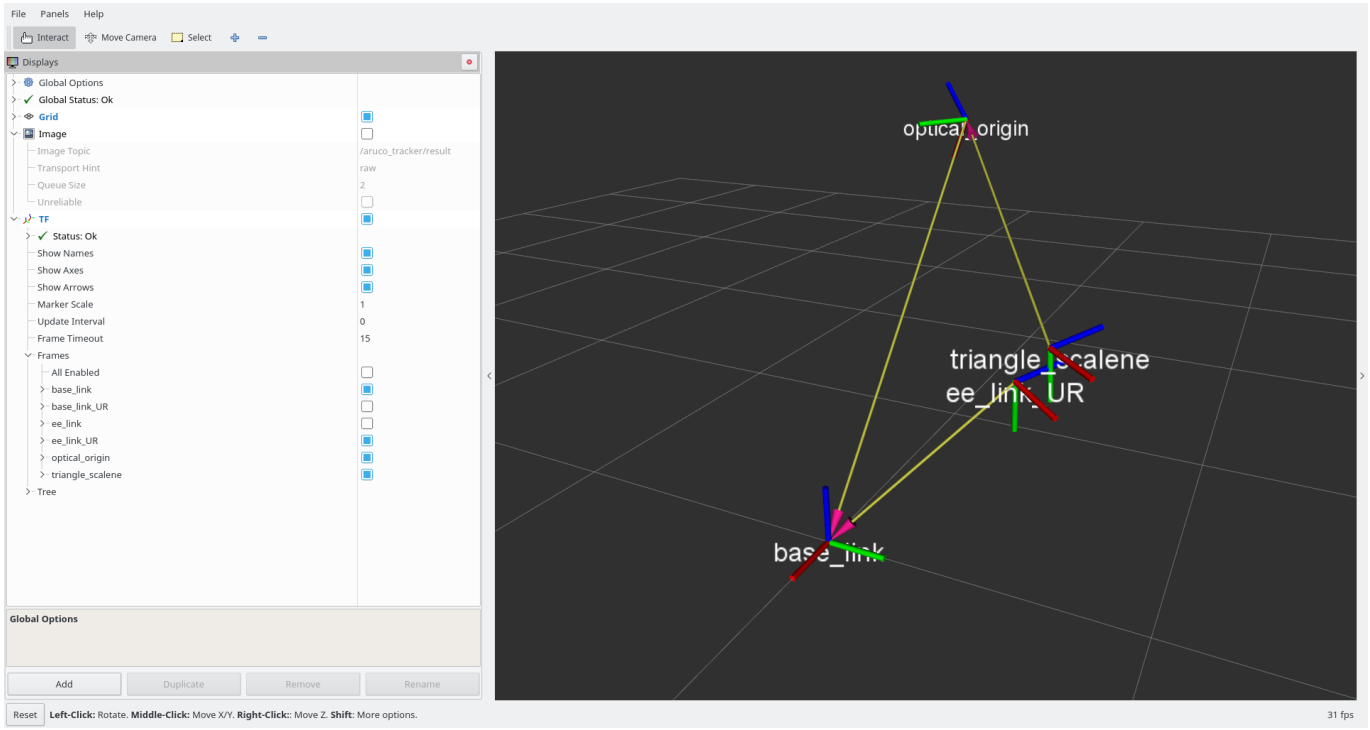
上式经过转换后，可得：

$$\underbrace{\underset{\text{Robot2}}{\overset{\text{End}}{T^{-1}}} * \underset{\text{Robot1}}{\overset{\text{End}}{T}}}_{A} * \underbrace{\underset{\text{Camera1}}{\overset{\text{Robot1}}{T}}}_{X} = \underbrace{\underset{\text{Camera2}}{\overset{\text{Robot2}}{T}}}_{X} * \underbrace{\underset{\text{Object}}{\overset{\text{Camera2}}{T}} * \underset{\text{Object}}{\overset{\text{Camera1}}{T^{-1}}}}_{B}$$

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

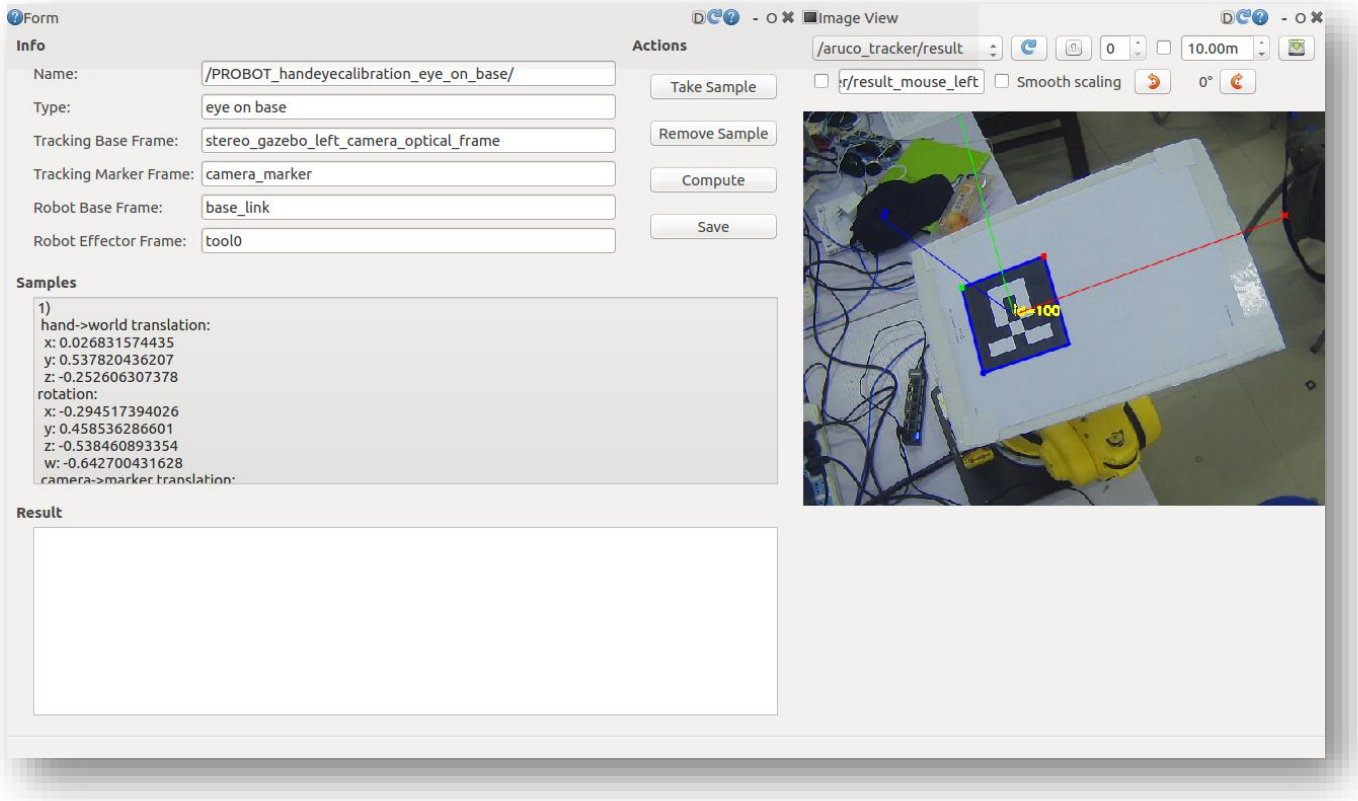
2. 手眼标定

easy_handeye: TF / VISP Hand-Eye Calibration



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

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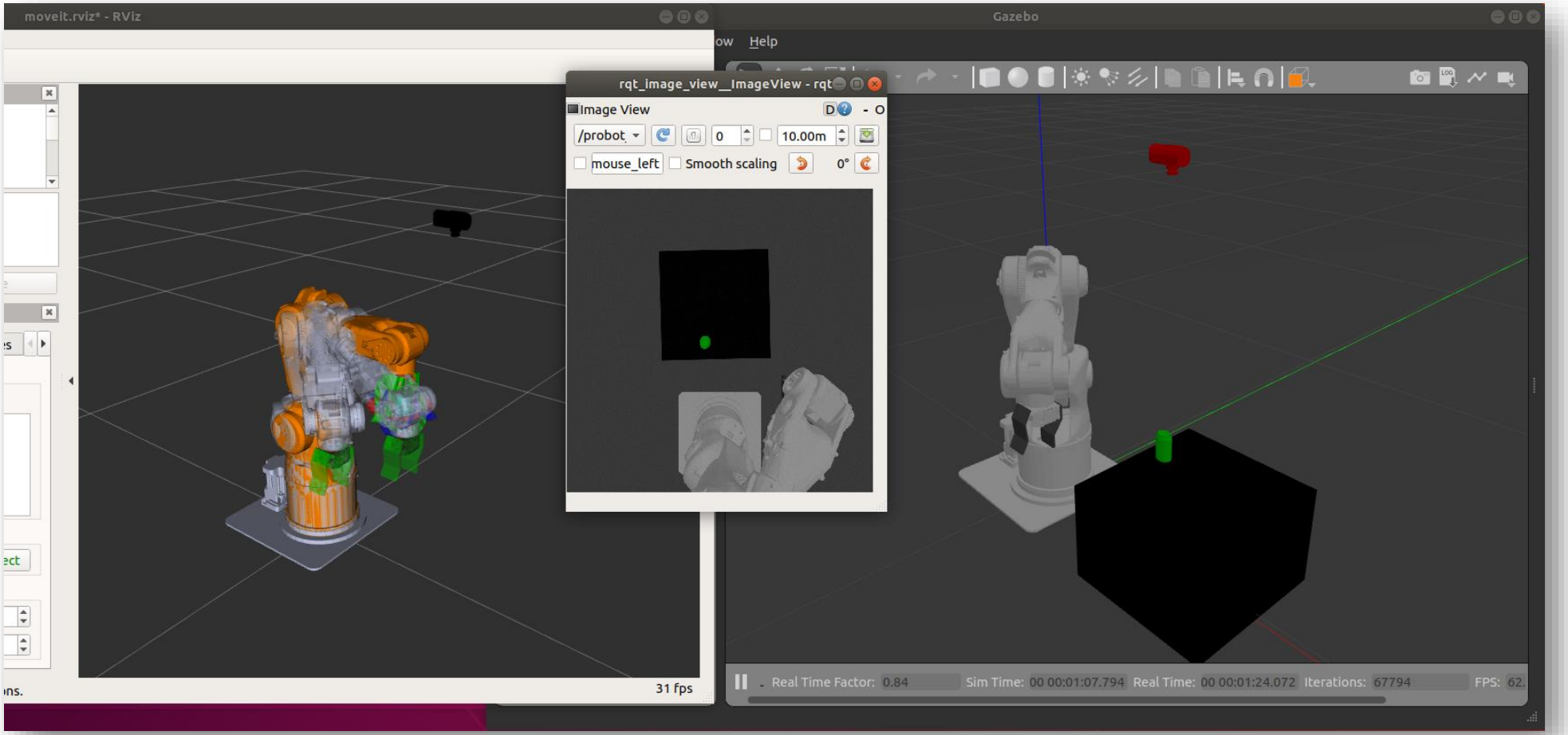


视觉抓取例程 $ roslaunch probot_grasping probot_anno_grasping_demo.launch

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);

    // 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);

    obj_robot_frame = camera_to_robot_ * obj_camera_frame;
    grasp_running = true;

    // 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;
  }
}
```

获取物体在图像中的位置

获取物体在相机坐标系下位置

计算物体在机器人坐标系下位置

3. 机械臂视觉抓取案例

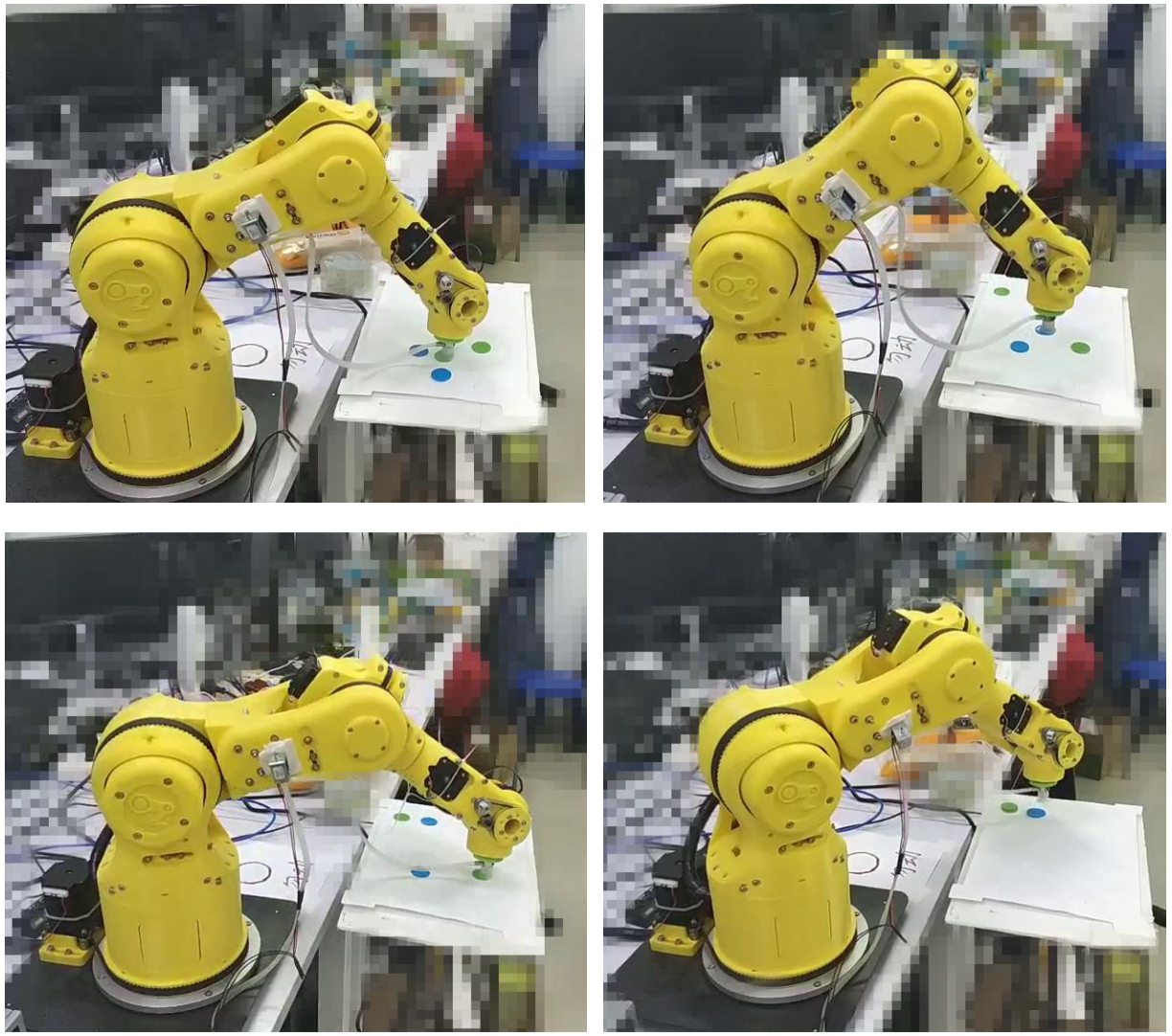
查询是否存在机器人基坐标系与摄像头坐标系之间的坐标变换

```
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

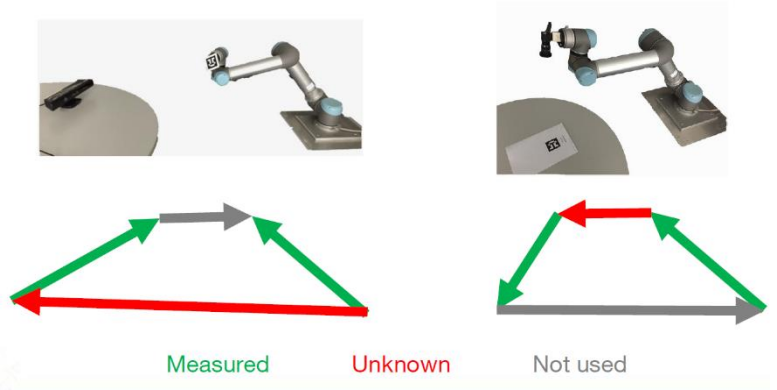
本讲小结

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

本讲作业

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。

扩展阅读

- 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

- Tensorflow Object Detection API
https://github.com/tensorflow/models/tree/master/research/object_detection

- Robotics、Vision and Control, Peter Corke

Thank You

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