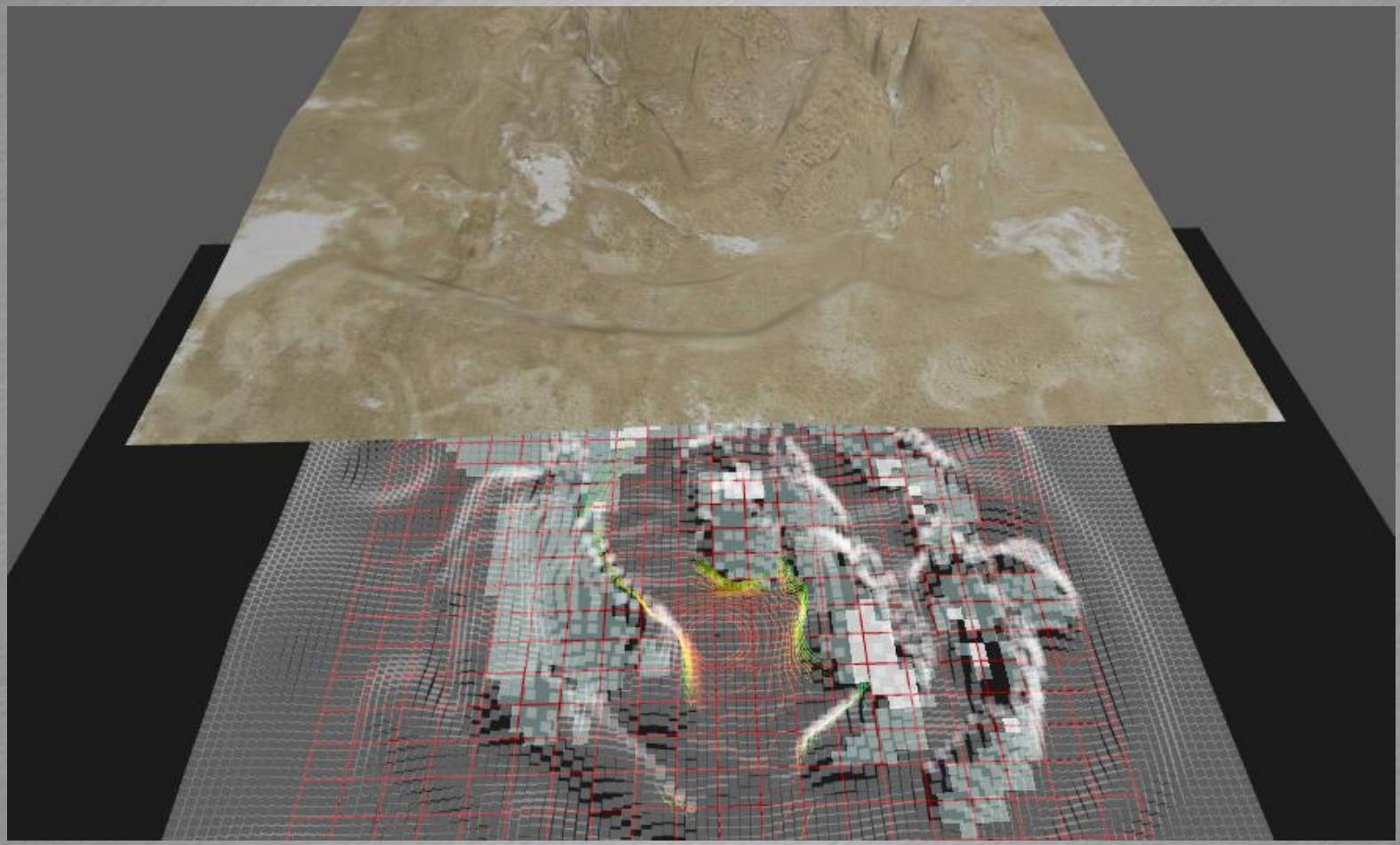
全地形自主导航



马庆华

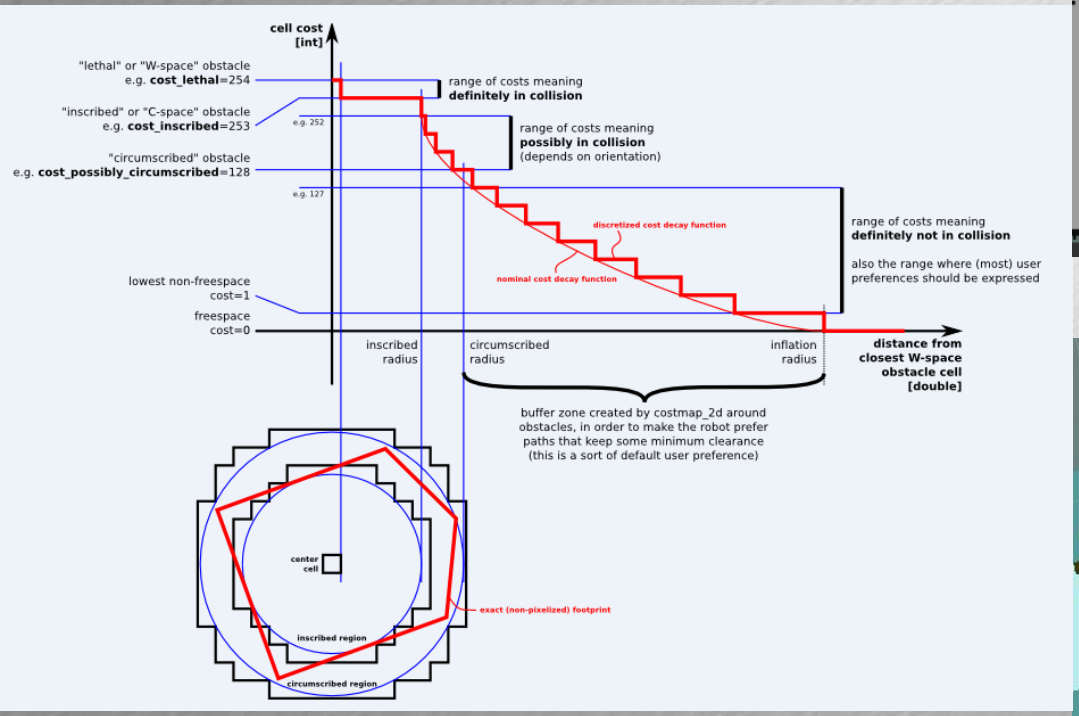
上海一坤电气工程有限公司

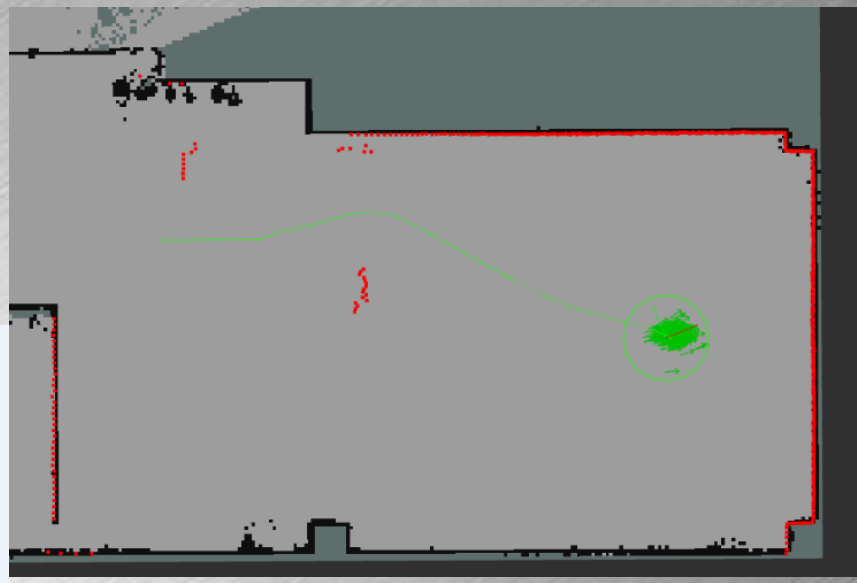
内容提要

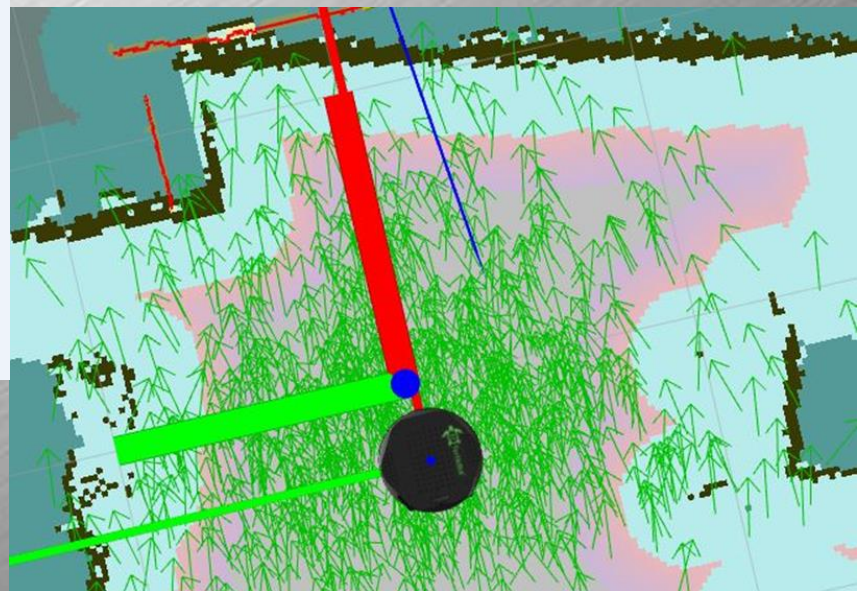
全地形自主导航
（1）三维地图的构建、定位、路径规划，二维地图对比
（2）全局与局部融合定位，坐标系约定与变换
（3）可通过性检测、costmap层级
（4）Gazebo仿真配置
（5）轮腿式机器人导航

（1）二维建图、定位

- SLAM
- 粒子定位
- costmap







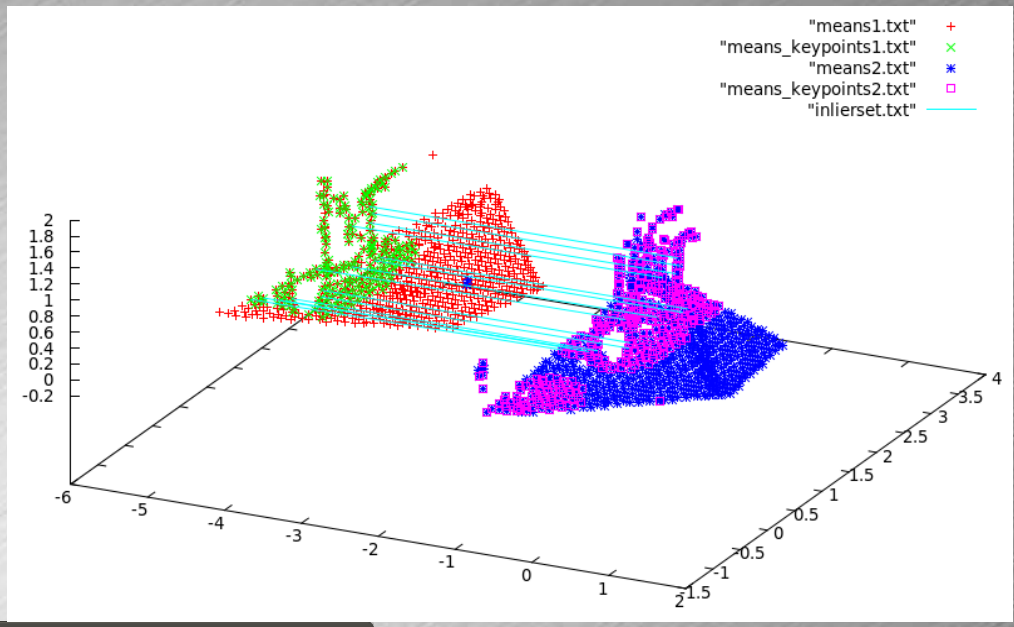
（1）三维建图—点云配准

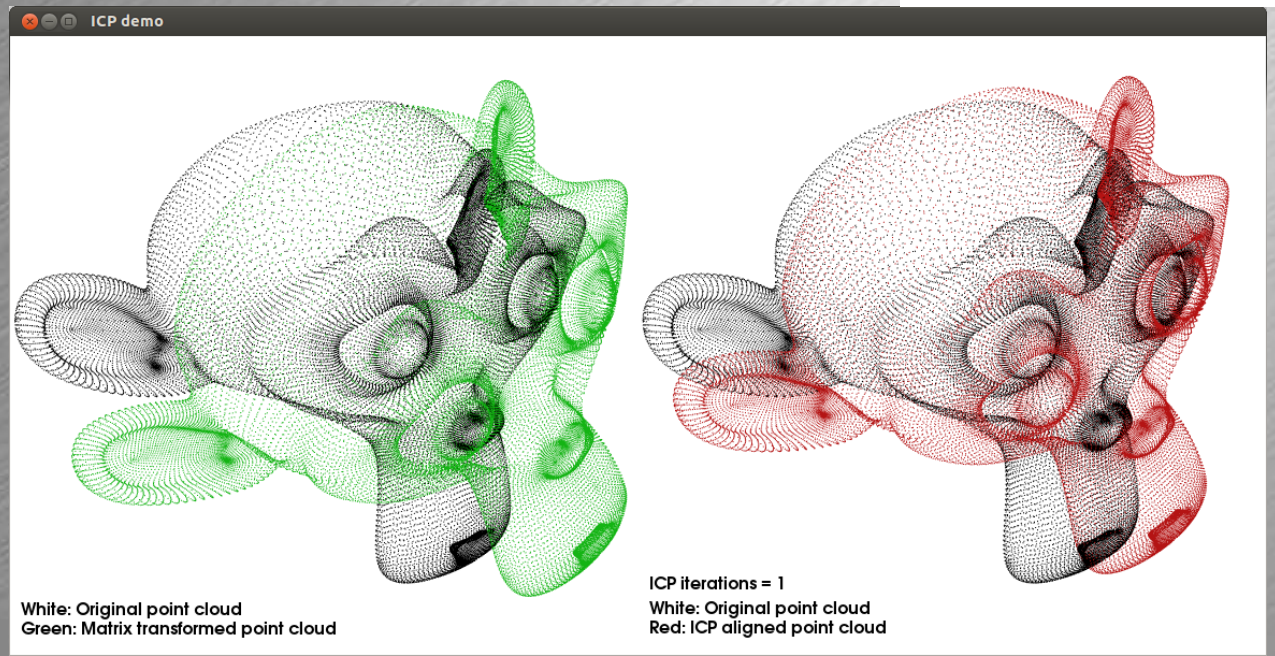
- NDT—正态分布变换

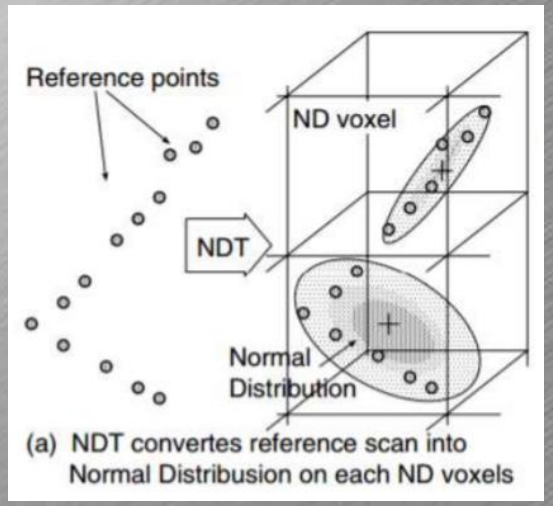
$$score(\mathbf{p}) = \sum_i exp(-\frac{(\mathbf{x}_i' - \mathbf{q}_i)^T \Sigma_i^{-1} (\mathbf{x}_i' - \mathbf{q}_i)}{2})$$

- ICP—迭代最近点

$$e(X,Y) = \sum_{i=1}^{m} (Rx_i + t - y_i)^2$$

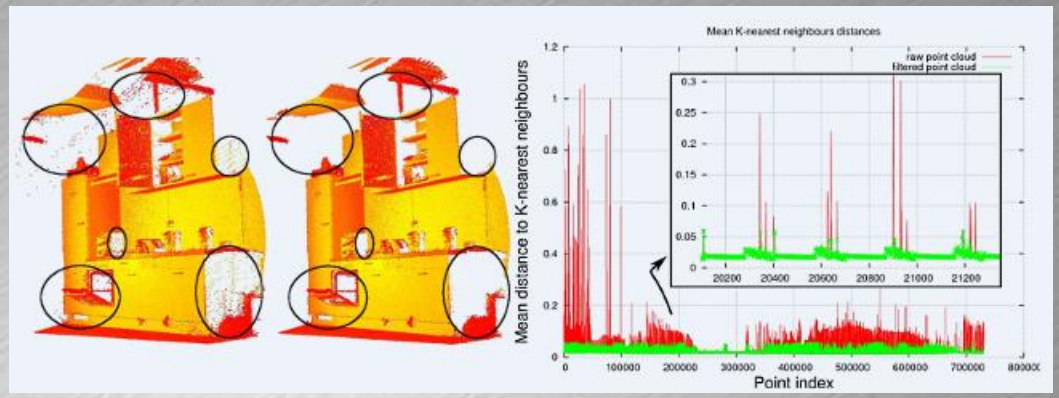


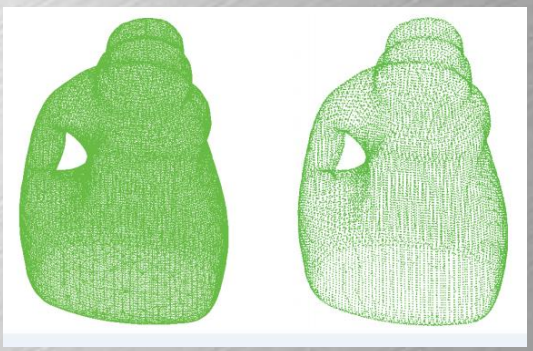


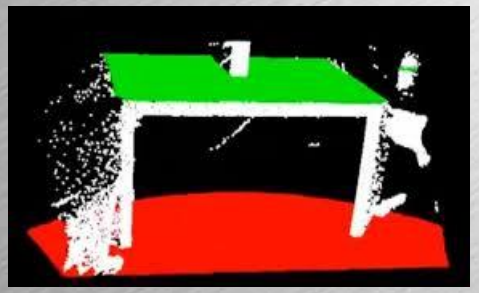


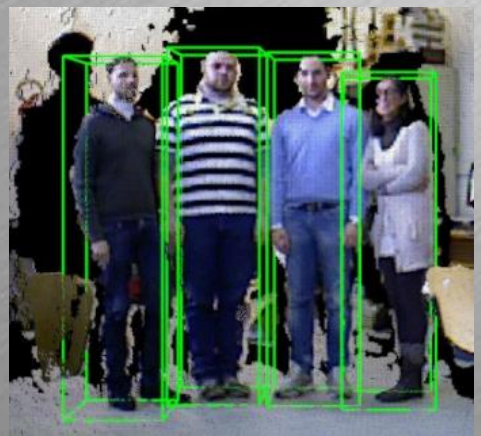
（1）三维建图—点云处理

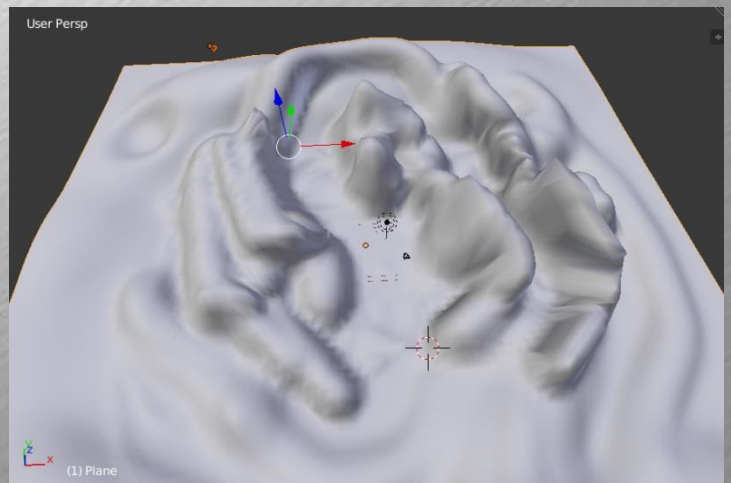
- 去除噪音
- 降采样
- 移除行人
- 移除地面
- 点云变换与增量式注册
- **Mesh化**



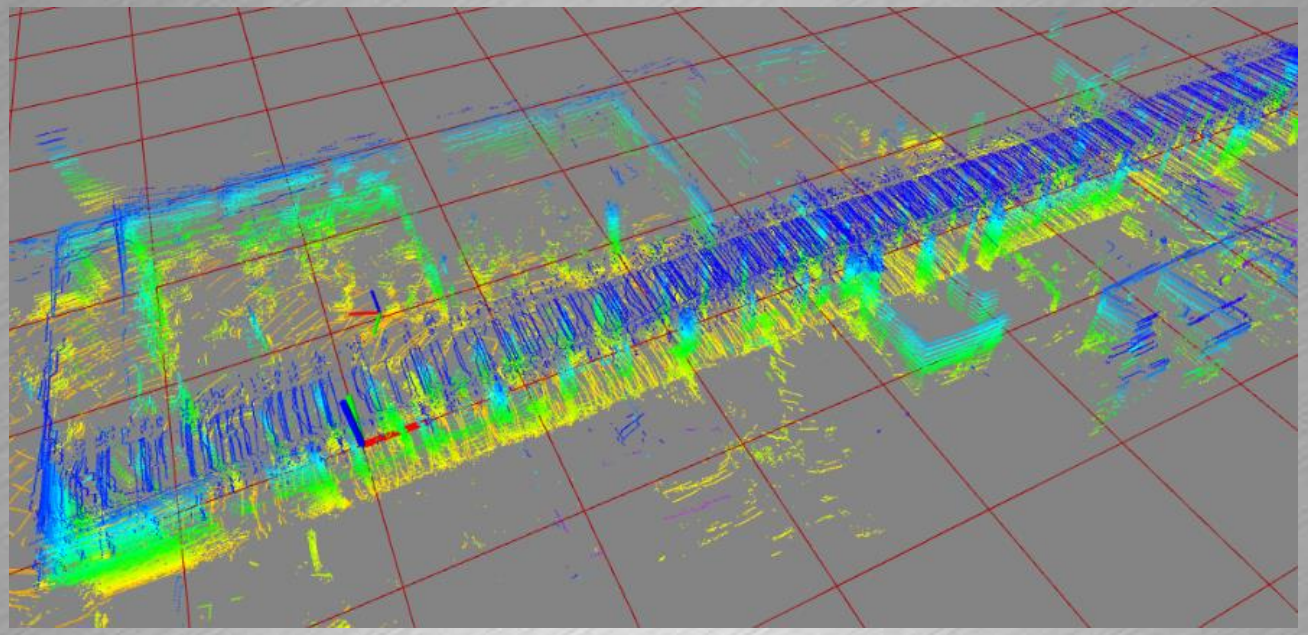


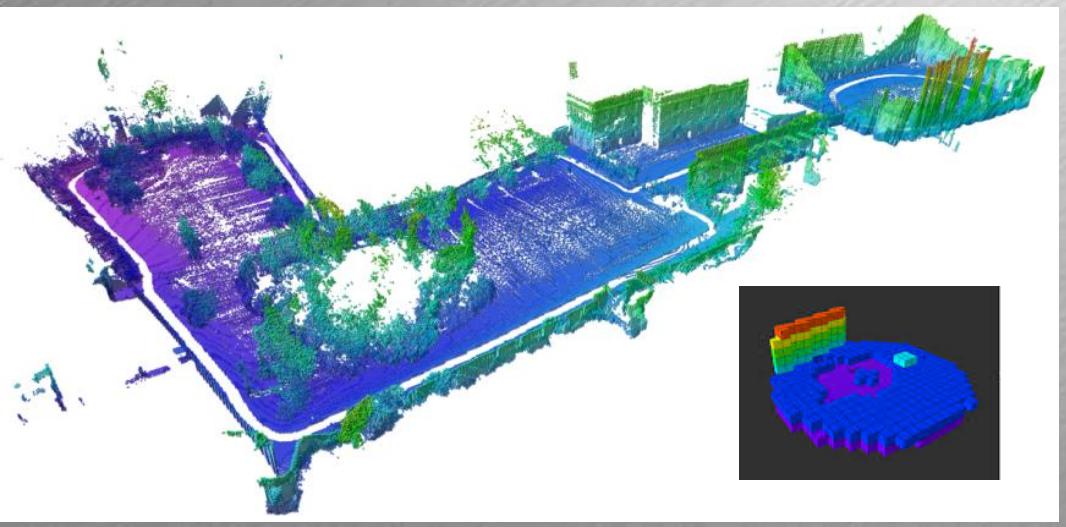


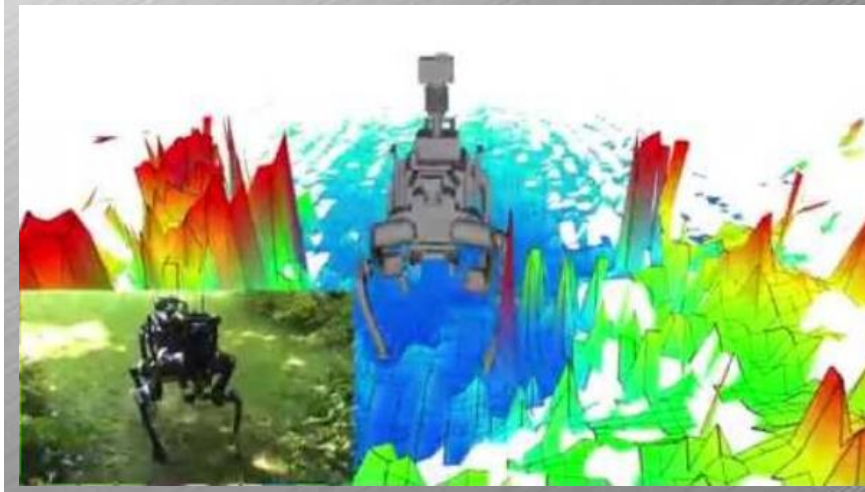




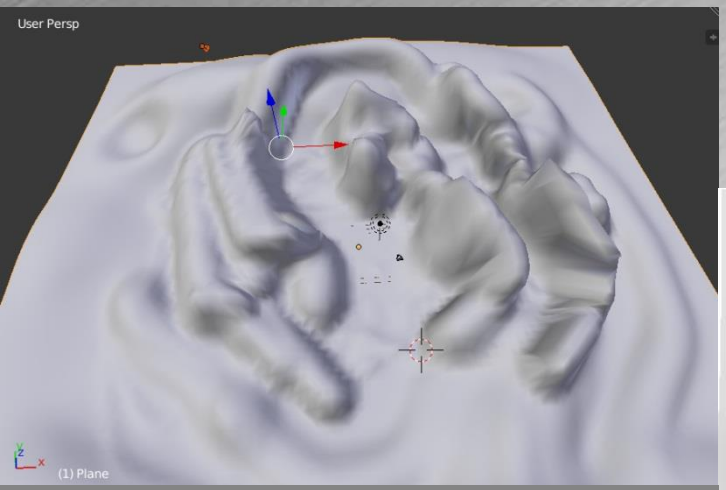
（1）三维建图—points、octomap、elevation

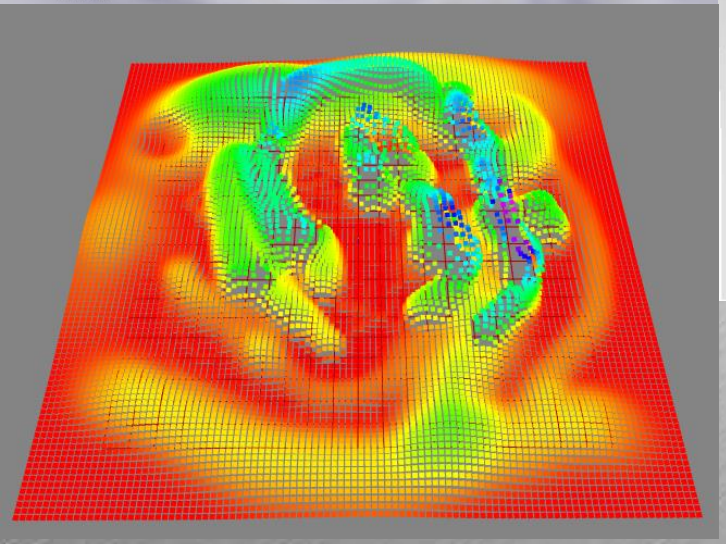


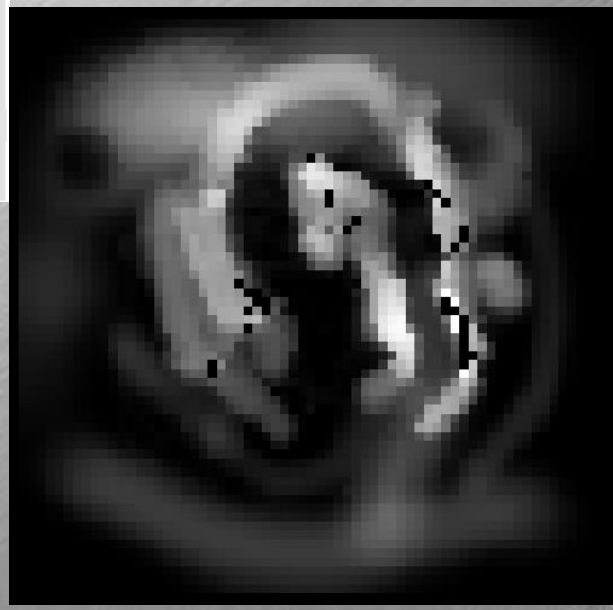




（1）三维建图—depth_map、costmap

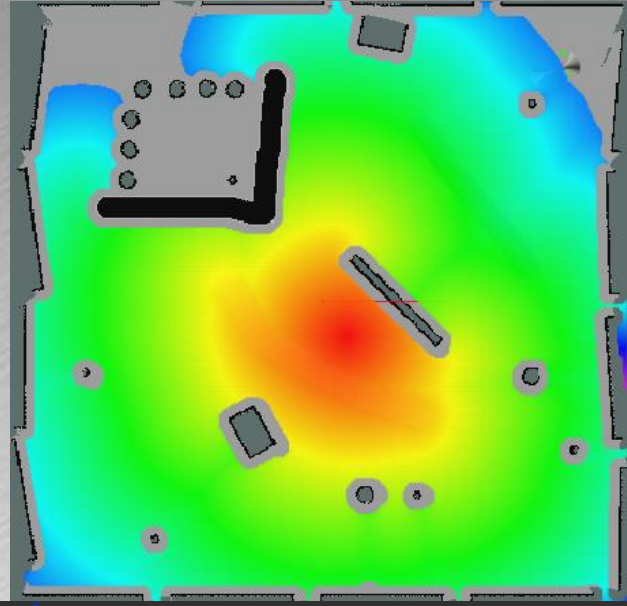


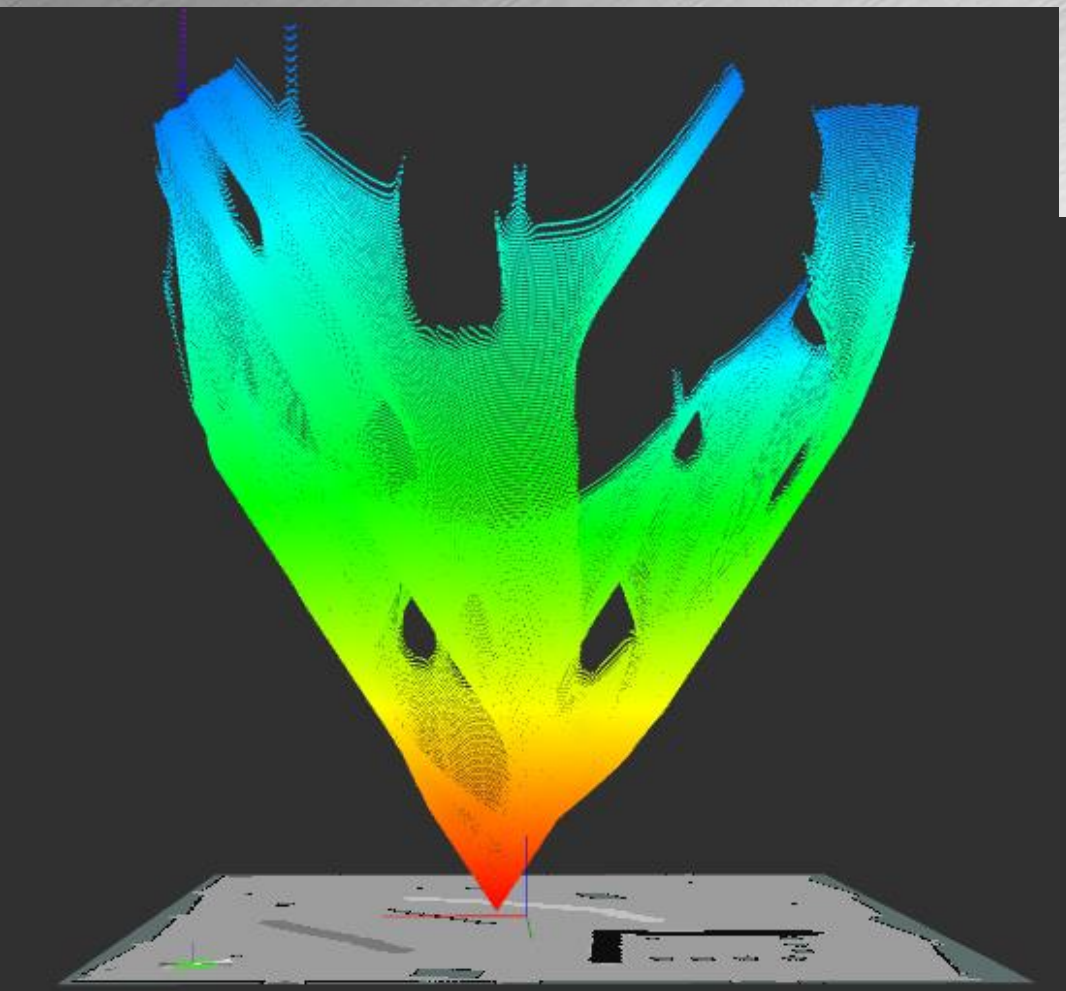


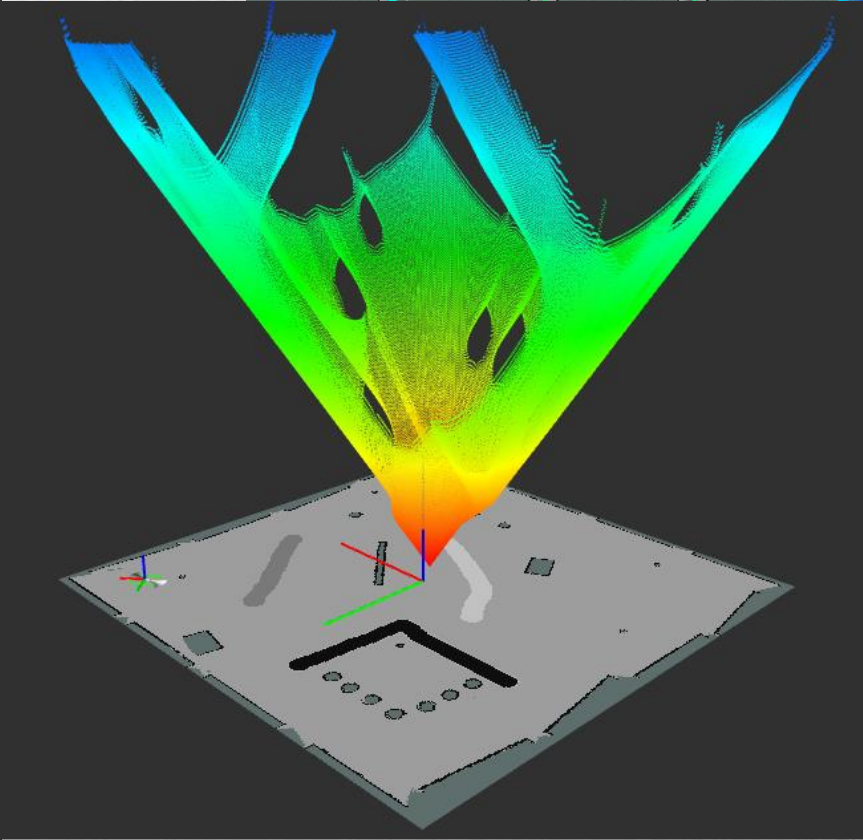


（1）三维建图—地图势场

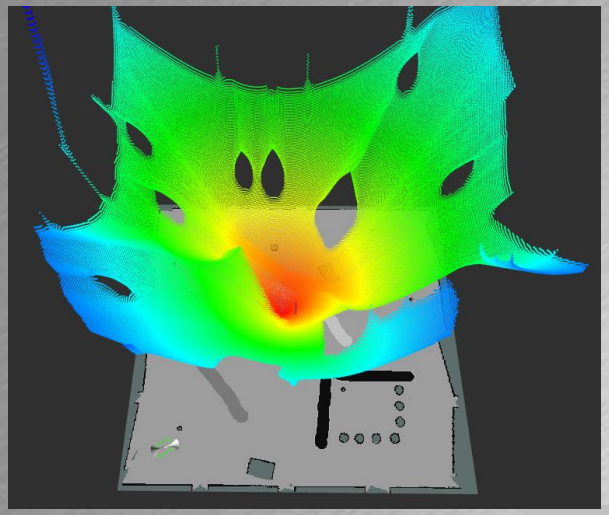
寻找最低能耗路径

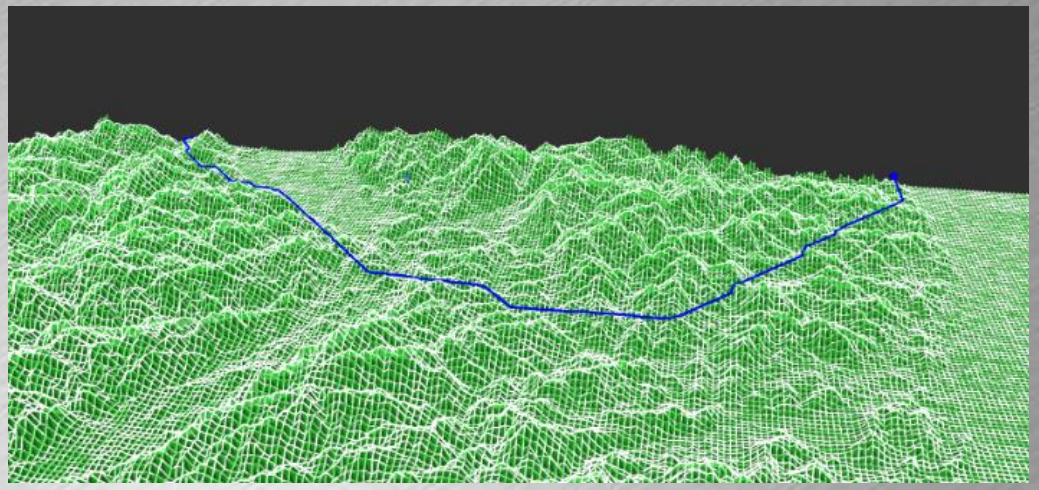


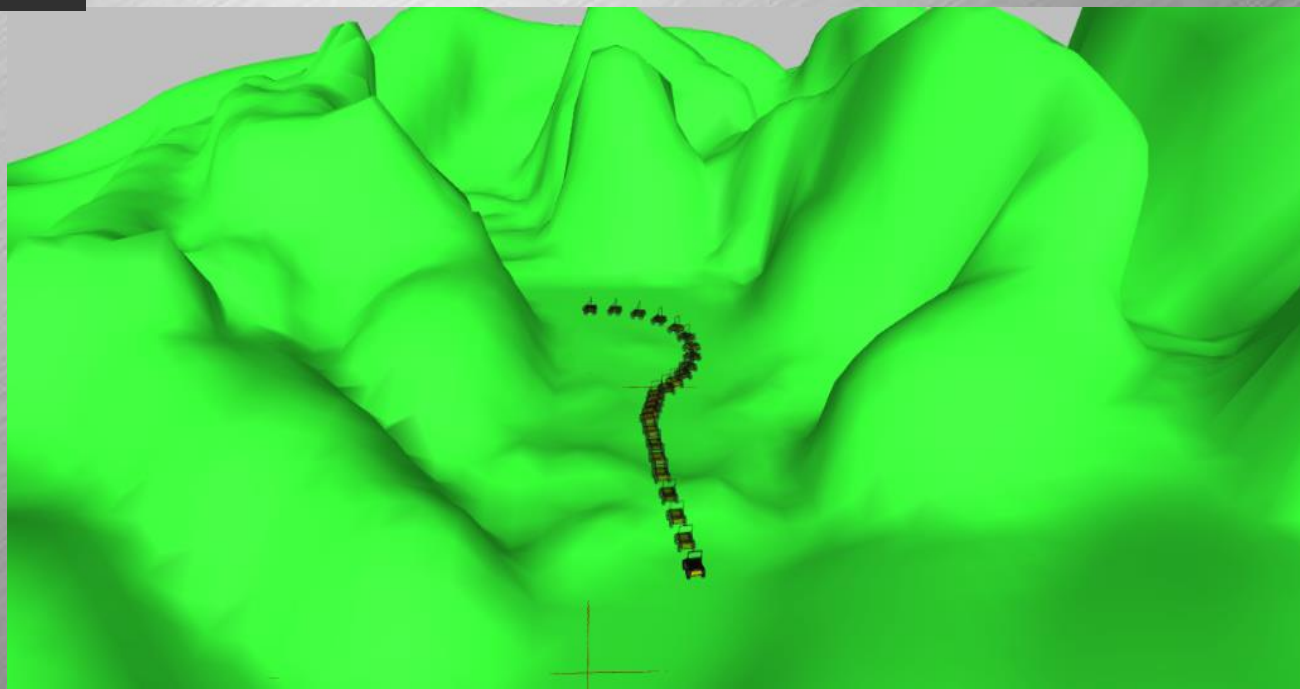




（1）三维建图—路径规划



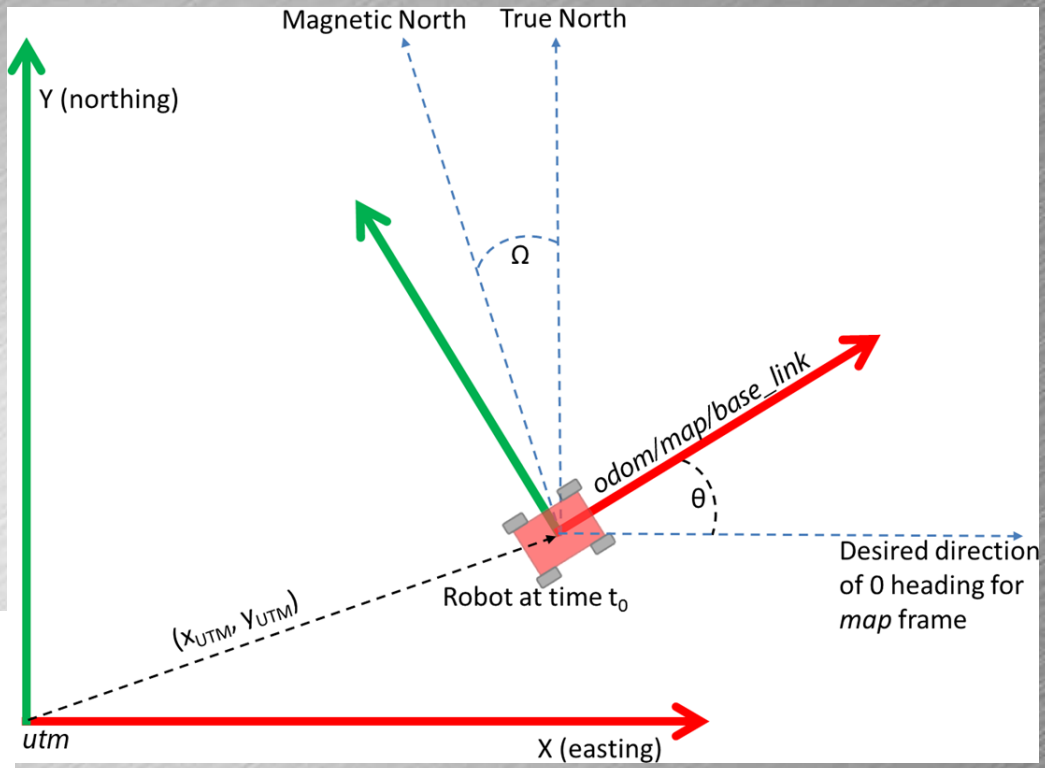


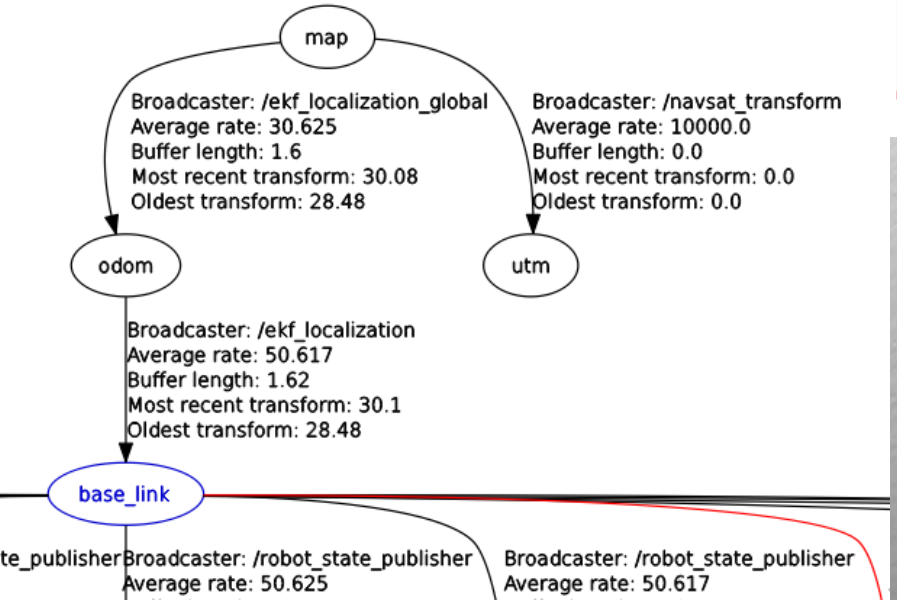


- 2D Costmap
- Hopfield network
- Moveit三维模型

（2）机器人定位—坐标系

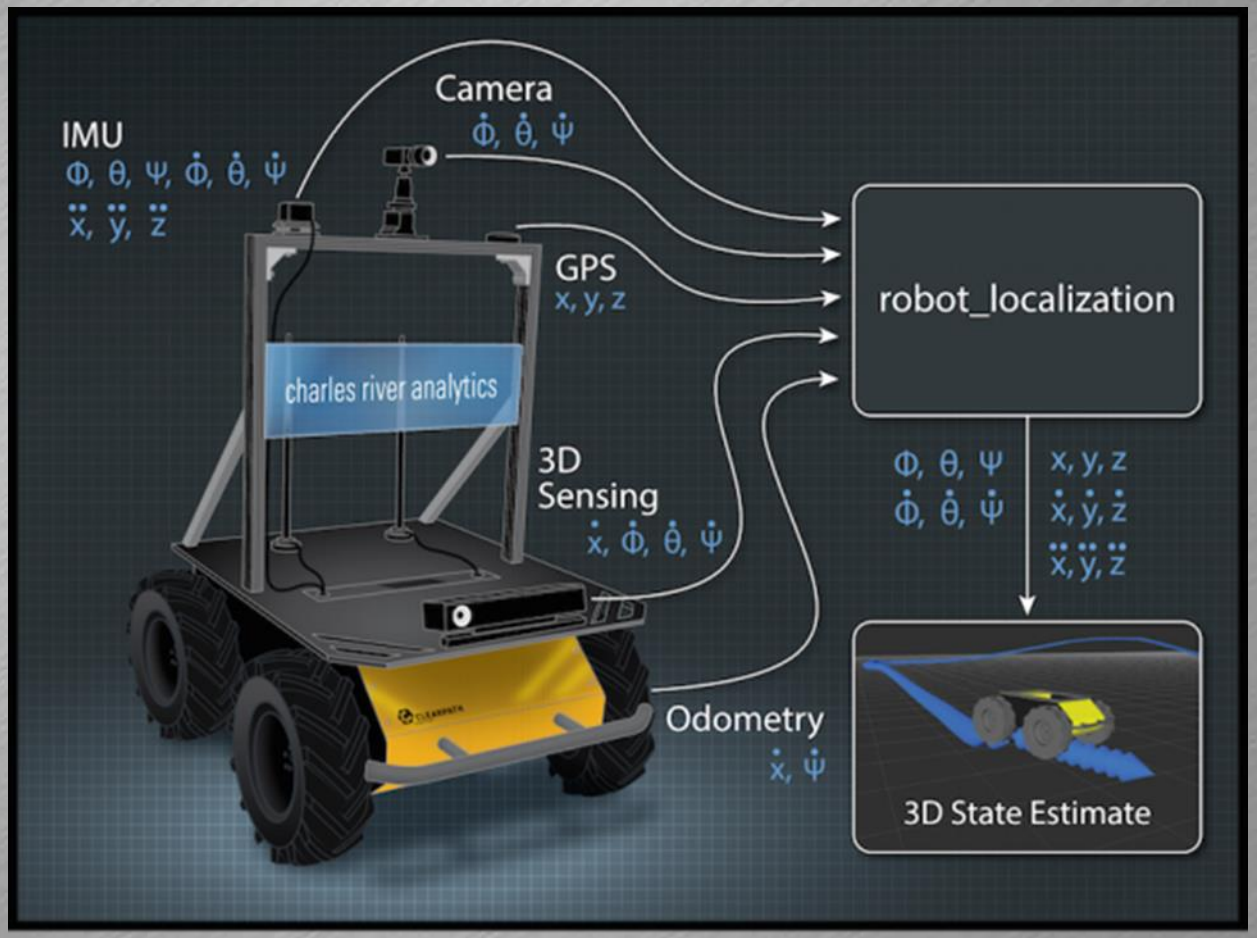
- WGS84、UTM
- ENU
- 磁偏角
- navsat_transform





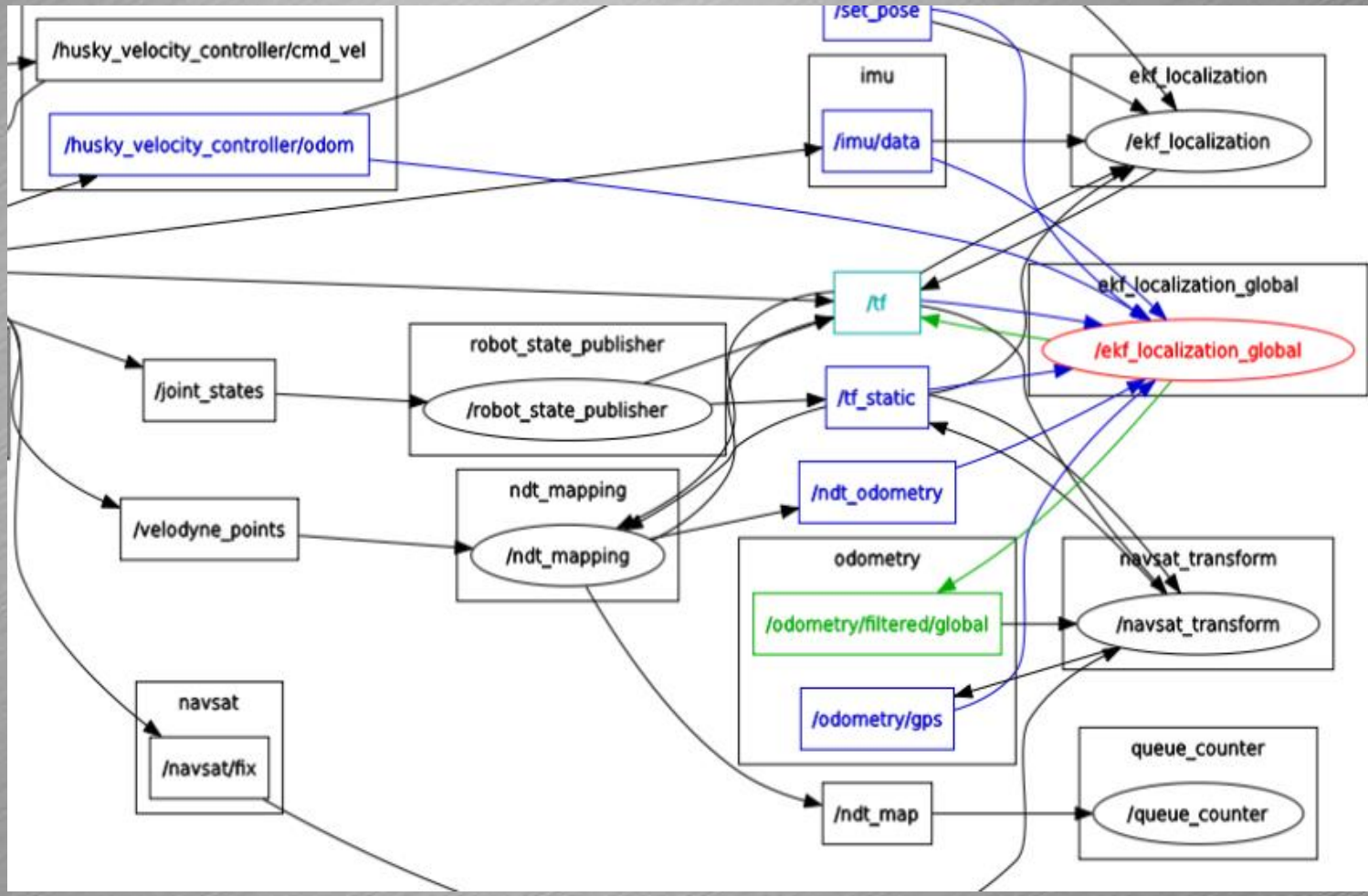
（2）机器人定位—局部定位

- EKF或UKF
- 里程计
- IMU



（2）机器人定位—全局定位

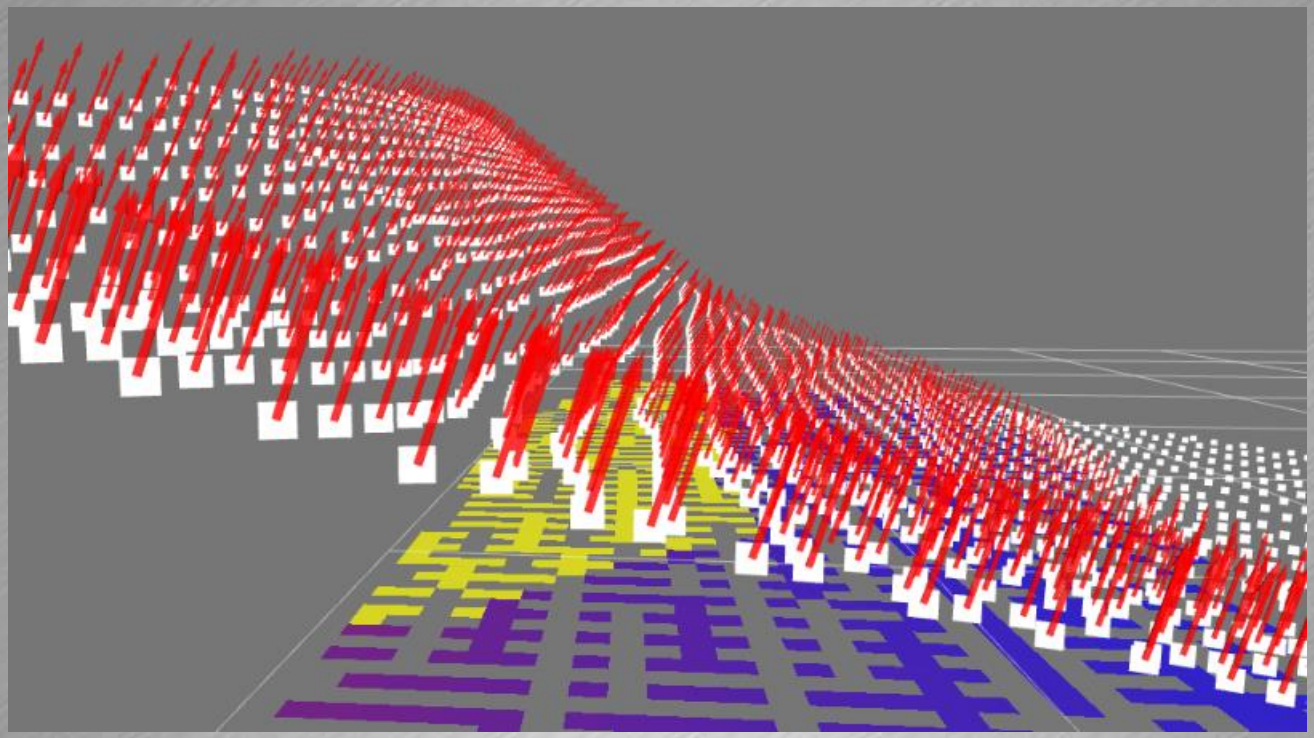
- EKF或UKF
- 里程计
- Laser odom
- IMU
- GPS odom



（3）可通过性检测—Traversability

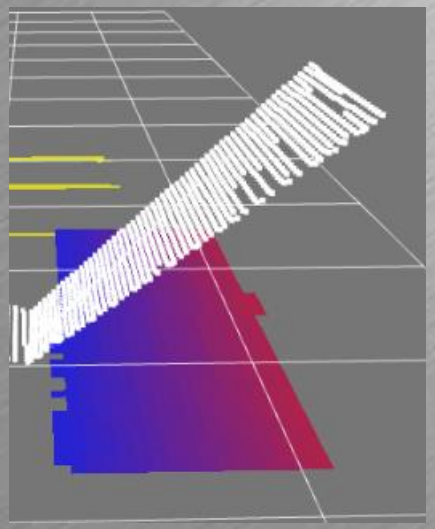
- 室内移动机器人
- 室外移动平台
- 双足/四足机器人
- 特种机器人
- （无人机？）

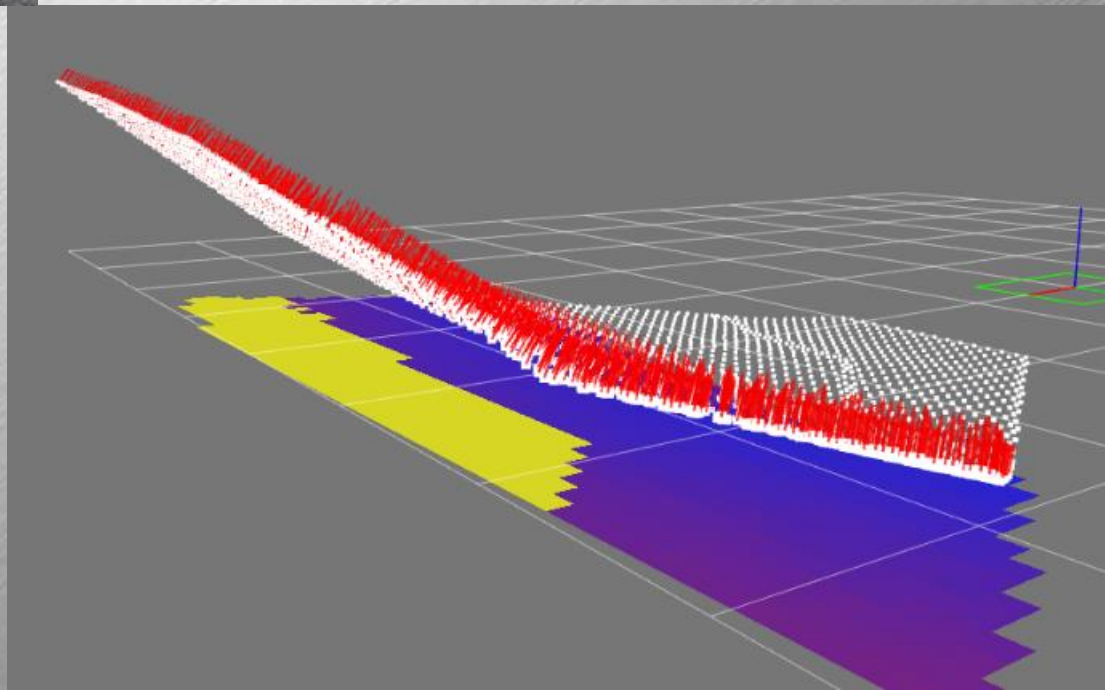
（3）可通过性检测—点云法向量



```
pcl::NormalEstimation<pcl::PointXYZ, pcl::Normal> ne;
ne.setInputCloud(tmp_cloud);
pcl::search::KdTree<pcl::PointXYZ>::Ptr tree (new pcl::search::KdTree<pcl::PointXYZ> ());
ne.setSearchMethod(tree);
pcl::PointCloud<pcl::Normal>::Ptr cloud_normals (new pcl::PointCloud<pcl::Normal>);
ne.setRadiusSearch(0.5);
ne.compute(*cloud_normals);
//ROS_INFO("cloud_size: %d, normal_size: %d", tmp_cloud->points.size(), cloud_normals->po
normals_marker_array_msg_.markers.resize(cloud_normals->points.size());
for (unsigned int i = 0; i < cloud_normals->points.size(); ++i)
{
```

（3）可通过性检测—traversability_layer





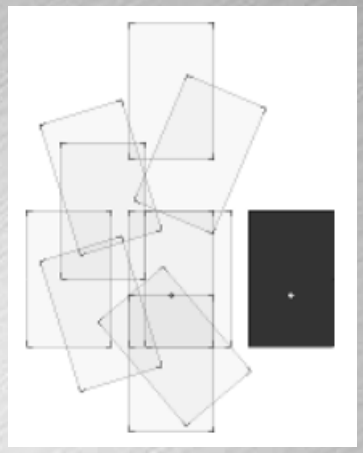
（4）Gazebo仿真配置

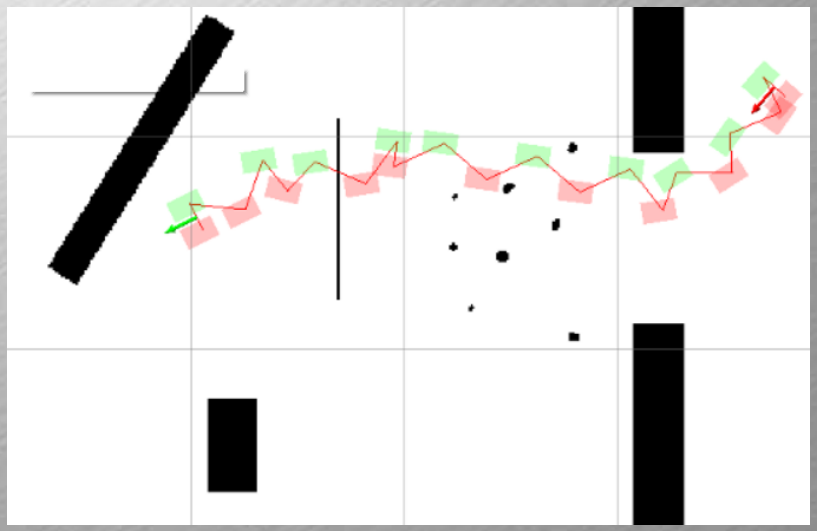
- 环境加载
- 传感器配置

```
<model name="120m_landscape_smooth_tri">
  <link name="120m_landscape_smooth_tri_link">
    <pose>0 0 0 0 0 0</pose>
    <collision name="120m_landscape_smooth_tri_collision">
      <geometry>
        <mesh>
          <uri>file://120m_landscape_smooth_tri.dae</uri>
          <scale>1 1 1</scale>
        </mesh>
      </geometry>
    </collision>
```

（5）轮腿式机器人导航

- 功耗
- 可通过性





（5）DARPA X-Vehicle

Ground X-Vehicle Technologies (GXV-T)

Final Demonstrations

QUESTIONS?

马庆华
+86-13564147965
hellocarp@gmail.com