感知预测模块操作实践

Apollo支持三种感知方式：基于激光点云的感知模型、基于相机的感知模型、基于融合感知的模型。支持多相机、多激光、毫米波雷达感知等多种传感设备。由于场地、设备等条件限制，这里仅仅对单相机感知，单激光感知，相机-激光融合感知算法进行测试实践。

[toc]

0 感知模块的准备

0.1 内外参标定文件

在完成感知任务之前，首先必须完成相机内参标定、Lidar和相机外参标定，并将校正数据存放在下述文件夹中：

- 相机内参文件：

  modules/calibration/data/dev_kit_pix_hooke/camera_params/front_6mm_intrinsics.yaml

- Lidar-Camera外参文件：

  modules/calibration/data/dev_kit_pix_hooke/camera_params/front_6mm_extrinsics.yaml

0.2 检查当前通道是的数据输入

- /apollo/sensor/lidar32/compensator/PointCloud2：激光感知和融合感知中必备
- /apollo/sensor/lidar32/compensator/PointCloud2：视觉感知和融合感知中必备
- /apollo/localization/pose：需要提供定位
- /tf及/tf_static：需要提供传感器外参和TF树

0.3 代码的目录组织结构

感知模块的目录组织结构如下：

```
.
├── BUILD
├── README.md
├── base        // 基础类
├── camera      // 相机相关       --- 子模块流程
├── common      // 公共目录
├── data        // 相机的内参和外参
├── fusion      // 传感器融合
├── inference   // 深度学习推理模块
├── lib         // 一些基础的库，包括线程、时间等
├── lidar       // 激光雷达相关      --- 子模块流程
├── map         // 地图
├── model       // 深度学习模型
├── onboard     // 各个子模块的入口    --- 子模块入口
├── production  // 感知模块入口（深度学习模型也存放在这里）--- 通过cyber启动子模块
├── proto       // 数据格式，protobuf
```

```
├── radar      // 毫米波          --- 子模块流程
├── testdata    // 上述几个模块的测试数据
└── tool       // 离线测试工具
```

其中：

- production：感知模块的入口在production目录，通过lanuch加载对应的dag，启动感知模块。
- onboard： 定义了多个子模块，分别用来处理不同的传感器信息（Lidar，Radar，Camera）。各个子模块的入口在onboard目录中，每个传感器的流程大概相似，可以分为预处理，物体识别，感兴趣区域过滤以及追踪。
- inference： 深度学习推理模块。部署的过程会对模型做加速，实现了caffe，TensorRT、 libtorch、onnx 等多种模型部署。训练好的深度模型放在modules\perception\production\data目录中，然后通过推理模块进行加载部署和在线计算。
- camera：主要实现车道线识别，红绿灯检测，以及障碍物识别和追踪。
- radar：主要实现障碍物识别和追踪（由于毫米波雷达上报的就是障碍物信息，这里主要是对障碍物做追踪）。
- lidar：主要实现障碍物识别和追踪（对点云做分割，分类，识别等）。
- fusion：对上述传感器的感知结果做融合。

1 基于激光点云的感知

1.1 CNNSegmentation算法

CNNSegmentation算法（以下简称cnnseg）是由百度研发、尚未开源的语义分割算法（而非传统上基于bbox的方法）。它分为center offset，objectness，positiveness，object height，class probability五个层级，由于鲁棒性和检测效果较好，后续如不额外声明，均以该方法作为基础。

cnnseg的模型权重文件位于：
modules/perception/production/data/perception/lidar/models/cnnseg/velodyne16/deploy.caffemodel

1.1.1 配置文件调整

创建/修改参数配置文件：

- modules/perception/production/conf/perception/lidar/velodyne16_segmentation_conf.pb.txt：

  ```
  sensor_name: "velodyne16"
  enable_hdmap: true
  lidar_query_tf_offset: 0
  lidar2novatel_tf2_child_frame_id: "lidar32"
  output_channel_name: "/perception/inner/SegmentationObjects"
  ```

- modules/perception/production/conf/perception/lidar/recognition_conf.pb.txt：

  ```
  main_sensor_name: "velodyne16"
  output_channel_name: "/perception/inner/PrefusedObjects"
  ```

- modules/perception/production/data/perception/lidar/models/multi_lidar_fusion/mlf_engine.conf:

```
main_sensor: "velodyne16"
use_histogram_for_match: true
histogram_bin_size: 10
output_predict_objects: false
reserved_invisible_time: 0.3
use_frame_timestamp: true
```

- modules/perception/production/conf/perception/fusion/fusion_component_conf.pb.txt:

```
fusion_method: "ProbabilisticFusion"
fusion_main_sensors: "velodyne16"
object_in_roi_check: true
radius_for_roi_object_check: 120
output_obstacles_channel_name: "/apollo/perception/obstacles"
output_viz_fused_content_channel_name:
"/perception/inner/visualization/FusedObjects"
```

1.1.2 启动文件调整

创建/修改dag启动文件： /apollo/modules/perception/production/dag/文件夹的 dag_streaming_perception_dev_kit_lidar.dag：

```
module_config {
 module_library : "/apollo/bazel-bin/modules/perception/onboard/component/libperception_component_lidar.so"

 components {
   class_name : "SegmentationComponent"
   config {
     name: "Velodyne16Segmentation"
     config_file_path: "/apollo/modules/perception/production/conf/perception/lidar/velodyne16_segmentation_conf.pb.txt"
     flag_file_path: "/apollo/modules/perception/production/conf/perception/perception_common.flag"
     readers {
        channel: "/apollo/sensor/lidar32/compensator/PointCloud2"
      }
   }
 }

 components {
   class_name : "RecognitionComponent"
   config {
```

```
      name: "RecognitionComponent"
      config_file_path:
"/apollo/modules/perception/production/conf/perception/lidar/recognition_conf.pb.txt"
      readers {
        channel: "/perception/inner/SegmentationObjects"
      }
    }
  }


  components {
    class_name: "FusionComponent"
    config {
      name: "SensorFusion"
      config_file_path:
"/apollo/modules/perception/production/conf/perception/fusion/fusion_component_conf.pb.txt
"
      readers {
        channel: "/perception/inner/PrefusedObjects"
      }
    }
  }

}
```

- 为了提高效率，同一个模块内的部分数据通道，如`/perception/inner/SegmentationObjects`或者`/perception/inner/PrefusedObjects`并不会在`cyber_monitor`中显示，但是它们依然存在并有效传递着数据。

1.2 PointPillar算法

PointPillar是基于激光点云进行目标检测的经典开源算法，在apollo和autoware上均有其实现。训练模型权重详见文件：`modules/perception/production/data/perception/lidar/models/detection/point_pillars`。

1.2.1 配置文件调整

创建/修改参数配置文件：

- `modules/perception/production/conf/perception/lidar/velodyne16_detection_conf.pb.txt`：

```
sensor_name: "velodyne16"
enable_hdmap: true
lidar_query_tf_offset: 0
lidar2novatel_tf2_child_frame_id: "lidar32"
output_channel_name: "/perception/inner/DetectionObjects"
```

- `modules/perception/production/conf/perception/lidar/recognition_conf.pb.txt`：

```
main_sensor_name: "velodyne16"
output_channel_name: "/perception/inner/PrefusedObjects"
```

- modules/perception/production/data/perception/lidar/models/multi_lidar_fusion/mlf_engine.conf:

```
main_sensor: "velodyne16"
use_histogram_for_match: true
histogram_bin_size: 10
output_predict_objects: false
reserved_invisible_time: 0.3
use_frame_timestamp: true
```

- modules/perception/production/conf/perception/fusion/fusion_component_conf.pb.txt:

```
fusion_method: "ProbabilisticFusion"
fusion_main_sensors: "velodyne16"
object_in_roi_check: true
radius_for_roi_object_check: 120
output_obstacles_channel_name: "/apollo/perception/obstacles"
output_viz_fused_content_channel_name:
"/perception/inner/visualization/FusedObjects"
```

1.2.2 启动文件调整

创建/修改dag启动文件： /apollo/modules/perception/production/dag/文件夹的 dag_streaming_perception_lidar.dag：

```
module_config {
 module_library : "/apollo/bazel-bin/modules/perception/onboard/component/libperception_component_lidar.so"

 components {
  class_name : "DetectionComponent"
  config {
   name: "Velodyne16Detection"
   config_file_path: "/apollo/modules/perception/production/conf/perception/lidar/velodyne16_detection_conf.pb.txt"
   flag_file_path: "/apollo/modules/perception/production/conf/perception/perception_common.flag"
   readers {
    channel: "/apollo/sensor/lidar32/compensator/PointCloud2"
   }
  }
 }
```

```
 components {
  class_name : "RecognitionComponent"
  config {
   name: "RecognitionComponent"
   config_file_path:
"/apollo/modules/perception/production/conf/perception/lidar/recognition_conf.pb.txt"
   readers {
    channel: "/perception/inner/DetectionObjects"
   }
  }
 }

 components {
  class_name: "FusionComponent"
  config {
   name: "SensorFusion"
   config_file_path:
"/apollo/modules/perception/production/conf/perception/fusion/fusion_component_conf.pb.txt
"
   readers {
    channel: "/perception/inner/PrefusedObjects"
   }
  }
 }
}
```

- 为了提高效率，同一个模块内的部分数据通道，如`/perception/inner/SegmentationObjects`或者`/perception/inner/PrefusedObjects`并不会在`cyber_monitor`中显示，但是它们依然存在并有效传递着数据。

1.3 启动激光点云感知模块

1. 启动感知模块，等待待显存稳定（一般在1-2分钟左右）

```
# cnn_seg
mainboard -d
modules/perception/production/dag/dag_streaming_perception_dev_kit_lidar.dag
# or pointpillar
# mainboard -d modules/perception/production/dag/dag_streaming_perception_lidar.dag
```

2. 待显存稳定后启动数据集

```
cyber_recorder play -f data/bag/20220203/20220203100813.record.0000*
```

   - 显存是否稳定可以通过指令：`watch -n 0.1 nvidia-smi`查询。该命令表示每间隔0.1 s执行一次`nvidia-smi`指令

- 显存稳定：

```
Every 0.1s: nvidia-smi

Sun Apr 10 10:46:48 2022
+-----------------------------------------------------------------------------+
| NVIDIA-SMI 470.42.01    Driver Version: 470.42.01    CUDA Version: 11.4     |
|-------------------------------+----------------------+----------------------+
| GPU  Name        Persistence-M| Bus-Id        Disp.A | Volatile Uncorr. ECC |
| Fan  Temp  Perf  Pwr:Usage/Cap|         Memory-Usage | GPU-Util  Compute M. |
|                               |                      |               MIG M. |
|===============================+======================+======================|
|   0  NVIDIA GeForce ...  Off  | 00000000:01:00.0 Off |                  N/A |
| N/A   50C    P8    14W /  N/A |   2073MiB /  5946MiB |      0%      Default |
|                               |                      |                  N/A |
+-------------------------------+----------------------+----------------------+

+-----------------------------------------------------------------------------+
| Processes:                                                                  |
|  GPU   GI   CI        PID   Type   Process name                  GPU Memory |
|        ID   ID                                                   Usage      |
|=============================================================================|
|    0   N/A  N/A      5306      C   mainboard                        2071MiB |
+-----------------------------------------------------------------------------+
```

3. 查看/apollo/perception/obstacles中是否由数据输出（cnnseg检测输出为多边形，PointPillar检测输出为矩形框）

```
cyber_monitor
```

对于每时刻的检测结果，有如下障碍物检测序列：

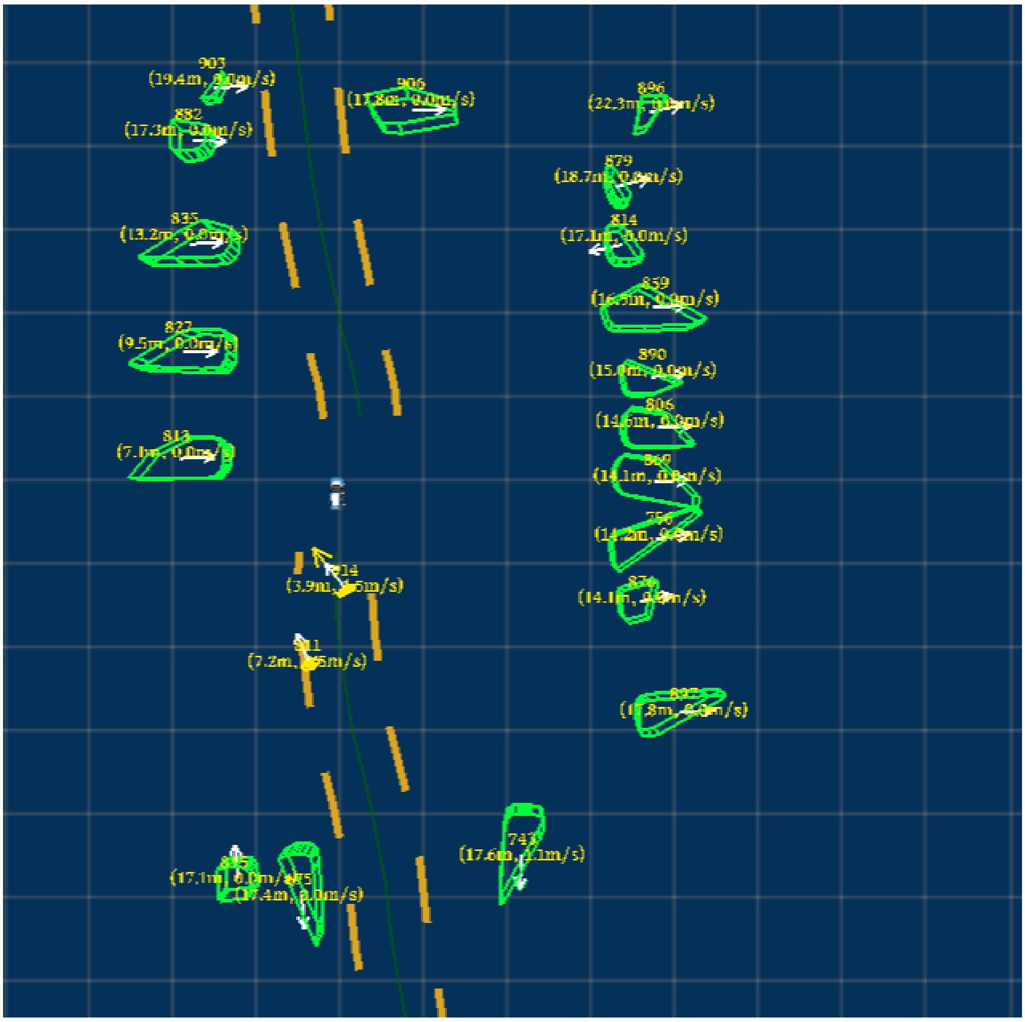
```
ChannelName: /apollo/perception/obstacles
MessageType: apollo.perception.PerceptionObstacles
FrameRatio: 0.00
RawMessage Size: 23558 Bytes (23.01 KB)
perception_obstacle: +[21 items]
header:
  timestamp_sec: 1649554907.004176140
  module_name: perception_obstacle
  sequence_num: 1441
  lidar_timestamp: 1648287224159765248
  camera_timestamp: 0
  radar_timestamp: 0
error_code: OK
```

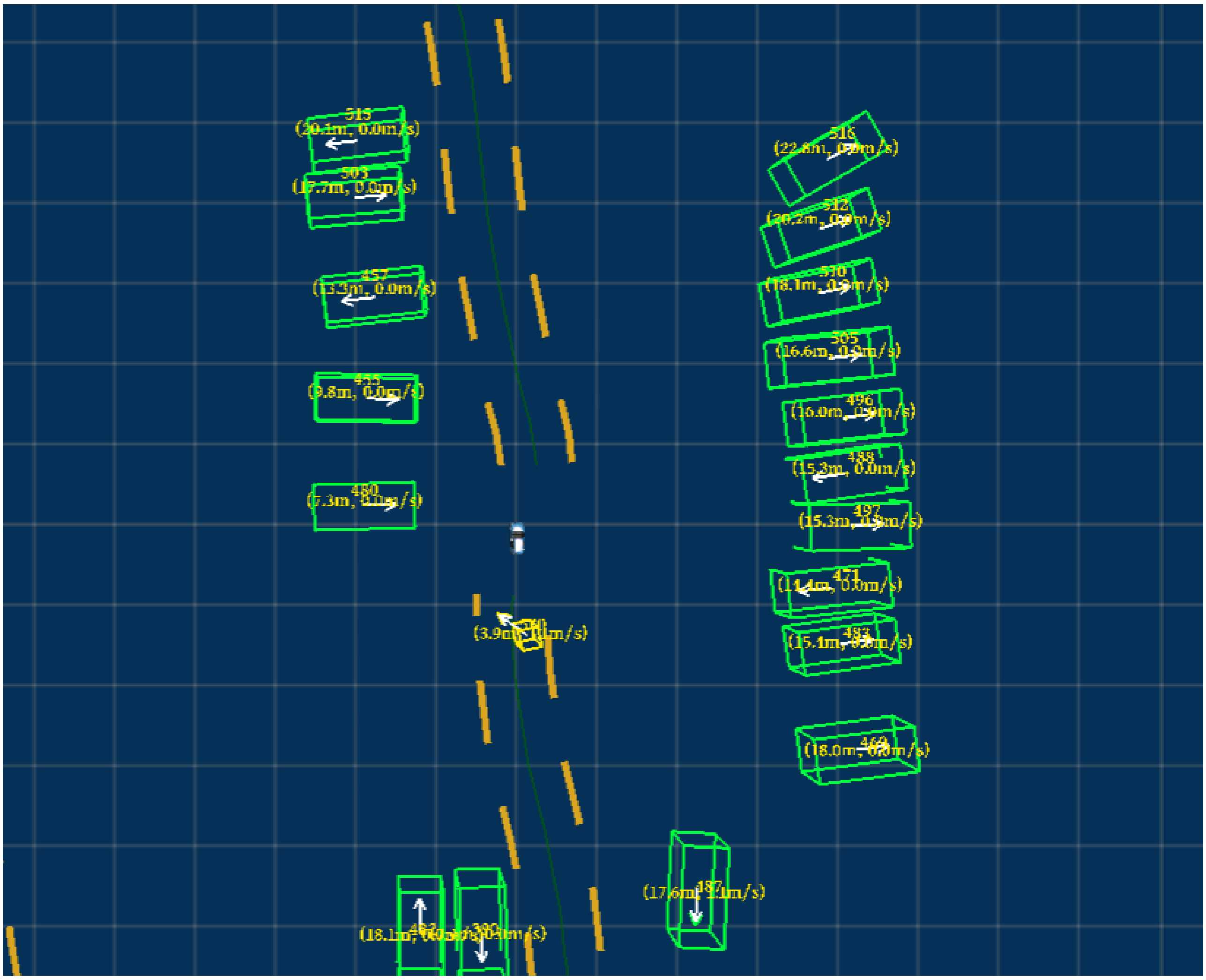
对于每一个障碍物检测结果，包含：

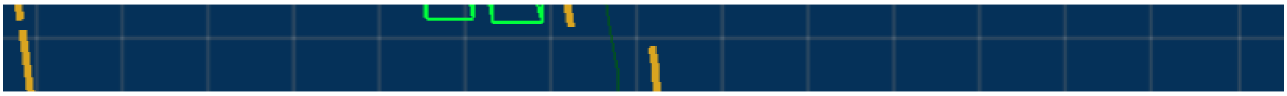
- 检测目标的id，类别，位置，朝向（仅包括yaw），速度，加速度
- 长宽高，多边形点（cnnseg，PointPillar），bbox2d（camera），archor
- 位置、速度、加速度协方差
- 追踪时间：数据关联成功时长
- light_status：仅在图像障碍物检测中出现

```
ChannelName: /apollo/perception/obstacles
MessageType: apollo.perception.PerceptionObstacles
FrameRatio: 0.00
perception_obstacle: [0]
  id: 675
  position:
    x: 443996.994114553
    y: 4436666.019773082
    z: 32.388639151
  theta: -1.497994423
  velocity:
    x: -0.0
    y: 0.0
    z: 0.0
  length: 4.122876167
  width: 1.470222116
  height: 1.344617486
  polygon_point: +[13 items]
  tracking_time: 42.900608778
  type: VEHICLE
  timestamp: 1648287224.159749746
  acceleration:
    x: -0.000000446
    y: -0.000004244
    z: 0.0
  anchor_point:
    x: 443997.130370396
    y: 4436666.995180999
    z: 33.152222815
  bbox2d:
    xmin: 0.0
    ymin: 0.0
    xmax: 0.0
    ymax: 0.0
  sub_type: ST_UNKNOWN
  measurements: +[1 items]
  height_above_ground: nan
  position_covariance: +[9 items]
  velocity_covariance: +[9 items]
  acceleration_covariance: +[9 items]
  light_status:
    brake_visible: 0.0
    brake_switch_on: 0.0
    left_turn_visible: 0.0
    left_turn_switch_on: 0.0
    right_turn_visible: 0.0
```

4. 在dreamviewer最终效果如下(第一个为cnnseg，第二个为PointPillar)：可以看出，雷达视野**覆盖360度**，但是感知距离相对较近。







2 基于图像的感知模块

图像感知模块基于单目yolo 3D障碍物感知算法进行测试，检测种类包括：CAR，VAN，BUS，TRUCK，CYCLIST，TRICYCLIST，PEDESTRIAN，TRAFFICCONE。其模型权重位于：modules/perception/production/data/perception/camera/models/yolo_obstacle_detector

2.1 配置文件调整

创建/修改配置文件，确保检测到的障碍物信息向指定channel输出：

- 修改文件位置为：modules/perception/production/conf/perception/camera/fusion_camera_detection_component.pb.txt
- 修改文件内容为：

```
output_final_obstacles : true
output_obstacles_channel_name : "/apollo/perception/obstacles"
```

2.2 启动文件调整

创建/调整启动文件：modules/perception/production/dag/dag_streaming_perception_dev_kit_camera.dag：

```
module_config {
  module_library : "/apollo/bazel-bin/modules/perception/onboard/component/libperception_component_camera.so"
  components {
    class_name : "FusionCameraDetectionComponent"
    config {
      name: "FusionCameraComponent"
      config_file_path: "/apollo/modules/perception/production/conf/perception/camera/fusion_camera_detection_component.pb.txt"
      flag_file_path: "/apollo/modules/perception/production/conf/perception/perception_common.flag"
    }
  }
}
```

2.3 启动图像感知模块

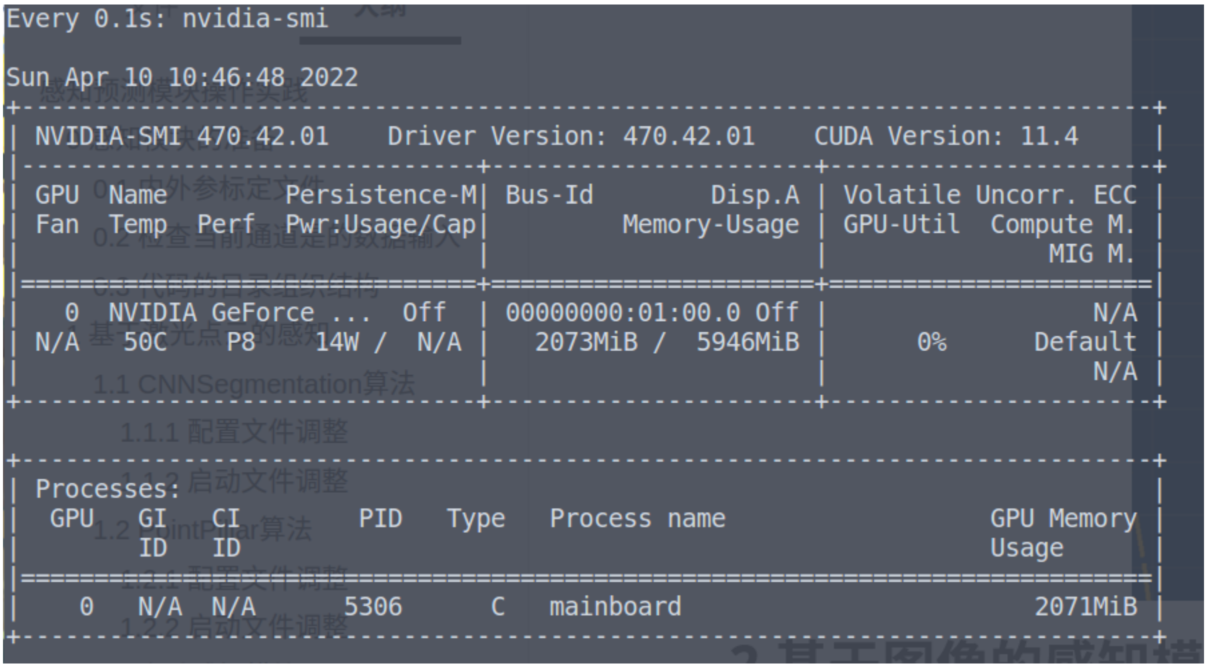
1. 启动图像模块，等待待显存稳定（一般在1-2分钟左右）。

```
mainboard -d
/apollo/modules/perception/production/dag/dag_streaming_perception_dev_kit_camera.
dag
```

2. 待显存稳定后启动数据集：

```
cyber_recorder play -f data/bag/20220203/20220203100813.record.0000*
```

   - 显存是否稳定可以通过指令：`watch -n 0.1 nvidia-smi`查询。该命令表示每间隔0.1 s执行一次`nvidia-smi`指令
   - 显存稳定：



```
Every 0.1s: nvidia-smi

Sun Apr 10 10:46:48 2022
+-----------------------------------------------------------------------------+
| NVIDIA-SMI 470.42.01    Driver Version: 470.42.01    CUDA Version: 11.4     |
|-------------------------------+----------------------+----------------------+
| GPU  Name        Persistence-M| Bus-Id        Disp.A | Volatile Uncorr. ECC |
| Fan  Temp  Perf  Pwr:Usage/Cap|         Memory-Usage | GPU-Util  Compute M. |
|                               |                      |               MIG M. |
|===============================+======================+======================|
|   0  NVIDIA GeForce ...  Off  | 00000000:01:00.0 Off |                  N/A |
| N/A   50C    P8    14W /  N/A |   2073MiB /  5946MiB |      0%      Default |
|                               |                      |                  N/A |
+-------------------------------+----------------------+----------------------+

+-----------------------------------------------------------------------------+
| Processes:                                                                  |
|  GPU   GI   CI        PID   Type   Process name                  GPU Memory |
|        ID   ID                                                   Usage      |
|=============================================================================|
|    0   N/A  N/A      5306      C   mainboard                        2071MiB |
+-----------------------------------------------------------------------------+
```

3. 查看输出结果：（camera检测输出为三维目标框）

```
cyber_monitor
```

观察到`/apollo/perception/obstacles`中有数据输出：

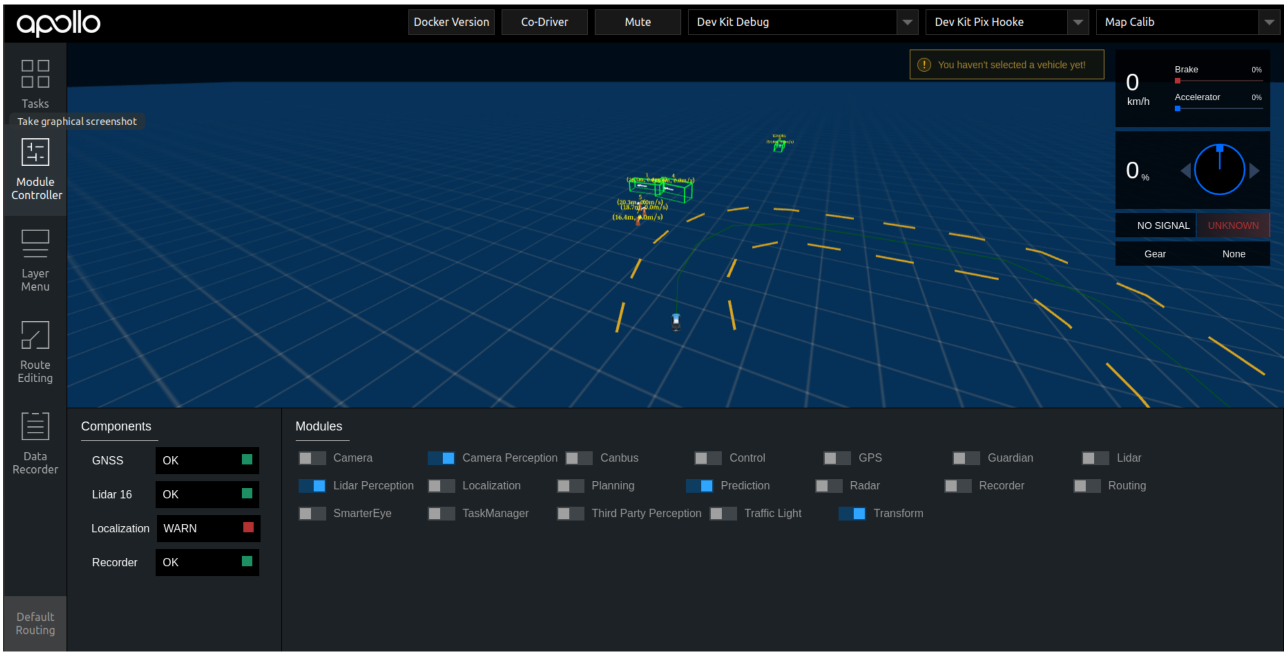
   - 障碍物序列为：

```
ChannelName: /apollo/perception/obstacles
MessageType: apollo.perception.PerceptionObs
FrameRatio: 0.00
RawMessage Size: 2690 Bytes (2.63 KB)
perception_obstacle: +[5 items]
header:
  timestamp_sec: 1649559114.608419418
  module_name: perception_camera
  sequence_num: 1580
  lidar_timestamp: 1644554795624157952
  camera_timestamp: 1644554795624157952
error_code: OK
lane_marker:
  left_lane_marker:
  right_lane_marker:
  next_left_lane_marker: +[1 items]
  next_right_lane_marker: +[1 items]
```

与激光雷达检测相比，多了车道线等信息，但是由于该模块尚未开启，因此没有数据。

- 单个障碍物信息（perception_obstacle[i]）的数据类型解析详见激光点云的检测说明。与激光相比，基于视觉的输出多了bbox2d和light_status，其余变化不大。

4. 在dreamviewer最终效果如下：可以看出，**相机的视野较远**，还能有效的检测到**小物体**，但是**视野受限**。



3 基于相机和激光融合的感知模块

3.1 配置文件调整

与单传感器感知不同，融合感知需要将点云、相机的感知结果进行后融合。为了保证输出通道不被占用，首先需要将相机感知的通道做一定调整，将结果传给位于点云感知的融合模块：

- 创建/修改文件：modules/perception/production/conf/perception/camera/fusion_camera_detection_component.

pb.txt

```
output_final_obstacles : true
output_obstacles_channel_name : "/perception/obstacles"
```

选择需要融合的主传感器，并设置输出通道：

- 创建/修改文件：modules/perception/production/conf/perception/fusion/fusion_component_conf.pb.txt

```
fusion_method: "ProbabilisticFusion"
fusion_main_sensors: "velodyne16"
fusion_main_sensors: "front_6mm"
object_in_roi_check: true
radius_for_roi_object_check: 120
output_obstacles_channel_name: "/apollo/perception/obstacles"
output_viz_fused_content_channel_name:
"/perception/inner/visualization/FusedObjects"
```

3.2 启动文件调整

创建/修改启动文件：modules/perception/production/dag/dag_streaming_perception.dag，内容如下：

```
module_config {
  module_library : "/apollo/bazel-
bin/modules/perception/onboard/component/libperception_component_camera.so"
  components {
    class_name : "FusionCameraDetectionComponent"
    config {
      name: "FusionCameraComponent"
      config_file_path:
"/apollo/modules/perception/production/conf/perception/camera/fusion_camera_detection_co
mponent.pb.txt"
      flag_file_path:
"/apollo/modules/perception/production/conf/perception/perception_common.flag"
    }
  }
}


module_config {
  module_library : "/apollo/bazel-
bin/modules/perception/onboard/component/libperception_component_lidar.so"

 components {
    class_name : "SegmentationComponent"
    config {
      name: "Velodyne16Segmentation"
```

```
    config_file_path:
"/apollo/modules/perception/production/conf/perception/lidar/velodyne16_segmentation_conf.pb.txt"
    flag_file_path:
"/apollo/modules/perception/production/conf/perception/perception_common.flag"
    readers {
      channel: "/apollo/sensor/lidar32/compensator/PointCloud2"
     }
   }
  }

  components {
   class_name : "RecognitionComponent"
   config {
    name: "RecognitionComponent"
    config_file_path:
"/apollo/modules/perception/production/conf/perception/lidar/recognition_conf.pb.txt"
    readers {
      channel: "/perception/inner/SegmentationObjects"
     }
   }
  }


  components {
   class_name: "FusionComponent"
   config {
    name: "SensorFusion"
    config_file_path:
"/apollo/modules/perception/production/conf/perception/fusion/fusion_component_conf.pb.txt"
    readers {
      channel: "/perception/inner/PrefusedObjects"
     }
   }
  }

}
```

3.3 启动融合感知模块

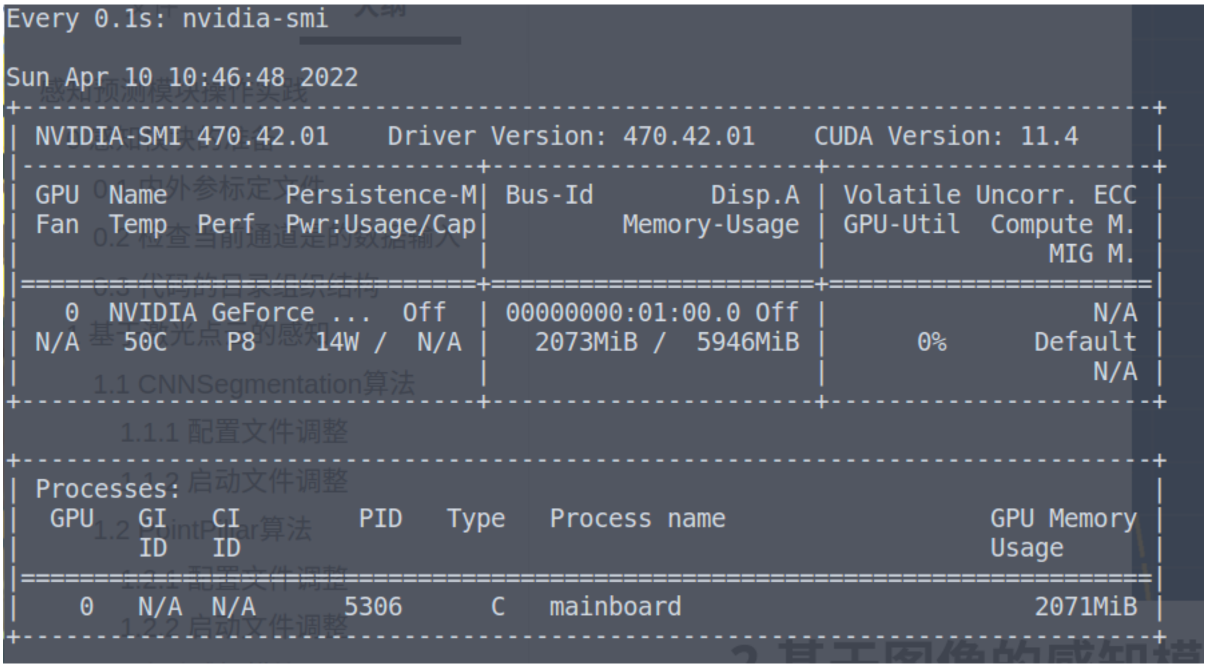
1. 启动融合感知模块，等待待显存稳定（一般在1-2分钟左右）。

   ```
   mainboard -d /apollo/modules/perception/production/dag/dag_streaming_perception.dag
   ```

2. 待显存稳定后启动数据集：

   ```
   cyber_recorder play -f data/bag/20220203/20220203100813.record.0000*
   ```

- 显存是否稳定可以通过指令：watch -n 0.1 nvidia-smi查询。该命令表示每间隔0.1 s执行一次nvidia-smi指令
- 显存稳定：



```
Every 0.1s: nvidia-smi

Sun Apr 10 10:46:48 2022
+-----------------------------------------------------------------------------+
| NVIDIA-SMI 470.42.01    Driver Version: 470.42.01    CUDA Version: 11.4     |
|-------------------------------+----------------------+----------------------+
| GPU  Name        Persistence-M| Bus-Id        Disp.A | Volatile Uncorr. ECC |
| Fan  Temp  Perf  Pwr:Usage/Cap|         Memory-Usage | GPU-Util  Compute M. |
|                               |                      |               MIG M. |
|===============================+======================+======================|
|   0  NVIDIA GeForce ...  Off  | 00000000:01:00.0 Off |                  N/A |
| N/A   50C    P8    14W /  N/A |   2073MiB /  5946MiB |      0%      Default |
|                               |                      |                  N/A |
+-------------------------------+----------------------+----------------------+

+-----------------------------------------------------------------------------+
| Processes:                                                                  |
|  GPU   GI   CI        PID   Type   Process name                  GPU Memory |
|        ID   ID                                                   Usage      |
|=============================================================================|
|    0   N/A  N/A      5306      C   mainboard                        2071MiB |
+-----------------------------------------------------------------------------+
```

3. 查看输出结果：（三维目标框和多边形框）

```
cyber_monitor
```

观察到/apollo/perception/obstacles中有数据输出，输出数据类型与之前类似。

4. 在dreamviewer最终效果如下：可以看出，**近处时为点云检测为主的多边形目标，远处时为相机检测到的矩形框**，兼具了两者的优势。

==TODO: picture path!==

4 启动预测模块

4.1 输入输出解析

预测模块输入消息类型为：

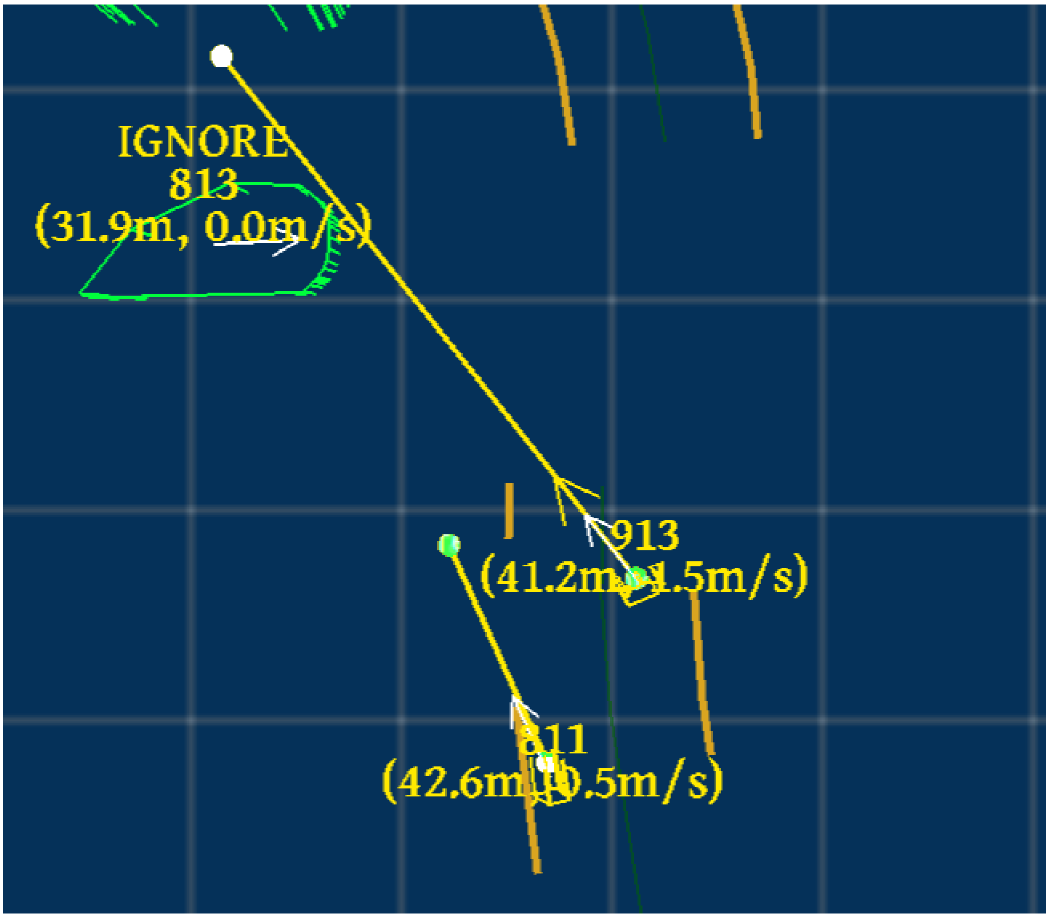
- perception::PerceptionObstacles：感知模块输出的障碍物信息，对应/apollo/perception/obstacles
- planning::ADCTrajectory：规划模块输出的行驶路径，对应/apollo/planning
- localization::LocalizationEstimate：车辆当前的位置，对应/apollo/localization/pose

预测模块输出消息类型为：

- prediction::PredictionObstacles：预测模块输出的障碍物信息，对应/apollo/prediction

4.2 预测模块启动

1. 启动cyber_launch start modules/prediction/launch/prediction.launch



2. 观测cyber_monitor的/apollo/prediction通道是否正常工作输出

```
ChannelName: /apollo/prediction
MessageType: apollo.prediction.PredictionObstacles
FrameRatio: 0.00
RawMessage Size: 3199 Bytes (3.12 KB)
header:
  timestamp_sec: 1644114068.160332918
  module_name: prediction
  sequence_num: 218
  lidar_timestamp: 1643854111485752064
  camera_timestamp: 1643854111485752064
  radar_timestamp: 0
pr Take graphical screenshot [6 items]
perception_error_code: OK
start_timestamp: 1644114068.156162262
end_timestamp: 1644114068.160304546
```