Claims

While some embodiments of the invention have been described by the illustrations with diagrams, a person skilled in the art will recognize that the invention can be carried out with many modifications, variations, and adaptions without departing from the scope of this invention defined in the following claims.

1. An efficient method for achieving environment perception based on automotive radar consisting of:
   1) A compact method of environment perception built on the basis of panoptic segmentation
   2) A method of designing and implementing the panoptic segmentation model consisting of one shared encoder stage and three separate functional branches corresponding to instance segmentation, semantic segmentation, and multipath detection, respectively.
   3) A method of data labeling for instance segmentation.
2. The method of claim 1, where the method of compact environment perception consists of:
   1) a basis of efficient panoptic segmentation that takes point cloud from radar sensors as input and outputs the target class information, target instance ID, as well as multipath detection
   2) from the results of panoptic segmentation, static environments are separated from the static classes, by, for example, indexing the points with class types belonging to static classes
   3) from the static environment, the perception functions like the OGM and FSD will be carried out by processing the point cloud belonging to the static environment.
   4) from the results of panoptic segmentation, dynamic environments are separated from the dynamic target classes, by, for example, indexing the points with class types belonging to static classes
   5) from the result of the dynamic environment, target tracking can be carried out by processing the points belonging to dynamic objects
   6) from the result of panoptic segmentation, multipath points are detected and removed.
3. The method of claim 1, where methods of the design and implementation of the efficient panoptic segmentation model consist of:
   1) one feature encoder network that takes raw point cloud along with other information such as ego-motion information as input and produces a matrix of global features
   2) one instance segmentation branch that processes the augmented global features using an MLP and produces the instance information for each point
   3) one semantic segmentation branch that processes the global features using a MLP and produces the semantic information for each point
   4) one multipath branch that processes the global features augmented with additional information and produces the multipath detection
   5) The training of the model on the training data by applying the weighted sum loss functions combining each loss function of the abovementioned individual branch, i.e., instance segmentation branch, semantic segmentation branch, and multipath branch
   6) applying the trained model to real data for panoptic segmentation in real time

4. The method of claim 3, where the feature augmentation in the instance segmentation branch may be
   1) implemented as augmentation with azimuth information, and other possible information such as elevation according to the labeling scheme
   2) implemented through, but not limited to, concatenating the azimuth as another feature or adding the azimuth information to the extracted features for each point

5. The method of claim 1, where the data labeling for instance segmentation consists of the following steps:
   1) clustering step that is applied to the point cloud so that the points corresponding to the same target are clustered into one cluster. This can be done, for example, manually by a human labeler or by automatic clustering methods.
   2) instance labeling step when gradually increased instance labels are assigned based on the azimuth value and the azimuth value of the instance can be computed, for example, from the center point of the cluster of the instance.

6. A system for achieving environment perception based on automotive radar consisting of:
   1) a system of panoptic segmentation model trained on labeled data, consisting of one shared encoder stage and three separate functional branches corresponding to instance segmentation, semantic segmentation, and multipath detection, respectively
   2) a compact system of environment perception built on the system of panoptic segmentation system

7. The system of claim 6, where the system of compact environment perception consists of:
   1) a system of efficient panoptic segmentation that takes point cloud from radar sensors as input and outputs the target class information, target instance ID, as well as multipath detection
   2) from the results of panoptic segmentation, static environments are separated based on point clouds of static classes
   3) from the static environment, the perception functions like the OGM and FSD will be carried out by processing static point clouds.
   4) from the results of panoptic segmentation, dynamic environments are separated based on point clouds of dynamic target classes
   5) from the result of the dynamic environment, target tracking can be carried out on point clouds of dynamic targets
   6) from the result of panoptic segmentation, multipath points are detected and removed.
8. The system of claim 6, where the system of efficient panoptic segmentation model consists of:
   1) one feature encoder network system that takes raw point cloud along with other information as input and produces a matrix of global features
   2) one instance segmentation system that processes the augmented global features using an MLP and produces the instance information for each point
   3) one semantic segmentation system that processes the global features using a MLP and produces the semantic information for each point
   4) one multipath system that processes the global features augmented with additional information and produces the multipath detection

9. The system of claim 8, where the feature augmentation in the instance segmentation system may be
   1) implemented as augmentation with azimuth information, and other possible information such as elevation according to the labeling scheme
   2) implemented in the system through, but not limited to, concatenating the azimuth as another feature or adding the azimuth information to the extracted features for each point
10. A system of the data labeling for instance segmentation consists of:
    1) clustering system that is applied to the point cloud so that the points corresponding to the same target are clustered into one cluster. This can be realized as automatic clustering software.
    2) an instance index assignment system that during the instance labeling assigns gradually increased instance labels to target belonging to the same class based on the azimuth value and the azimuth value of the target instance can be computed, for example, from the center point of the cluster of the instance.