

PREDICTING THREE-DIMENSIONAL FEATURES FOR AUTONOMOUS DRIVING

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation of, and claims priority to, U.S. Patent App. No. 16/265720 titled “PREDICTING THREE-DIMENSIONAL FEATURES FOR AUTONOMOUS DRIVING” and filed on February 1, 2019, the disclosure of which is hereby incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

[0002] Deep learning systems used for applications such as autonomous driving are developed by training a machine learning model. Typically, the performance of the deep learning system is limited at least in part by the quality of the training set used to train the model. In many instances, significant resources are invested in collecting, curating, and annotating the training data. Traditionally, much of the effort to curate a training data set is done manually by reviewing potential training data and properly labeling the features associated with the data. The effort required to create a training set with accurate labels can be significant and is often tedious. Moreover, it is often difficult to collect and accurately label data that a machine learning model needs improvement on. Therefore, there exists a need to improve the process for generating training data with accurate labeled features.

SUMMARY

[0002a] According to an aspect, the present disclosure refers to a system, comprising: a processor configured to: receive image data based on an image captured by a camera of a vehicle; determine a three-dimensional trajectory of a machine learning feature based on input of the image data to a machine learning model, wherein the machine model was trained based on training data comprising: a ground truth associated with a plurality of time series elements, the ground truth comprising a particular three-dimensional trajectory associated with a particular machine learning feature generated based on the time series elements, the timeseries elements

comprising respective images captured at respective times within a period of time, wherein the ground truth is generated based on particular portions of individual time series elements, and a selected time series element of the plurality of time series elements, wherein the machine model was trained to output the ground truth associated with the plurality of time series elements based on an input of the selected time series element; and provide the three-dimensional trajectory of the machine learning feature in automatically controlling the vehicle; and a memory coupled to the processor and configured to provide the processor with instructions.

[0002b] According to another aspect, the present disclosure refers to a computer program product, the computer program product being embodied in a non-transitory computer readable storage medium and comprising computer instructions for: receiving image data based on an image captured by a camera of a vehicle; determining a three-dimensional trajectory of a vehicle lane line based on input of the image data to a machine learning model, wherein the machine model was trained based on training data comprising: a ground truth associated with a plurality of time series elements comprising respective images, the ground truth comprising a particular three-dimensional trajectory associated with a particular lane line represented in the images, and a selected time series element of the plurality of time series elements, wherein the machine model was trained to output the ground truth associated with the plurality of time series elements based on an input of the selected time series element; and providing the three-dimensional trajectory of the vehicle lane in automatically controlling the vehicle.

[0002c] According to another aspect, the present disclosure refers to a method, comprising: receiving image data based on an image captured by a camera of a vehicle; determining a three-dimensional trajectory of a vehicle lane line based on input of the image data to a machine learning model, wherein the machine model was trained based on training data comprising: a ground truth associated with a plurality of time series elements comprising respective images, the ground truth comprising a particular three-dimensional trajectory associated with a particular lane line represented in the images, and a selected time series element of the plurality of time series elements, wherein the machine model was trained to output the ground truth associated with the plurality of time series elements based on an input of the selected time series element; and providing the three-dimensional trajectory of the vehicle lane in automatically controlling the vehicle.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] Various embodiments of the invention are disclosed in the following detailed description and the accompanying drawings.

[0004] Figure 1 is a block diagram illustrating an embodiment of a deep learning system for autonomous driving.

[0005] Figure 2 is a flow diagram illustrating an embodiment of a process for training and applying a machine learning model for autonomous driving.

WHAT IS CLAIMED IS:

1. A system, comprising:
a processor configured to:
 receive image data based on an image captured by a camera of a vehicle;
 determine a three-dimensional trajectory of a machine learning feature based on input of the image data to a machine learning model,
 wherein the machine model was trained based on training data comprising:
 a ground truth associated with a plurality of time series elements, the ground truth comprising a particular three-dimensional trajectory associated with a particular machine learning feature generated based on the time series elements, the timeseries elements comprising respective images captured at respective times within a period of time, wherein the ground truth is generated based on particular portions of individual time series elements, and
 a selected time series element of the plurality of time series elements,
 wherein the machine model was trained to output the ground truth associated with the plurality of time series elements based on an input of the selected time series element;
and
 provide the three-dimensional trajectory of the machine learning feature in automatically controlling the vehicle; and
a memory coupled to the processor and configured to provide the processor with instructions.
2. The system of claim 1, wherein the machine learning feature is associated with a vehicle lane line.
3. The system of claim 2, wherein portions of the three-dimensional trajectory of the vehicle lane line are occluded in the image data.
4. The system of claims 2-3, wherein the processor is further configured to use the vehicle lane line to identify a vehicle lane occupied by the vehicle.
5. The system of claims 2-4, wherein the vehicle lane is used to identify a drivable space.

6. The system of claim 5, wherein the identified drivable space is used to maintain the vehicle in the vehicle lane.
7. The system of claims 1-6, wherein the camera of the vehicle includes at least one of the following: a front-facing camera, a side-facing camera, or a rear-facing camera.
8. The system of claims 1-7, wherein the predicted three-dimensional trajectory is one of a plurality of identified potential trajectories.
9. The system of claim 8, wherein the predicted three-dimensional trajectory has a probability of occurring value that is the highest of the plurality of identified potential trajectories.
10. The system of claim 1, wherein the training data further includes a related set of odometry data associated with the time series elements.
11. The system of claim 11, wherein at least a portion of the training data is automatically labeled as the ground truth.
12. The system of claims 1-12, wherein the controlling of the vehicle includes adjusting a speed and a steering of the vehicle.
13. The system of claims 1-12, wherein the three-dimensional trajectory is represented by a spline.
14. The system of claims 1-13, wherein the three-dimensional trajectory is represented by one or more piecewise polynomials.
15. The system of claims 1-14, wherein the machine learning feature is associated with a predicated path of a second vehicle.
16. The system of claim 16, wherein the predicated path of the second vehicle is used to determine whether the second vehicle is likely to enter a lane occupied by the vehicle being automatically controlled.
17. The system of claim 17, wherein the controlling of the vehicle includes adjusting a speed or steering to avoid a collision with the second vehicle.
18. A computer program product, the computer program product being embodied in a non-transitory computer readable storage medium and comprising computer instructions for:

receiving image data based on an image captured by a camera of a vehicle;
determining a three-dimensional trajectory of a vehicle lane line based on input of the image data to a machine learning model,
wherein the machine model was trained based on training data comprising:
a ground truth associated with a plurality of time series elements comprising respective images, the ground truth comprising a particular three-dimensional trajectory associated with a particular lane line represented in the images, and
a selected time series element of the plurality of time series elements,
wherein the machine model was trained to output the ground truth associated with the plurality of time series elements based on an input of the selected time series element; and
providing the three-dimensional trajectory of the vehicle lane in automatically controlling the vehicle.

19. A method, comprising:

receiving image data based on an image captured by a camera of a vehicle;
determining a three-dimensional trajectory of a vehicle lane line based on input of the image data to a machine learning model,
wherein the machine model was trained based on training data comprising:
a ground truth associated with a plurality of time series elements comprising respective images, the ground truth comprising a particular three-dimensional trajectory associated with a particular lane line represented in the images, and
a selected time series element of the plurality of time series elements,
wherein the machine model was trained to output the ground truth associated with the plurality of time series elements based on an input of the selected time series element; and
providing the three-dimensional trajectory of the vehicle lane in automatically controlling the vehicle.