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Monitoring Object Detection Abnormalities via Data-Label and Post-Algorithm Abstractions

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❖ Motivation

- Object detection modules are essential functionalities for any autonomous vehicle.
- The performance of such modules that are implemented using deep neural networks can be unreliable in many cases.
- The abstraction-based monitoring method we developed in this paper serves as a logical framework for filtering these potentially erroneous detection results.

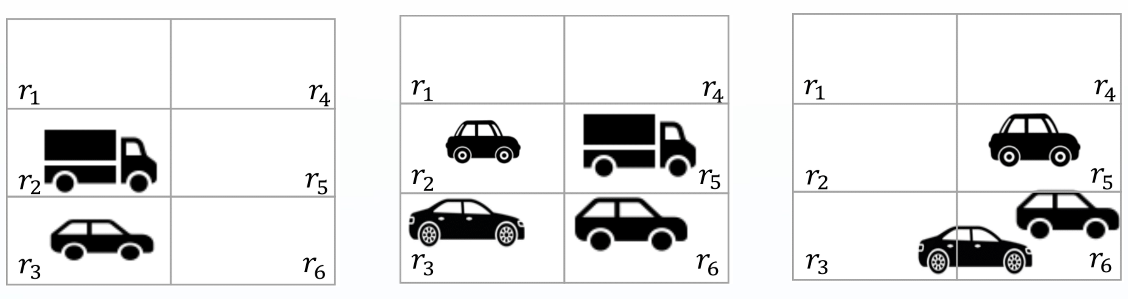
❖ Our Method

➢ Overview

- To develop monitors, our key approach is to utilize the concept of **abstraction**.
- We propose two new types of abstraction: **data-label abstraction** and **post-algorithm abstraction**.

➢ Data-label abstraction

- The monitor on data-label abstraction can be regarded as a dictionary mapping from the set of classes to an abstraction over the traces accumulated from ground-truth.



(a) Time *t-1* (b) Time *t* (b) Time *t+1*

Fig. 1. Data-label abstraction – the ground-truth on a sequence of images

- To check abnormalities with the monitor on data-label abstraction, we need to compare the detected objects with the constructed dictionaries.

➢ Post-algorithm abstraction

- The construction of the monitor involves the following steps:
  - 1) Blur the classes of objects to be tracked;
  - 2) Perform the relaxed tracking over the objects;
  - 3) Enlarge the candidates with a given bound;
  - 4) Restore the classes for the candidate objects.
- The abnormality checking with post-algorithm abstraction is to check whether the class of an object at time *t-1* and the class of the tracked object at time *t* are consistent.

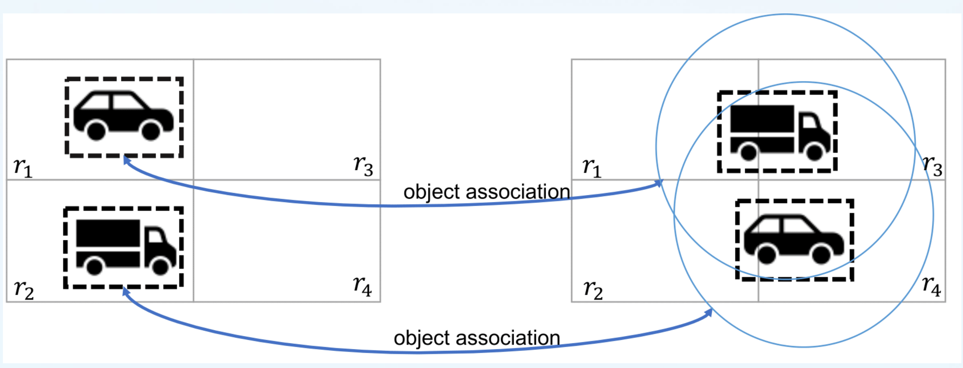
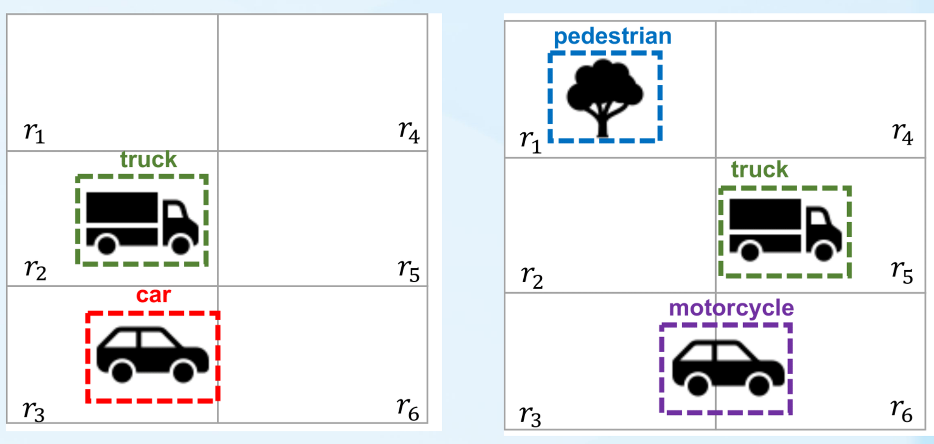


Fig. 2. Post-algorithm abstraction - class relaxation and weak association

➢ An example for abnormal checking

- The monitor based on **data-label abstraction** finds that the identified pedestrian can be problematic, because in the training data, region r_1 never has a pedestrian.
- The monitor based on **post-algorithm abstraction** finds that the motorcycle class can be problematic; by abstracting the information of object class, performing tracking, and then matching the tracked result, there seems to be a class flip over the detected object.



(a) Time *t-1* (b) Time *t*

Fig. 3. An example for abnormal checking

❖ Experiment Results

➢ Effectiveness evaluation with ground-truth

- Monitoring randomly modified labels and bounding boxes on KITTI dataset:

alarm type	# injected	TP	FP	precision	recall
abnormal location	34	27	5	0.844	0.794
abnormal size	50	47	6	0.887	0.940
object loss	112	109	10	0.916	0.973
label flip	180	180	2	0.989	1.000

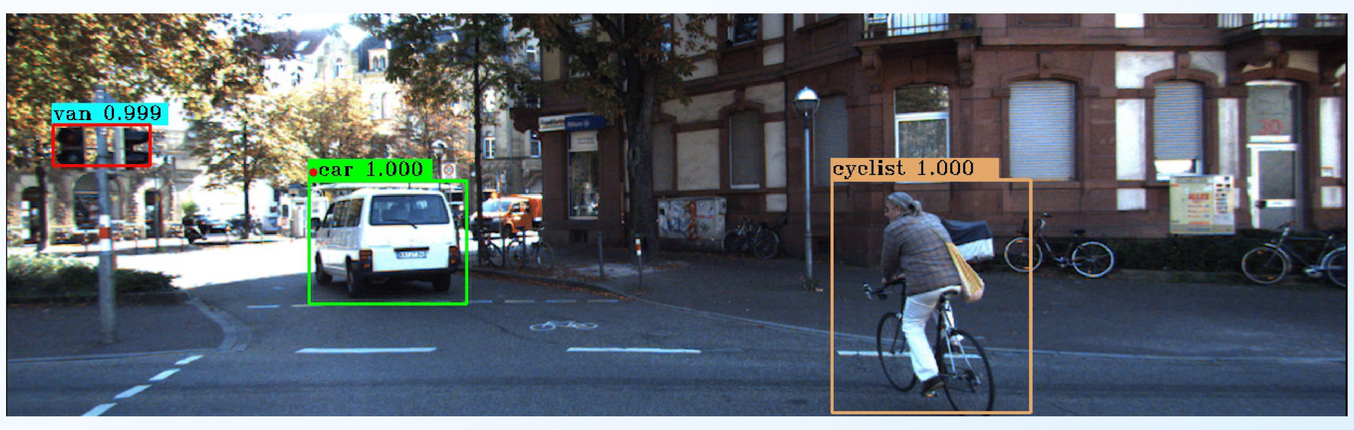
➢ Performance evaluation on run-time detected results

- Monitoring the detected results from fine-tuned object detector on selected KITTI dataset scenarios:

scenario	alarm type	TP	FP	max OH	min OH	average
1	abnormal location	1	0	0.155s	0.025s	0.064s
	abnormal size	7	1			
	object loss	72	8			
	label flip	78	4			
2	abnormal location	1	0	0.148s	0.008s	0.072s
	abnormal size	4	0			
	object loss	157	29			
	label flip	16	2			
3	abnormal location	2	0	0.126s	0.001s	0.058s
	abnormal size	4	1			
	object loss	92	15			
	label flip	15	2			
4	abnormal location	0	0	0.076s	0.012s	0.039s
	abnormal size	2	0			
	object loss	25	2			
	label flip	7	0			
5	wrong location	0	0	0.130s	0.012s	0.047s
	unusual size	25	6			
	object	140	25			
	label flip	37	6			

➢ Qualitative evaluation

- Error examples filtered by our implemented monitors on detected results of KITTI dataset:



a) The traffic light on the left is mis-classified as **van**. The data-label abstraction monitor detects that it is impossible to have a **van** of such a small size at that region.

b) At time *t-1*, the bus object is detected as the **truck** class; in KITTI, buses and trucks share the same class.

c) The post-algorithm abstraction monitor detects that the **truck** object at time *t-1* is flipped to class **tram** at time *t*.

Fig. 4. Qualitative evaluation on the KITTI dataset

❖ Conclusion

- We developed abstraction-based monitoring as a logical framework for checking abnormalities over detected results..
- The data-label abstraction extracts characteristics of objects from existing datasets.
- The post-algorithm abstraction relaxes class labels in tracking algorithms to associate the objects in consecutive images.
- Our initial evaluation using publicly available object detection datasets demonstrated promise in integrating the developed technologies into autonomous driving products.