# Thing Detection

## Abstract

## 1. Introduction

### 1.1 Background

Semantic classes in images can be either things (objects with a well-defined shape, e.g. car, person) or stuff (amorphous background regions, e.g. grass, sky) [10]. Often things are also dynamic and able to move, while stuff is more stationary.

The goal of this paper is to present datasets, algorithms and implementations to detect and localize things in an image. The conclusions are made according to how well thing detection is achieved in the context of image-based awareness, Fig. 1.

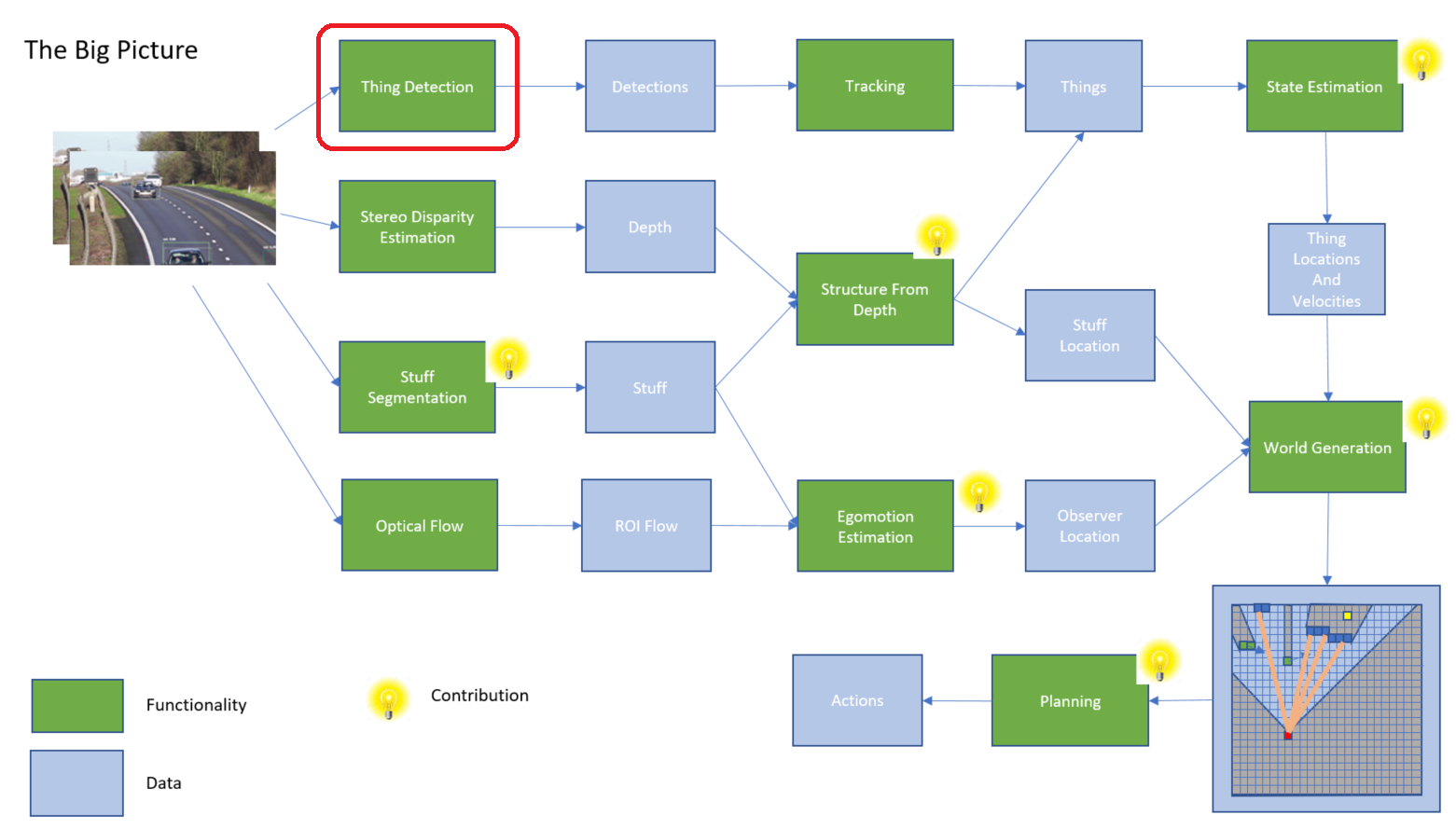


Fig. 1. The role of thing detection in image-based awareness.

### 1.2 Terminology and Tasks

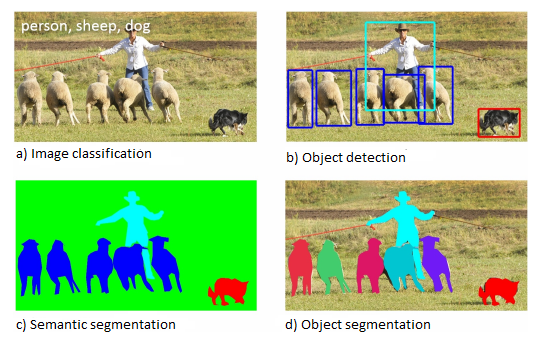
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Fig. 2. Tasks related to scene understanding.

One of the primary goals of computer vision is the understanding of visual scenes. Scene understanding involves numerous tasks [1]:

**Image classification** requires binary labels indicating whether objects are present in an image.

**Object detection** includes both stating that an object belonging to a specified class is present and localizing it in the image. The location of an object is typically represented by a bounding box.

**Semantic segmentation** requires that each pixel of an image be labelled as belonging to a category. Individual instances of objects do not need to be segmented.

**Object segmentation** combines object detection and semantic segmentation. It requires stating that an object belonging to a specified class is present and localizing it in the image using mask.

**Object recognition** requires binary labels indicating whether specific objects are present in an image, like face recognition for individual persons.

**Instance segmentation** is a synonym for object segmentation.

**Object localization** is object detection for a specific object category.

**Scene recognition** is best defined in [16]. “By ‘scene’ we mean a place in which a human can act within, or a place to which a human being could navigate.”

**Video object segmentation**…

### 1.3 Scope

The scope of this paper is thing detection which is composed of object detection and object segmentation. Object segmentation is more accurate and the preferred task. However, object segmentation also requires more computational power.

## 2. Problem Setup

### 2.1 Input

### 2.2 Output

## 3. Datasets

Selection of dataset determines which categories are available as well as off-the-shelf algorithm implementation. Following common datasets exist (object detection and instance segmentation task related datasets displayed in red):

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Name | Task | Categories | Images | Year | Reference | Notes |
| COIL | Image classification | 20 | 1 440 | 1996 | [6] | Household objects |
| MNIST | Image classification | 10 | 70 000 | 1998 | [5] | Handwritten digits |
| Caltech 101 | Image classification | 101 | 9 146 | 2004 | [7] |  |
| ESP | Image classification | ? (free format labels) | 350 000 | 2004 | [13] | Game driven. Only part of data publicly available (60 000 images) |
| PASCAL VOC (Visual Object Classes) | Object detection,  Instance segmentation | 20 | 11 000 | 2005…2012 | [9] | Several generations |
| MSRC | Image classification | 21 | 591 | 2006 | [11] |  |
| Caltech 256 | Image classification | 256 | 30 607 | 2007 | [8] |  |
| Lotus Hill | Image classification, Object detection, Instance segmentation | ~200 | >50 000 | 2007 | [15] | Available only through purchase |
| The Berkeley Segmentation Data Set | (Semantic) segmentation | ? | 300/500 | 2007/2011 | [21] | Only partially labelled |
| TinyImage | Image classification | 75 062 | 79 302 107 | 2008 | [12] | 32\*32 colour images |
| LabelMe | Image classification, Object detection, Instance segmentation | ~200 | >30 000 | 2008 | [14] | WordNet classification for part of objects |
| ImageNet | Image classification, Object detection | >20 000  (>1000 for bounding boxes) | 14 197 122  (>1 000 000 for bounding boxes) | 2009… | [2] | WordNet classification structure (synset). No image rights. |
| CIFAR-10 | Image classification | 10 | 60 000 | 2009 | [17] | 32\*32 colour images |
| CIFAR-100 | Image classification | 100 | 60 000 | 2009 | [17] | 32\*32 colour images |
| CamToy (Cambridge-Toyota Labelled Video Database) | Semantic segmentation | 32 | 10 minutes at 1 Hz = 6 000 | 2009 | [20] | Video format |
| SUN | Scene recognition | 899 | 130 519 | 2010 | [16] |  |
| Caltech Pedestrian Dataset | Object localization | 1 | 250 000 | 2012 | [18] |  |
| Indoor Segmentation  Dataset | Semantic segmentation | 26 | 1 449 | 2012 | [19] |  |
| KITTI | Object detection, Instance segmentation, Semantic segmentation | Depends on task | Depends on task | 2012 | [24] | Includes also stereo, depth, 2 and 3d object detection and odometry |
| COCO | Object detection, object segmentation, semantic segmentation | 80 (91) | 330 000 | 2015… | [1], [22] | COCO Stuff was added 2017 |
| Open Images | Object detection | >6000 | >9 000 000 | 2016 | [23] |  |
| CityScapes | Semantic segmentation,  Instance segmentation | 30 | 5 000 (fine), 20 000 (coarse) | 2016 | [25] |  |
| DAVIS: Densely Annotated VIdeo Segmentation | Video instance segmentation | 50 (number of different objects) | 10 459 | 2017 | [26] | Video format |

## 4. Algorithms

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Name | Task | Reference | Year | Notes |
| Selective Search | Object detection | [27] | 2013 |  |
| Region-based Convolutional Network (R-CNN) | Object detection | [28] | 2015 |  |
| Fast Region-based Convolutional Network (Fast R-CNN) | Object detection | [29] | 2015 |  |
| ResNet-101 | Object detection | [32] | 2015 |  |
| Faster Region-based Convolutional Network (Faster R-CNN) | Object detection | [30] | 2016 |  |
| Region-based Fully Convolutional Network (R-FCN) | Object detection | [31] | 2016 |  |
| You Only Look Once (YOLO) | Object detection | [33] | 2016 |  |
| Single-Shot Detector (SSD) | Object detection | [34] | 2016 |  |
| YOLO9000 | Object detection | [35] | 2016 |  |
| SqueezeNet | Object detection | [38] | 2016 |  |
| Inception V1 |  |  |  |  |
| Inception V2 |  |  |  |  |
| Neural Architecture Search Net (NASNet) | Object detection | [36] | 2017 |  |
| YOLOv2 |  |  |  |  |
| Retinanet |  |  |  |  |
| YOLOv3 |  |  |  |  |
| Mask RCNN | Instance segmentation | [37] | 2017 |  |
| Multibox |  |  |  |  |
| MobileNet V1 | Object detection | [39] | 2017 |  |
| SEP-Net | Object detection | [40] | 2017 |  |
| MobileNet v2 | Object detection | [41] | 2018 |  |

## 5. Implementations

Following common implementations are currently available:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Name | Algorithms | Dataset | Platform | Speed | mAP | Model Zoo |
| ssd\_mobilenet\_v1\_coco | SSD, MobileNet V1 | COCO | Tensorflow | 30 | 21 | [Tensorflow detection model zoo](https://github.com/tensorflow/models/blob/master/research/object_detection/g3doc/detection_model_zoo.md) |
| ssd\_mobilenet\_v2\_coco | SSD, MobileNet V2 | COCO | Tensorflow | 31 | 22 | [Tensorflow detection model zoo](https://github.com/tensorflow/models/blob/master/research/object_detection/g3doc/detection_model_zoo.md) |
| ssd\_inception\_v2\_coco | SSD, Inception V2 | COCO | Tensorflow | 42 | 24 | [Tensorflow detection model zoo](https://github.com/tensorflow/models/blob/master/research/object_detection/g3doc/detection_model_zoo.md) |
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## 6. Conclusions

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