

Detecting Contextual Anomalies by Discovering Consistent Spatial Regions

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Abstract

We describe a method for modeling spatial context to enable video anomaly detection. The main idea is to discover regions that share similar object-level activities by clustering joint object attributes using Gaussian mixture models. We demonstrate that this straightforward approach, using orders of magnitude fewer parameters than competing models, achieves state-of-the-art performance in the challenging spatial-context-dependent Street Scene dataset. As a side benefit, the high-resolution discovered regions learned by the model also provide explainable normalcy maps for human operators without the need for any pre-trained segmentation model.

1. Introduction

Determining whether an event observed in a video stream is anomalous often depends on its spatial context. For example, pedestrians are expected on sidewalks and cyclists in bike lanes, but not vice versa. In real-world video anomaly detection, the appearance and motion of objects alone are insufficient to classify anomalies; we should learn the “normal” behavior of objects at different locations in the video based on long-term observation.

A major trend in modern video anomaly detection (VAD) algorithms is to train convolutional auto-encoders using a reconstruction proxy task [8, 10, 20]. Future frame prediction [13, 14, 17, 20] can be considered a special form of reconstruction that also addresses temporal regularity. These reconstruction-based methods have achieved great success on widely adopted VAD benchmark datasets, such as UCSD Ped2 [33], CUHK Avenue [16], and ShanghaiTech [14]. However, we observe a large performance drop when such algorithms are applied to datasets in which spatial context plays a critical role in making the anomaly decision, such as the relatively new Street Scene benchmark dataset [23]. One reason is that convolutional auto-encoders are poorly suited to learning spatial context due to their shift-invariant nature [9].

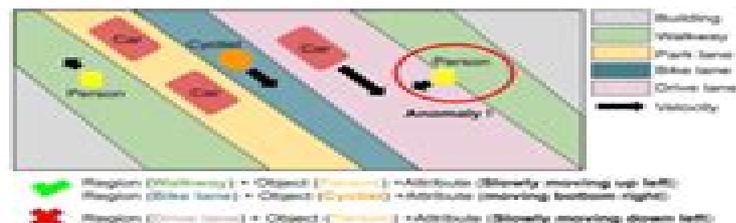


Figure 1. A toy example of building spatial context. Using the discovered semantically meaningful regions, spatial-context-dependent anomalies can be easily detected.

In contrast, high-performing VAD algorithms on the Street Scene dataset (e.g., [23, 25]) usually separate videos into hundreds of rectangular subregions, each with a dedicated normalcy model. Hundreds of subregions not only result in hundreds of normalcy models but also reduce model robustness due to the small number of available object samples per region. However, a typical surveillance camera does not capture hundreds of small regions with different normalcy patterns; meaningful regions should be automatically discovered from long-term observations.

Fig. 1 illustrates a toy experiment mimicking a typical street scenario. Suppose we can extract representations like “pedestrians walk or jog on the sidewalk,” “cyclists ride within the bike lane,” and “cars move quickly in the traffic lane in the correct direction” from training videos. Then, given a new event represented in the same “region-object-attribute” form, we should be able to achieve an almost perfect anomaly detection result. Leveraging object categories and their corresponding attributes is already widespread in the VAD community [19, 24, 28]. However, automatically extracting consistent spatial regions based on these behaviors and using them as the basis for anomaly detection is relatively unexplored territory.

In this paper, we describe a natural approach to discovering spatial regions that have similar expected object motion

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Table of Contents Spatial And Contextual Models In Political Research

1. Understanding the eBook Spatial And Contextual Models In Political Research
 - The Rise of Digital Reading Spatial And Contextual Models In Political Research
 - Advantages of eBooks Over Traditional Books
2. Identifying Spatial And Contextual Models In Political Research
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Spatial And Contextual Models In Political Research
 - User-Friendly Interface
4. Exploring eBook Recommendations from Spatial And Contextual Models In Political Research
 - Personalized Recommendations
 - Spatial And Contextual Models In Political Research User Reviews and Ratings
 - Spatial And Contextual Models In Political Research and Bestseller Lists
5. Accessing Spatial And Contextual Models In Political Research Free and Paid eBooks
 - Spatial And Contextual Models In Political Research Public Domain eBooks
 - Spatial And Contextual Models In Political Research eBook Subscription Services
 - Spatial And Contextual Models In Political Research Budget-Friendly Options

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 - ePub, PDF, MOBI, and More
 - Spatial And Contextual Models In Political Research Compatibility with Devices
 - Spatial And Contextual Models In Political Research Enhanced eBook Features
7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Spatial And Contextual Models In Political Research
 - Highlighting and Note-Taking Spatial And Contextual Models In Political Research
 - Interactive Elements Spatial And Contextual Models In Political Research
8. Staying Engaged with Spatial And Contextual Models In Political Research
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Spatial And Contextual Models In Political Research
9. Balancing eBooks and Physical Books Spatial And Contextual Models In Political Research
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Spatial And Contextual Models In Political Research
10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
11. Cultivating a Reading Routine Spatial And Contextual Models In Political Research
 - Setting Reading Goals Spatial And Contextual Models In Political Research
 - Carving Out Dedicated Reading Time
12. Sourcing Reliable Information of Spatial And Contextual Models In Political Research
 - Fact-Checking eBook Content of Spatial And Contextual Models In Political Research
 - Distinguishing Credible Sources
13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
14. Embracing eBook Trends
 - Integration of Multimedia Elements

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