A Deep Learning-Based Robot Analysis Model for Semantic Context Capturing by Using Predictive Models in Public Management

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ABSTRACT

In the realm of robotics, the ability to comprehend intricate semantic contexts within diverse environments is paramount for autonomous decision-making and effective human-robot collaboration. This article delves into the realm of enhancing robotic semantic understanding through the fusion of deep learning techniques. This work presents a pioneering approach: integrating several neural network models to analyze robot images, thereby capturing nuanced environmental semantic contexts. The authors augment this analysis with predictive models, enabling the robot to adapt the changing contexts intelligently. Through rigorous experimentation, our model demonstrated a substantial 25% increase in accuracy when compared to conventional methods, showcasing its robustness in real-world applications. This research marks a significant stride toward imbuing robots with sophisticated visual comprehension, paving the way for more seamless human-robot interactions and a myriad of practical applications in the evolving landscape of robotics.

KEYWORDS

CNN, Deep Learning, Robotics, Semantic Context, U-Net

INTRODUCTION

The significance of semantic analysis of robot images (Elmquist et al., 2022) lies in enhancing the perceptual ability and intelligence level of robots in complex environments, enabling them to accurately comprehend the surrounding environment and make corresponding decisions and actions. Through image semantic analysis (Lu et al., 2021), robots can identify and understand objects, scenes, and contexts in images, thereby better perceiving the surrounding environment. This capability is crucial for robots in navigating and interacting in complex and uncontrollable environments, such as disaster rescue (Zhao et al., 2022), outdoor exploration (Shah et al., 2021), and unknown environment detection tasks (Singh et al., 2022). Utilizing semantic analysis of robot images can help robots understand human actions, expressions, and intentions, facilitating better interaction with humans.

In the fields of service robots (Okafuji et al., 2022) and social robots (Li et al., 2023), semantic analysis of robot images can assist robots in understanding user needs, providing more personalized and intelligent services and enhancing the user experience. Through image semantic analysis, robots can recognize different objects and situations and make corresponding decisions and plans based on this information. This ability is essential for key tasks such as autonomous navigation, obstacle avoidance, and task planning, enabling robots to independently accomplish various tasks without the need for real-time human intervention.

In the industrial sector (Lin et al., 2022), semantic analysis of robot images can help robots automatically identify and detect product defects, thereby improving production quality and efficiency. Moreover, it can be applied in intelligent warehousing (Dai et al., 2021), logistics (Wang & Chen, 2021), and other fields to achieve automated and intelligent logistics management. In the medical field (Sun et al., 2021), semantic analysis of robot images can be used for tasks such as surgical assistance, disease diagnosis, and rehabilitation treatment, assisting doctors in improving diagnostic accuracy and surgical precision and providing better rehabilitation services for patients.

An important real-world application case is presented herein, where the outcomes of semantic analysis of robot images can aid autonomous vehicles in comprehending their surroundings. Through image semantic analysis, vehicles can recognize roads, traffic signs, pedestrians, and other vehicles, enabling intelligent driving decisions. This constitutes a significant application case, as the comprehension of environmental images and semantic analysis thereof stand as pivotal modules within autonomous vehicles, facilitating intelligent automated driving (Chen & Zhang, 2023; Du & Chen, 2023).

Deep learning plays a crucial role in the task of semantic analysis of images for robots. Through convolutional neural networks (CNNs) (Nagata et al., 2021), robots can efficiently recognize objects and scenes within images. Recurrent neural networks (RNNs) (Kong, 2020) and long short-term memory networks (LSTMs) (Gao et al., 2021) are employed to handle image sequences, aiding robots in understanding dynamic scenes and predicting object movements. The integration of CNNs and RNNs enables comprehensive modeling of both image content and contextual information. Transfer learning, utilizing pretrained models, enhances performance on small-scale datasets. Generative adversarial networks (GANs) (Kushwaha et al., 2022) are used to generate images relevant to specific tasks, simulating complex environments. Self-supervised learning and reinforcement learning methods assist robots in learning features from images and optimizing decision-making strategies. These deep-learning techniques enable robots to comprehend images rapidly and accurately, enhancing their perceptual abilities and intelligence levels in complex environments and allowing them to better address various challenges. The deep-learning models commonly used in the research on semantic analysis of images for robots are as follows:

(1) U-Net (Li et al., 2021), a classic fully convolutional neural network, incorporates an encoder–decoder architecture designed for image-segmentation tasks. In the realm of robot-assisted surgery, U-Net has application in the segmentation of organs within medical images, aiding robots in precise localization and manipulation.

(2) DeepLab (Zhenzhen et al., 2021) utilizes deep convolutional neural networks and atrous convolution techniques to effectively capture contextual information within images. In the domain of autonomous vehicles, DeepLab is employed for road segmentation, enabling vehicles to recognize road boundaries and obstacles.

(3) Mask R-CNN (Zhang et al., 2021) combines object detection and semantic segmentation, allowing simultaneous detection of object positions and generation of precise segmentation masks. Within robotic grasping tasks, Mask R-CNN is utilized for object detection and segmentation, enabling robots to accurately grasp objects of various shapes.

(4) FCN (Cen, 2023) represents an end-to-end fully convolutional network that maps input images pixel-wise to semantic segmentation maps. In the realm of unmanned aerial vehicle (UAV) image

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