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OBJECT-ORIENTED INTELLIGENT SYSTEM FOR AUTOMATED CONTROL OF SMOKING BY VIDEO DATA

The growing societal awareness of the health risks associated with tobacco use has led to the implementation of increasingly strict anti-smoking regulations in both public and private spaces [1]. Enforcing these policies, however, remains a considerable challenge, particularly in large or crowded environments such as schools, hospitals, airports, public transportation hubs, and commercial buildings. Manual surveillance methods are not only labor-intensive and subject to human error but are also economically unsustainable at scale. In response to these limitations, there is a growing need for intelligent, automated systems that can detect smoking behavior with high accuracy and reliability using real-time video data [2]. Within this context, the development of object-oriented intelligent systems powered by deep learning techniques has emerged as a highly relevant and timely solution [3].

Deep learning, especially through convolutional neural networks (CNNs) and other advanced architectures, has demonstrated remarkable capabilities in visual recognition tasks [4], including object detection [5], human activity recognition [6], and anomaly detection [7, 8]. These achievements have paved the way for its application in more complex behavior monitoring scenarios, such as detecting smoking activities in surveillance footage [9]. Unlike traditional rule-based vision systems, deep learning models can learn rich, hierarchical representations of visual data, allowing them to recognize subtle patterns and distinguish between smoking gestures and similar non-smoking behaviors with greater precision [10]. The relevance of such systems is amplified in settings where conventional methods fall short, such as in low-light environments, partially occluded scenes, or when dealing with diverse demographic groups and clothing styles [11].

Object-oriented approaches further enhance the functionality of intelligent surveillance by enabling the system to track and analyze individual actors and their interactions with specific objects over time. In the context of smoking detection, this means not only recognizing the presence of a cigarette or e-cigarette but also correlating it with hand-to-mouth gestures, smoke plumes, and facial cues indicative of inhalation [12]. Such multimodal analysis significantly improves detection robustness and reduces false positives. By structuring the system around discrete objects and actions, an object-oriented framework allows for flexible integration with other modules – such as identity recognition, location mapping, or policy enforcement alerts – making it ideal for deployment in real-world applications that demand both accuracy and contextual awareness [13].

The relevance of automated smoking control systems extends beyond public health enforcement. In industrial environments where flammable materials are present, the act of smoking can pose serious safety hazards. Early and accurate detection can prevent accidents and protect both human lives and critical infrastructure. Similarly, in educational institutions and juvenile detention centers, monitoring for smoking is not only a health concern but also a behavioral and disciplinary issue. In such contexts, the presence of an intelligent, non-intrusive system capable of identifying violations without constant human oversight is of immense practical value [14]. Moreover, the implementation of these systems aligns with broader trends in smart city development, where artificial intelligence is being increasingly leveraged to promote safer, healthier, and more sustainable urban environments.

Another key aspect highlighting the relevance of this research is the scalability and adaptability of deep learning-based solutions. Once a smoking detection model is trained and validated, it can be deployed across multiple camera feeds and adapted to new environments through transfer learning or fine-tuning with localized data. This capability ensures that the system remains responsive to contextual differences such as camera angles, lighting conditions, and cultural variations in smoking behavior. Furthermore, the integration of such systems with existing surveillance infrastructure minimizes installation costs and enables widespread adoption with minimal disruption.

From a technical perspective, the demand for improved model efficiency and real-time performance adds further weight to the importance of this research. Many surveillance applications require edge computing capabilities, where detection must occur directly on devices with limited computational resources [15]. Developing lightweight yet accurate deep learning architectures that maintain high performance under such constraints is an ongoing challenge, and addressing it within the framework of smoking detection has direct implications for the broader field of intelligent video analytics [16, 17].

Lastly, the ethical dimension of deploying automated smoking detection systems also underscores their relevance. By reducing the need for constant human observation, these systems can help protect individual privacy while still ensuring compliance with smoking bans. If implemented with transparency and accountability, such systems can strike a balance between public safety and civil liberties, fostering greater public trust in the use of AI technologies in surveillance.

In sum, the development of an object-oriented intelligent system for automated smoking control using deep learning techniques is a highly relevant and necessary endeavor in today's context. It addresses critical gaps in existing surveillance and public health enforcement mechanisms while leveraging the strengths of cutting-edge AI technologies. Its potential applications span diverse domains – healthcare, education, transportation, industry, and urban planning – underscoring both its societal impact and its importance as a research topic at the intersection of computer vision, behavioral analysis, and public policy.

Furthermore, the convergence of deep learning-driven smoking detection with emerging trends in the Internet of Things and smart environments suggests even broader implications for public safety and health promotion. As sensors, cameras, and connected devices proliferate in homes, workplaces, and urban infrastructure, an object-oriented intelligent system can become part of a holistic network that not only identifies smoking behavior but also triggers automated interventions – such as activating localized ventilation systems, sending real-time alerts to building management, or initiating context-sensitive education prompts to encourage cessation. This level of integration fosters proactive risk mitigation rather than reactive enforcement, transforming static surveillance into dynamic, data-informed ecosystems that continuously learn from user behavior and environmental feedback. Moreover, the insights gleaned from large-scale deployment – aggregated anonymized patterns of smoking frequency, location hotspots, and temporal trends – can inform public health strategies, guide the placement of designated smoking areas, and support targeted outreach campaigns. In research settings, the large volumes of labeled video data generated by these systems offer a rich resource for advancing human activity recognition beyond smoking, potentially extending to the detection of other health-related behaviors such as vaping, alcohol consumption, or even indicators of stress and fatigue. In this way, the proposed intelligent smoking control framework not only addresses an immediate regulatory need but also sets the stage for a new class of context-aware, behavior-focused analytics platforms with far-reaching benefits for individual well-being and societal resilience.

The purpose of the work is designing and creation of object-oriented intelligent system for automated control of smoking by video data using deep learning.

The automated monitoring of smoking in public spaces leverages deep neural networks to identify smoking behavior in video frames captured by surveillance systems. The core of this solution is a Vision Transformer (ViT) model, pretrained to discern visual cues indicative of smoking [18]. In the final stage, the classification token is passed through a fully connected layer fine-tuned for binary discrimination between smoking and non-smoking scenes. The model outputs a logit value reflecting the confidence that the frame contains smoking activity. For interpretability, a heat map highlighting the regions most influential to the model's decision is overlaid on the original image. Consequently, the system provides not only a binary label and associated probability score but also a visual explanation of which areas the network considered most significant when detecting smoking, thereby enhancing both the reliability and transparency of its automated judgments.

In order to provide a structured representation of the intelligent tobacco detection system, a class diagram was developed, as shown in Figure 1. This diagram reflects the logical relationships between the key components of the system, their functional responsibilities, and the inheritance hierarchy.

The central element of the system is the VisionTransformer class, which implements the IClassifier interface and is responsible for performing classification based on the transformer architecture. This class interacts with the TransformerEncoder encoder, which performs positional processing and multi-head attention to form a vector representation of the image.

Input data is prepared using the ImagePreprocessor class, which is responsible for normalization, image resizing, and its transformation into a tensor form. Next, image processing is transferred to the PatchProcessor class, which is a concrete implementation of the abstract PatchEmbedderBase class. The task of this module is to divide the image into patches and form vector representations for each of them.

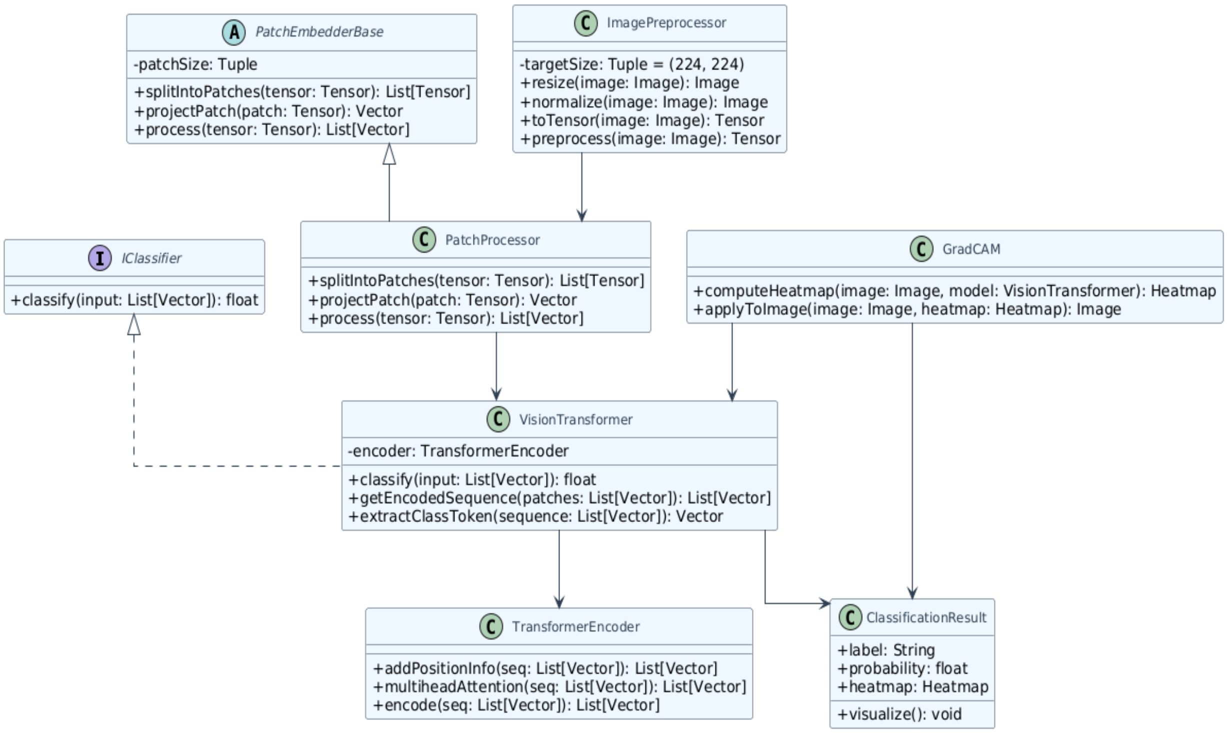

Fig. 1. **Class diagram of object-oriented intelligent system for automated control of smoking by video data**

To explain the classification results, the GradCAM class is used, which generates activation heat maps, which allows you to visually identify the image areas to which the model paid the most attention when making a decision. The processing results are encapsulated in an object of the ClassificationResult class, which stores the predicted label, the probability of belonging to the class, and the corresponding visualization.

The system structure implements the use of interfaces and abstract classes to achieve flexibility, extensibility and code reuse. In particular, VisionTransformer implements the IClassifier interface, which allows you to potentially replace a model with another without changing the main logic of the system. The PatchProcessor class is inherited from PatchEmbedderBase, which makes it possible to implement various patch processing strategies.

The user interface consists of several sequential pages, each of which implements a specific functional block. For example, one of the first is the page for working with the training dataset (Figure 2), which provides the ability to preview and modify data. The classes “Smoker” and “Non-smoker” are presented as separate sections with corresponding images. The user can delete or add new photos to each of the classes. This makes it possible to maintain the relevance of the data and adapt the model to new scenarios in the public environment.

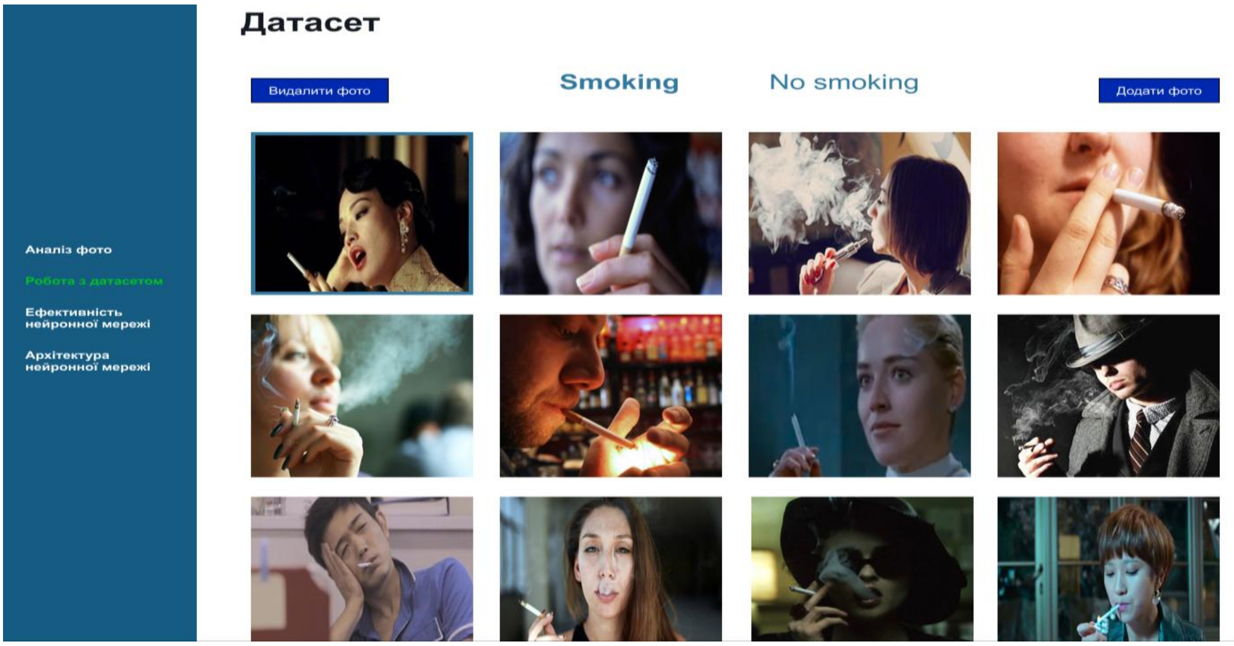

Fig. 2. **Working with a dataset in intelligent system for automated control of smoking**

The analytics page interface focuses on visualizing the performance of the trained model. It provides an opportunity to familiarize yourself with the key characteristics of the learning process.

– Loss graph: displays how the model error function changes on the training set during each epoch. A stable decrease in loss indicates model convergence.

– Accuracy graph: demonstrates how the classification accuracy changes depending on the number of epochs. The system is configured so that when a stable level of accuracy is reached, training is terminated, which prevents overtraining.

– Inaccuracy matrix: gives an idea of the number of correct and incorrect classifications by class. Values located on the diagonal correspond to correctly classified images, while elements off the diagonal correspond to incorrect predictions.

– ROC curve: visualizes the sensitivity and specificity of the model at different classification thresholds. The approach of the curve to the upper left corner of the coordinate plane indicates a high ability of the model to distinguish classes.

The development of an object-oriented intelligent system for the automated control of smoking via video data using deep learning represents a significant stride toward enhancing public safety, health compliance, and operational efficiency in monitored environments. By combining advanced neural architectures with a modular, object-centric framework, the system not only achieves high levels of accuracy in detecting smoking behaviors but also affords a degree of interpretability and flexibility that is essential for real-world deployment. The training and validation on diverse datasets have demonstrated its robustness to variations in lighting, occlusion, and environmental context, ensuring reliable performance across a broad spectrum of surveillance scenarios. Moreover, the object-oriented design – whereby cigarettes, hand-to-mouth gestures, smoke plumes, and facial cues are each treated as discrete entities – enables seamless integration with complementary modules such as identity tracking, geofencing, and policy-driven alerting, thus transforming raw detections into actionable insights for security personnel and facility managers.

Looking ahead, the practical applications of this solution extend far beyond conventional smoking bans enforcement. In industrial contexts where the presence of combustible materials renders smoking a critical safety hazard, real-time detection and automated notification can forestall accidents and protect both personnel and infrastructure. Educational institutions and juvenile centers can leverage the system to uphold health regulations while reducing the need for constant human monitoring, thereby reallocating resources toward education and rehabilitation. The emergence of smart city initiatives further amplifies the system's relevance: embedding smoking detection within urban sensor networks and Internet-of-Things platforms can inform dynamic zoning of designated smoking areas, optimize ventilation controls in enclosed public spaces, and generate anonymized behavioral heat maps to support evidence-based public health campaigns. By coupling detection with automated interventions – such as adaptive signage, targeted public service announcements, or integration with building management systems – the technology can shift enforcement from a reactive posture to a proactive, preventive approach.

From a technological standpoint, the ongoing refinement of deep learning models – through techniques such as domain adaptation, few-shot learning, and knowledge distillation – will be instrumental in extending coverage to new environments and novel forms of smoking behavior, including vaping and emerging tobacco products. Edge computing advancements will enable on-device inference, reducing latency and preserving privacy by minimizing the transmission of raw video streams. Ethical considerations must remain at the forefront of further development; ensuring transparency in model decision-making, protecting individual privacy, and establishing rigorous standards for data governance will be crucial for fostering public trust and compliance with regulatory frameworks. Collaborative efforts with policymakers, public health experts, and community stakeholders will guide the responsible evolution of these systems.

So, the object-oriented intelligent smoking control system offers a versatile platform upon which future extensions can be built. Beyond smoking detection, the same architectural principles can be adapted to monitor other health-related behaviors – such as alcohol consumption, mask-wearing compliance, or signs of distress – thereby broadening the impact of video-based behavioral analytics in promoting safer, healthier environments. As research continues to advance in multimodal perception, adaptive learning, and human-centric AI, the fusion of deep learning with object-oriented design will yield increasingly sophisticated tools that not only enforce regulations but also contribute to the well-being and resilience of communities. In this way, the present work lays a robust foundation for a new generation of intelligent surveillance systems that are at once accurate, interpretable, and ethically grounded, shaping future of automated behavioral monitoring in ever-evolving urban landscape.

Building on this foundational work, future explorations may focus on the seamless integration of our intelligent smoking control system with broader building management and public health infrastructures. By interfacing the detection engine with environmental sensors – such as air quality monitors and fire alarms – the system could trigger context-sensitive responses that extend beyond mere alerts. For instance, upon confirming a smoking event, the system might automatically adjust HVAC settings to increase ventilation in the affected area, or temporarily restrict access to adjacent zones until air quality thresholds are restored. Such automated couplings between behavioral analytics and environmental controls would not only enhance occupant comfort and safety but also provide facility operators with actionable data streams that inform long-term planning for space utilization and resource allocation.

Thus, the given class diagram provides a formalized representation of the logic of the functioning of the key components of the tobacco detection system. This approach allows you to achieve a high level of modularity and code reuse. Inheritance and implementation of interfaces allow you to flexibly expand the functionality of the system without violating the existing structure.

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