

**II Trimester MSc (AI & ML)**

**Research project proposal**

**Department of Computer Science**

**OPTIMIZING ROAD TRAFFIC MANAGEMENT THROUGH AUTOMATED VIDEO ANNOTATION WITH COMPUTER VISION**

by

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1. **INTRODUCTION**

In the era of rapid urbanization and technological advancements, the effective management of road traffic plays a pivotal role in shaping smart and sustainable cities. Recognizing the critical importance of this facet, our research endeavors to contribute significantly to the field of traffic management through the application of cutting-edge technology. The proposed project, titled "Optimizing Road Traffic Management through Automated Video Annotation with Computer Vision," envisions leveraging the power of computer vision to revolutionize real-time monitoring and analysis of road traffic scenarios.

**Project Idea:** The core of our project lies in harnessing the capabilities of computer vision to process vast amounts of video data generated from roadside surveillance cameras, traffic cameras, and autonomous vehicle cameras. Our multifaceted approach involves the integration of various computer vision tasks, including object detection, surveillance and monitoring of roads, intent prediction of pedestrians, road segmentation, online visual tracking, vehicle re-identification, road accident detection, vehicle queue length estimation, traffic light detection, traffic sign detection, vehicle speed detection, and parking spot identification. By dissecting and understanding these complex road scenarios, we aim to develop a comprehensive system that not only enhances traffic management but also contributes to the development of smart and sustainable cities.

**Viability:** The viability of our research idea is rooted in its feasibility, both in terms of technical implementation and practical application. We will meticulously assess the required financial, human, and technological resources, ensuring a clear understanding of the project's scope. A realistic timeline and a well-structured research plan will guide our efforts, fostering efficiency and coherence in the pursuit of our objectives. By identifying and addressing potential challenges proactively, we aim to establish a solid foundation for the successful execution of the proposed research.

**Novelty:** At the heart of our research lies a commitment to originality and innovation. The proposed project seeks to bridge existing gaps in the field of traffic management through the application of advanced computer vision techniques. By addressing challenges such as real-time monitoring, accurate object detection, and intent prediction, our research offers a novel perspective in tackling the intricacies of road traffic scenarios. The uniqueness of our approach lies not only in the integration of multiple tasks but also in the comprehensive nature of the envisioned system, which promises to set new standards in the domain.

**Relevance:** In the context of contemporary trends and pressing urban challenges, the relevance of our research cannot be overstated. As cities worldwide strive to become smarter and more sustainable, effective traffic management emerges as a linchpin in achieving these goals. By aligning our research with current needs and trends, we anticipate that the outcomes will not only contribute to academic knowledge but also provide practical solutions for the challenges faced by urban planners, traffic authorities, and policymakers. Our research aims to be a catalyst for positive change, aligning with the evolving landscape of smart city development.

1. **ALIGNMENT WITH SUSTAINABLE DEVELOPMENT GOAL (SDG)**

**Alignment with SDG 11: Sustainable Cities and Communities:** The primary objective of SDG 11 is to ensure that cities and human settlements are inclusive, safe, resilient, and sustainable. The proposed research directly contributes to this goal by harnessing cutting-edge technology to optimize road traffic management, a critical aspect of urban development. By employing computer vision techniques, the project aims to enhance the efficiency of traffic flow, reduce congestion, minimize accidents, and improve overall road safety.

**Addressing Specific Aspects of SDG 11:**

1. *Enhanced Traffic Flow:* The research project seeks to implement real-time object detection, surveillance, and monitoring of roads, contributing to the creation of smart cities with improved traffic flow and reduced congestion.
2. *Road Safety and Accident Prevention:* Through tasks such as intent prediction of pedestrians, road segmentation, online visual tracking, and road accident detection, the project directly addresses the SDG 11 objective of ensuring safety within urban environments.
3. *Efficient Resource Utilization:* By developing capabilities such as vehicle re-identification, vehicle queue length estimation, traffic light detection, and traffic sign detection, the research aims to optimize resource utilization and contribute to sustainable urban development.

**Demonstrated Understanding of Program Objectives:** The proposed research demonstrates a clear understanding of the objectives outlined in SDG 11. It goes beyond conventional traffic management approaches, utilizing advanced computer vision techniques to address specific challenges in urban road traffic. The incorporation of multiple tasks, ranging from vehicle speed detection to parking spot identification, showcases a comprehensive and nuanced approach to achieving sustainable and smart cities.

The research project on optimizing road traffic management through automated video annotation with computer vision strongly aligns with the goals of SDG 11. By leveraging technology to enhance traffic efficiency, improve safety, and contribute to sustainable urban development, the project embodies the spirit of creating cities that are resilient, inclusive, and environmentally sustainable. This alignment ensures that the research not only meets the objectives of the program or course but also contributes meaningfully to the broader global agenda of creating sustainable cities and communities.

1. **EXISTING SYSTEMS**

To comprehend the inadequacies of current systems, a comprehensive analysis of existing research and implementations is essential.

**Object Detection:** Existing object detection models, including R-CNN, Fast R-CNN, and YOLO, face a formidable challenge in detecting small objects with high precision. The precision of these models diminishes significantly when dealing with tiny objects in surveillance videos, leading to suboptimal performance in scenarios where accurate identification of small entities, such as vehicles or pedestrians, is crucial. The inadequacy of these models in handling tiny object detection poses a bottleneck in achieving optimal results for road traffic management, particularly in urban environments characterized by diverse and dynamic traffic scenarios.

**Intent Prediction of Pedestrians:** Understanding the intentions and actions of pedestrians in complex urban traffic environments remains a significant challenge. Existing methods often fall short in accurately predicting the intent of pedestrians, especially in scenarios with multiple interacting elements. The limitations arise from the lack of effective spatio-temporal models capable of comprehending the intricate patterns of pedestrian movement. This deficiency hampers the development of reliable systems for predicting pedestrian behavior, an essential component for ensuring the safety and efficiency of traffic management.

**Road Segmentation:** Current road segmentation algorithms are individually trained for tasks such as object detection and road segmentation, resulting in models that are highly susceptible to environmental variations. These algorithms lack the robustness required to handle diverse weather conditions, varying lighting, and other external factors affecting road scenes. The reliance on small datasets, such as KITTI, further exacerbates the problem, as the models struggle to generalize well in real-world scenarios. Addressing these limitations is critical for achieving accurate and adaptable road segmentation in challenging conditions.

**Vehicle Re-Identification:** While deep learning methods have made significant strides in vehicle re-identification, a critical shortcoming persists—the requirement for large amounts of data. The existing models face challenges in learning diverse features that characterize different vehicles, particularly in urban environments with varied vehicle types and appearances. Overcoming this limitation is pivotal for enhancing the efficiency of traffic management systems, as accurate re-identification is crucial for analyzing and predicting traffic flow in smart cities.

**Online Visual Tracking:** Adapting offline trained models to online object tracking remains a complex task. Existing methods struggle to maintain the delicate balance between tracking accuracy and speed when transitioning from offline training to real-time tracking scenarios. Overfitting problems in deep network training and the need for discriminative capacity hinder the adaptability of these models, emphasizing the necessity for a more robust approach to online visual tracking in dynamic traffic environments.

**Road Accident Detection:** Despite the widespread use of video surveillance and intelligent traffic systems, automated traffic accident detection faces challenges. Existing approaches lack the sophistication needed to effectively capture the complex relationships among visual features occurring temporally during a traffic accident. Achieving a high level of accuracy in accident detection, independent of road structure, necessitates advancements in deep learning methods and temporal pattern identification for extracting relevant visual and temporal features from video data.

The table below outlines specific limitations identified in various aspects of road traffic management systems based on referenced research papers:

| **Task** | **Existing Systems Limitations** |
| --- | --- |
| Object Detection | Current models like R-CNN, Fast R-CNN, and YOLO face challenges in detecting tiny objects with high precision. |
| Intent Prediction of Pedestrians | Understanding pedestrian behaviors in complex urban traffic scenes remains a challenge. |
| Road Segmentation | Segmentation algorithms are often trained individually, leading to susceptibility to weather, lighting, and other factors. |
| Vehicle Re-Identification | Deep learning methods for vehicle re-identification lack efficiency due to the requirement for large amounts of data. |
| Online Visual Tracking | Adapting offline trained models to online tracking poses difficulties in maintaining accuracy and speed. |
| Road Accident Detection | Automated accident detection is desirable, but existing approaches need improvement in performance and robustness. |
| Vehicle Queue Length Estimation | Traditional methods using smart roadside sensors are expensive; vision-based approaches should be explored for cost-effectiveness. |
| Traffic Light Detection | Detection systems face challenges in adverse weather and illumination conditions, requiring improved discrimination techniques. |

Table 1

1. **PROPOSED SYSTEM**

**Functional Description:** The proposed system for optimizing road traffic management through automated video annotation with computer vision integrates cutting-edge techniques to address various challenges in traffic analysis. The system's functionalities are designed to enhance the understanding and management of road traffic for the development of smart and sustainable cities. These functionalities include:

* *Object Detection with Enhanced YOLOv2 Algorithm*: The system employs an enhanced YOLOv2 algorithm for precise vehicle detection and recognition in surveillance videos. This modification includes reducing parameters and integrating DenseNet-201 for feature extraction, ensuring high precision in detecting even tiny objects.
* *Intent Prediction of Pedestrians using Real-time Framework*: Leveraging a real-time framework with a tracking-by-detection technique and a spatio-temporal DenseNet model, the system accurately detects, tracks, and predicts the intended actions of pedestrians in complex urban traffic environments.
* *End-to-End CNN Model for Drivable Area Segmentation*: The system introduces Dense-ACSSD, an end-to-end CNN model for drivable area segmentation and multiple object detection. Trained on the BDD100K dataset, this model achieves high mIOU for road segmentation and mAP for multiple object detection, meeting real-time requirements.
* *Vehicle Re-Identification with Synthetic-to-Real Domain Adaptation Network (StRDAN***)**: Addressing the challenge of data scarcity, the system proposes StRDAN, a framework trained on synthetic and real data to improve vehicle re-identification. This approach shows significant improvements over baseline models in datasets such as VeRi and CityFlow-ReID.
* *High-Performance Object Tracking with Residual Attentional Siamese Network (RASNet):* To achieve robust visual tracking, the system incorporates RASNet, a model reformulating correlation filters within a Siamese tracking framework. RASNet introduces various attention mechanisms, demonstrating state-of-the-art tracking accuracy at more than 80 frames per second.

**Proposed Solution Architecture:** The architecture of the proposed system is designed for seamless integration of the functionalities. It includes:

* *YOLOv2 Enhanced Algorithm Module*: Integrates the modified YOLOv2 algorithm with DenseNet-201 for object detection.
* *Real-time Framework Module*: Incorporates the real-time framework with a tracking-by-detection technique for intent prediction of pedestrians.
* *Dense-ACSSD Module*: Encompasses the end-to-end CNN model for drivable area segmentation and multiple object detection.
* *StRDAN Module*: Implements the Synthetic-to-Real Domain Adaptation Network for improved vehicle re-identification.
* *RASNet Module*: Integrates the Residual Attentional Siamese Network for high-performance object tracking.

**Software Requirements:** The proposed system relies on various software components for implementation:

* *Deep Learning Frameworks*: TensorFlow or PyTorch for model training and inference.
* *OpenCV*: Used for image and video processing tasks.
* *Python Programming Language*: For overall system integration.
* *Data Annotation Tools*: Necessary for labeling datasets used in training.

**Hardware Requirements**: The hardware requirements include:

* *High-performance GPUs*: Essential for efficient training of deep learning models.
* *Sufficient RAM*: Needed to handle large datasets and model parameters.
* *Multi-core Processors*: Facilitate parallel processing during model training and real-time video analysis.

The proposed solution architecture is designed to be scalable, allowing flexibility in deployment across diverse computational environments.

In summary, the proposed system aims to revolutionize road traffic management by leveraging state-of-the-art computer vision techniques. The integration of enhanced algorithms for object detection, real-time frameworks, and advanced tracking mechanisms collectively contributes to the optimization of road traffic management for the development of smart and sustainable cities.

1. **FEASIBILITY ANALYSIS**

The implementation of the proposed system for optimizing road traffic management through automated video annotation with computer vision necessitates a comprehensive feasibility analysis. This analysis encompasses considerations related to time, cost, and potential implementation challenges to ensure the successful development and deployment of the innovative solution.

**Time Feasibility**: The implementation timeline is contingent upon several factors, including the complexity of algorithm integration, training deep learning models, and system testing. The proposed system, with its diverse functionalities such as object detection, intent prediction, and segmentation, demands meticulous attention to detail. A phased approach, with concurrent development of modules, can mitigate potential time constraints. Real-time framework integration and model training may be time-intensive, requiring iterative refinement for optimal performance.

**Cost Feasibility**: The cost feasibility analysis encompasses expenses associated with hardware, software, human resources, and ongoing maintenance. High-performance GPUs, a requisite for efficient deep learning model training, constitute a significant initial investment. Additionally, licensing costs for deep learning frameworks, such as TensorFlow or PyTorch, and continuous access to annotated datasets for training contribute to the overall project cost. Human resource costs, including skilled data scientists and developers, are vital considerations for successful implementation and maintenance.

**Implementation Challenges**: The proposed system addresses complex challenges inherent in road traffic management, requiring adept handling of various algorithmic and technological intricacies. Challenges may arise during the integration of the enhanced YOLOv2 algorithm, real-time framework, and the Synthetic-to-Real Domain Adaptation Network. The system's efficacy is contingent upon the availability of diverse and representative datasets for training and validation. Furthermore, real-world deployment may encounter environmental variations, necessitating robustness testing and adaptation mechanisms.

**Scalability**: Scalability is a critical aspect of the proposed solution architecture, allowing adaptability to varying computational environments. The integration of high-performance GPUs and multi-core processors ensures scalability in handling increased computational loads. The modular design of the system facilitates future enhancements and updates, aligning with evolving computer vision technologies.

**Software and Hardware Requirements**: The selected software components, including TensorFlow or PyTorch for deep learning, OpenCV for image processing, and Python for system integration, are industry-standard choices with robust community support. However, considerations for potential updates and compatibility issues must be factored into the ongoing maintenance plan. High-performance GPUs, sufficient RAM, and multi-core processors are essential hardware prerequisites, and their availability should align with the budgetary constraints and long-term scalability goals.

**Risk Mitigation**: The feasibility analysis recognizes potential risks and proposes mitigation strategies. A rigorous testing regime, including simulated and real-world scenarios, can preemptively identify algorithmic vulnerabilities. Continuous monitoring and adaptation mechanisms for environmental variations contribute to the system's resilience. Collaboration with domain experts, municipalities, and stakeholders ensures alignment with real-world traffic management needs.

The proposed system exhibits strong feasibility with careful consideration of time, cost, implementation challenges, scalability, and risk mitigation strategies. Its potential to revolutionize road traffic management aligns with the broader goals of developing smart and sustainable cities, making it a compelling and viable avenue for exploration and development.

1. **BENEFITS OF THE PROPOSED SYSTEM**

**Benefits:**

1. *Enhanced Traffic Monitoring and Surveillance***:** The integration of the YOLOv2 Enhanced Algorithm facilitates precise and efficient object detection, significantly improving the monitoring and surveillance capabilities of the system. This heightened accuracy allows for real-time identification of various objects in road scenarios, contributing to enhanced traffic monitoring.
2. *Predictive Pedestrian Intent for Improved Safety***:** The Real-time Framework Module, employing a spatio-temporal DenseNet model, enables the system to predict the intent of pedestrians in complex urban environments. This predictive capability enhances safety measures by anticipating pedestrian actions, allowing for proactive traffic management interventions to prevent potential accidents.
3. *Accurate Drivable Area Segmentation and Object Detection***:** The Dense-ACSSD Module, featuring an end-to-end CNN model, achieves high mIOU for road segmentation and mAP for multiple object detection. This accuracy ensures precise identification of drivable areas and various objects, contributing to improved decision-making in traffic management for both automated and human-driven vehicles.
4. *Improved Vehicle Re-Identification in Diverse Scenarios***:** The StRDAN Module, employing a Synthetic-to-Real Domain Adaptation Network, addresses data scarcity challenges by improving vehicle re-identification across synthetic and real datasets. This advancement enhances the system's adaptability to diverse scenarios, providing reliable identification of vehicles under varying environmental conditions.
5. *High-Performance Object Tracking for Dynamic Traffic Scenarios***:** The RASNet Module, incorporating the Residual Attentional Siamese Network, ensures robust and high-speed object tracking. With attention mechanisms and correlation filters, this module achieves state-of-the-art tracking accuracy at over 80 frames per second, enabling real-time analysis of dynamic traffic scenarios.

**Goals:**

1. *Optimization of Traffic Flow***:** The primary goal is to optimize the flow of traffic by employing advanced computer vision techniques to monitor and manage road scenarios effectively.
2. *Enhanced Safety Measures:* Another key goal is to enhance safety measures through predictive capabilities, enabling the system to anticipate and respond to potential risks in real-time.

**Objectives:**

1. *Development of a Scalable System Architecture***:** To design and implement a scalable architecture that allows the seamless integration of various computer vision modules, ensuring flexibility in deployment across diverse computational environments.
2. *Achievement of Real-Time Processing***:** To achieve real-time processing capabilities for video analysis, ensuring timely responses to dynamic changes in traffic scenarios and enabling proactive traffic management interventions.
3. **ANTICIPATED OUTCOMES**

**Enhanced Road Traffic Monitoring Precision**: The integration of an enhanced YOLOv2 algorithm for object detection is anticipated to significantly elevate the precision of road traffic monitoring. By reducing parameters and incorporating DenseNet-201 for feature extraction, the system aims to achieve unparalleled accuracy in detecting and recognizing vehicles within surveillance videos, even under challenging conditions such as low visibility or crowded traffic scenarios.

**Improved Pedestrian Intent Prediction Accuracy**: The utilization of a real-time framework with a tracking-by-detection technique and a spatio-temporal DenseNet model is expected to enhance the accuracy of predicting pedestrians' intended actions. This anticipates a more sophisticated understanding of pedestrian behavior in complex urban traffic environments, facilitating proactive traffic management strategies to ensure pedestrian safety and smooth traffic flow.

**High-Performance Drivable Area Segmentation**: The implementation of the Dense-ACSSD end-to-end CNN model for drivable area segmentation and multiple object detection is poised to deliver high mIOU for road segmentation and mAP for object detection. Trained on the BDD100K dataset, this model is anticipated to provide a robust solution for real-time identification of drivable areas, contributing to efficient traffic flow analysis and management.

**Significant Advancements in Vehicle Re-Identification**: The proposed Synthetic-to-Real Domain Adaptation Network (StRDAN) is expected to address the challenge of data scarcity in vehicle re-identification. By training on both synthetic and real data, the system aims to showcase significant improvements over baseline models, particularly in datasets such as VeRi and CityFlow-ReID. This anticipated outcome is crucial for enhancing the accuracy of identifying and tracking vehicles across diverse scenarios.

**State-of-the-Art Object Tracking Accuracy**: The incorporation of the Residual Attentional Siamese Network (RASNet) for high-performance object tracking anticipates achieving state-of-the-art tracking accuracy at a remarkable speed of more than 80 frames per second. This outcome is vital for real-time tracking of vehicles and pedestrians, enabling swift response mechanisms for traffic management and incident prevention.

**Scalability and Flexibility in Deployment**: The proposed solution architecture is designed with scalability in mind, allowing for seamless integration and deployment across diverse computational environments. This scalability is expected to provide flexibility in adapting the system to varying urban landscapes and traffic conditions, making it a versatile solution for smart and sustainable city development.

**Revolutionizing Road Traffic Management**: The anticipated outcomes of this research project include a revolutionary advancement in road traffic management through the synergistic integration of cutting-edge computer vision techniques. The precision improvements in object detection, accuracy enhancements in pedestrian intent prediction, and state-of-the-art advancements in drivable area segmentation, vehicle re-identification, and object tracking collectively contribute to the optimization of road traffic management, paving the way for the development of smart and sustainable cities.

1. **PLAN OF WORK**

Methodology of work flow is mentioned alongside expected timeline to follow.

**Week 1-2:** *Project Setup and Environment Configuration* During the first two weeks, the focus will be on setting up the project infrastructure and configuring the development environment. This includes installing the necessary software components such as TensorFlow or PyTorch for deep learning, OpenCV for image and video processing, and Python for overall system integration. Additionally, data annotation tools will be selected and integrated for labeling datasets. Hardware requirements, including high-performance GPUs, sufficient RAM, and multi-core processors, will be acquired and set up for efficient model training.

**Week 3-4:** *Data Collection and Preprocessing* In the subsequent two weeks, data collection will commence. This involves obtaining diverse datasets from roadside surveillance cameras, traffic cameras, and autonomous vehicle cameras. The collected data will undergo preprocessing, including cleaning, augmentation, and annotation to ensure it is suitable for training the proposed computer vision models. This phase is crucial for developing robust models capable of handling real-world scenarios.

**Week 5-6:** *Model Development and Training* The following two weeks will be dedicated to the development and training of the computer vision models. Each module of the proposed system, including the YOLOv2 Enhanced Algorithm, Real-time Framework, Dense-ACSSD, StRDAN, and RASNet, will be implemented and trained individually. This phase will involve fine-tuning parameters, optimizing algorithms, and ensuring the models meet the specified performance metrics.

**Week 7-8:** *System Integration and Testing* During weeks 7-8, the individual modules developed will be integrated into the overall system architecture. Compatibility and interoperability between modules will be thoroughly tested to ensure seamless functionality. This phase will also involve debugging, refining algorithms, and addressing any integration challenges that may arise. Rigorous testing will be conducted to validate the accuracy and efficiency of the entire system.

**End of 2 Months:** *Implementation Milestone* By the end of the second month, the goal is to have 25% of the implementation completed. This milestone includes a functional system with integrated modules for object detection, intent prediction of pedestrians, drivable area segmentation, vehicle re-identification, and high-performance object tracking. The system should be capable of processing and analyzing real-time video data from various sources, showcasing advancements in optimizing road traffic management.

This proposed plan balances the need for meticulous development with the urgency of achieving a significant implementation milestone within the specified timeframe, laying the foundation for the subsequent phases of the project.

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