

# The Convergence of Deep Learning and Computer Vision: Smart City Applications and Research Challenges

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## ABSTRACT

In recent years, deep learning strategies started to outshine traditional machine learning methods in a few fields, with Computer Vision being one of the most noticeable ones. The Computer Vision is becoming more suitable nowadays at identifying patterns from images than the human visual cognitive system. It ranges from raw information recording to methods and ideas that span digital image processing, machine learning, and computer graphics. The wide utilization of Computer Vision has attracted many researchers to incorporate their ideas with different fields and disciplines. The era of smart cities has emerged to meet the recent demands of citizens using information and communication technology. This paper reviews research efforts that utilize Deep Learning Frameworks and Computer Vision Applications in support of smart city applications like smart healthcare, smart transportation, smart agriculture, etc. Furthermore, the paper identified key research challenges that emanate from the use of deep learning and computer vision in support of smart city services.

**Keywords:** Agriculture, Computer Vision, Deep Learning, Healthcare, Smart City, Transportation, Video Surveillance.

## 1. INTRODUCTION

Computer Vision is one of the active research fields, especially in the era of AI and robotics science [1]. Computer vision has a very important role to make remarkable improvements [2]. The availability of AI especially deep learning makes revolution from Image Process to Computer vision, with very rich support from Deep learning model like CNN, RNN, LSTM, and many more make CV more applicable in different field of automation like manufacturing, driverless car, healthcare, education, agriculture, satellite images, visual QNA, etc. Name computer vision is very vast in terms of applicability [3]. Computer vision is a combination of object detection, segmentation, reorganization, localization, restoration, etc. [4-6]. With covering such features in computer vision, its applicability became

more impactful in the field of face recognition as part of biometrics identification, automated car, AR/VR, disease identification plays a major role in medical science, smart city [7]. Deep learning models can operate complex data from different sources like video, audio, medical images, social media, sensor data (IoT), satellite images [8-11]. Computer vision algorithms are a key element to make smart cities a reality. Smart transportation, energy-saving automatic visual sensor, looking at the infrastructure to alert anomalies activities, counting number of users in infrastructure, taking statistics in peak hour, smart monitoring of human resources as well as infrastructures [12-14]. Computer vision plays a significant role in the development and management of smart cities as they are the "Eyes of the city." In this paper we are going to see below important aspects of smart city in detail like Smart

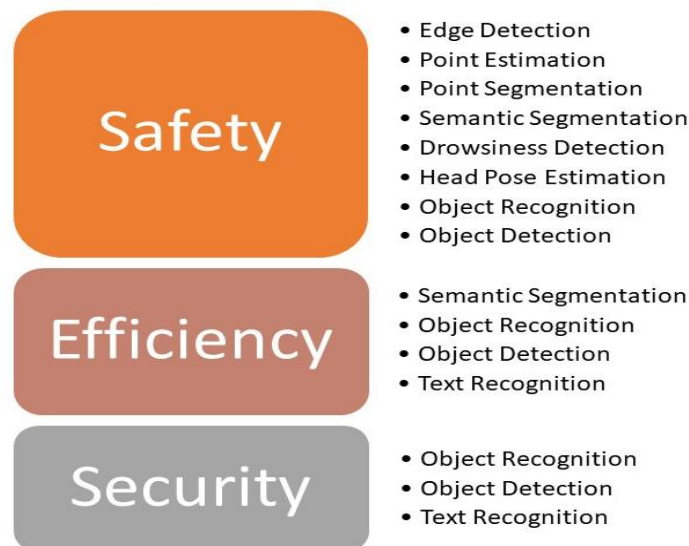
Transportation, Smart Healthcare, Smart Agriculture, and Smart Security [15].

## 2. COMPUTER VISION FOR SMART CITY

### 2.1 Smart Transportation

The transportation system is the lifeline of any development and routine of the city [16]. The smooth functioning of the transport system is necessary for any smart city concept. Smart transport offers novel and innovative approaches in different modes of transportation like advanced infrastructure, mobility, traffic control, safety. It provides an advanced, safer, faster, and smart way of travelling. Features of smart transportation systems are public transport management, smart infrastructure management, advanced route management, advance vehicle control and safety, smart payment system, and route information [17-19].

Different technologies in smart transportation like GPS based tracking [20], advance sensing technology, advance video surveillance. Smart transportation system set makeable improvement in smooth transit in city, minimization of pollution, effective parking system, enhance security, utilization of resources [21-25]. Smart Transportation mainly divide in Safety, Efficiency, Security also known as safe secure and effective transportation. Safety in transportation involves applications like Lane Detection, Pedestrian Detection and Driver Monitoring. Efficiency cover application like Traffic flow control, adaptive driving & warning system, while Security is covered by advance traffic surveillance [26-29]. Figure 1 shows different computer vision technique which are used in different domain of smart transportation. Smart transportation is not limited to listed domain, there is also minor domains like government rules for transportation [30], vehicle support facility, transportation payment facilities

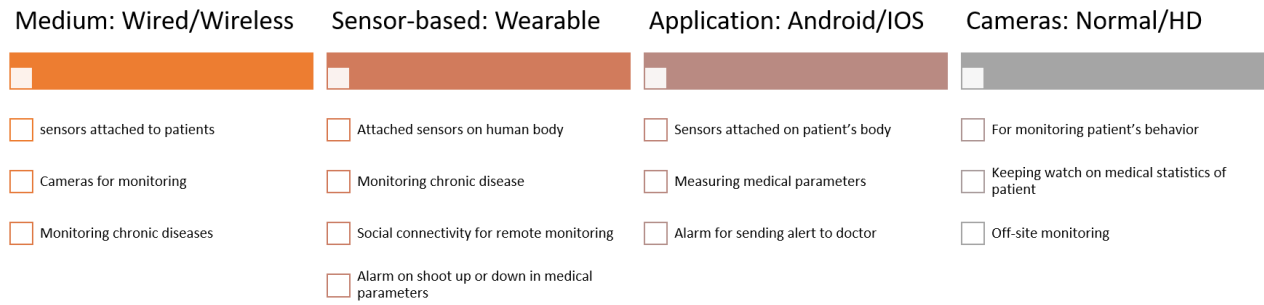


**Figure 1** Pictorial representation of Computer Vision Techniques for Smart Transportation

### 2.2 Smart Healthcare

Smart healthcare includes various health parameters [31]; one of them includes a health monitoring system, which detects the motion of the human body using various techniques like vision-based and sensor-based detection for identifying abnormal activities of a patient to stop unexpected death of humans because of various illness factors. Motion detection is one of the most important technologies in building intelligent healthcare [32]. There are various

characteristics for patient monitoring solutions in healthcare which will be useful in upcoming 5-10 years [33]. This characteristic is based on various categories like medium, sensor-based, application based and type of camera required for monitoring [34]. Figure 2 depicts the characteristics in various categories. Motion detection falls mainly into two major categories, vision-based, and sensor-based detection. We can have the vision-based and sensor-based motion detection methods to recognize the fall detection and identify the movements of the patient [35].



**Figure 2** Pictorial representation of Key Characteristics for Patient Monitoring in Span of Upcoming 5 Years

### 2.3 Smart Video Surveillance

Importance of the video surveillance recognition of suspected human activities is to avoid robbery cases [36], objects which are abandoned by terrorists for

explosive attacks, mischiefs [37], fights between people and personal attack on someone in the many different places such as banks [38], hospitals, shopping area, parking space, public transport stations, airports, colleges, cities, etc. [39].

**Table 1.** Approaches for Suspicious Activity Recognition and Detection

Works/ Author	Datasets	Classification methods	Result discussion
Tian et al. (2012) [39]	Video Sequences of PETS2006, i-LIDS	Region Growing and Edge Energy	Shows poor performance in low contrast video sequences, for instance white bottles in white background.
Zin et al. (2012a) [40]	PETS 2006 and Own dataset	Rule Based Classifier	Able to detect tiny objects from video sequences
Fan and Pankanti (2012) [41]	i-LIDS, AB-L1 and ABL2	Structure Similarity and Region Growing	AB-L1 and AB-L2 shows that false positive measure is reduced by 6% and 3% respectively
SanMiguel et al. (2012) [42]	ASODds dataset (2011)	Boundary spatial color contrast	Proven that feasible for real – time video sequences.
Tripathi et al. (2013) [43]	PETS 2006 and PETS 2007	Edge based object recognition	Achieved very good accuracy for both the dataset respectively 84.71% and 100 %.
Sajith and Nair (2013) [44]	PETS 2006 and PETS 2007	Neural Network classifier (NN) and HOG descriptor	From PETS 2006, detected a static person as an abandoned object
Ferryman et al. (2013) [45]	PETS 2006	Logic based inference engine	-

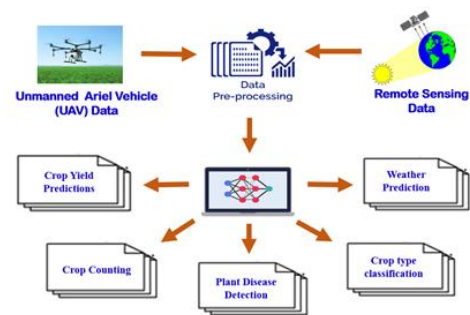
Chitra et al. (2013) [46]	PETS 2006	Support Vector Machine (SVM)	-
Nam (2016) [47]	PETS 2006, PETS 2007 and i-LIDS	Spatio-Temporal	Achieved for i-LIDS-Precision-98.88%, Recall-82.28%, F-measure-82.64%
Virender Singh (2020) [48]	UCF-Crime Dataset, Annotation, Preprocessing Testing Set	CNN and RNN	Achieved accuracy about 96%
Amrutha (2020) [49]	KTH	CNN, LSTM, ReLU	Gained accuracy about 87.15%
Rohit (2020) [50]	Cohn-Kanade, faces94, faces95	SVM, CNN, RNN	Achieved accuracy about 82%
Arvind (2020) [51]	Own Dataset	Local binary pattern histogram (LBPH) Classifier	Achieved accuracy about 93.67%

### 2.4 Smart Agriculture

There has been ever-increasing demand for food supplies due to exponential growth in the world population. Conventional methods alone might not be able to keep up with this demand. Smart agriculture which is considered as one of the few realistic ways, smart agriculture integrates the use of different technologies to better monitor growth crop yield prediction, plant disease detection, weed detection, irrigation management, prediction of soil properties etc. Smart agriculture happens to be one of the many disciplines where use of deep learning and computer vision are being realized to be of major impact. The use of technology in relation to smart agriculture should enable transmission of correct and accurate information to farmers at right time.

Figure 3 shows popular application of Computer Vision and Deep Learning in Agriculture like plant disease detection wherein accurate diagnosis of

probable plant disease can save the entire crop from getting infected, fruit counting and yield production can help farmers make necessary packing and storage requirements before sale, weather prediction to minimize crop loss due to severe weather conditions and crop type classification to identify variety of crops using deep learning models.



**Figure 3** Popular Applications of Computer Vision and Deep Learning in Agriculture

**Table 2.** Major application areas of Computer Vision and Deep Learning in Agriculture

Category	Reference	Application	DL Model Used	Dataset
Plant disease detection	Shradha et al. [52] (2020)	Detection of healthy leaves and thirteen different diseases	Alexnet, VGG, Inception (Modified)	Plant village dataset

	Konstantinos et al. [53] (2018)	Detection of plant disease for 25 plants.	AlexNet, AlexNetOWTBn, GoogleNet, Overfeat, VGG	Plant village dataset
	Mohanty et al. [54] (2016)	Identification of 14 crop species and 26 diseases	Deep CNN	Plant village dataset
Crop Count	Joao Valente et al. [55] (2020)	To detect number of plants on the field that emerged after sowing.	Alexnet	UAV-acquired spinach images from field of Netherland
	Bruno et al. [56] (2019)	To detect number of plants on the field that emerged after sowing. Corn Plant Counting	U-Net	UAV acquired images
	Steven et al. [57] (2017)	Orange and Apple count	Neural Network + Linear Regression	UAV acquired images
Weather Prediction	Ashesh et al. [58] (2020)	prediction of heat waves and cold spells	ConvNet and CapsNet	LENS dataset
	Snehlata et al. [59] (2020)	Cyclone Prediction	Xception, NasNetMobile, and Mobile Net	IMD, MOSDAC and KALPANA-I satellite images
	Renato et al. [60] (2019)	Crop Yield prediction based on crop genotype, environment and their interactions.	Neural network	2018 Syngenta Crop Challenge
Crop Yield Prediction	Peteri et al. [61] (2019)	Crop yield prediction of 5 crops: Corn, Cotton, Rice, Soyabean, Sugarcane	DNN + LSTM	Produo Agrcola Municipal (PAM)
	Anna et al. [62] (2019)	Prediction of wheat and barley yield	Customised CNN model with Adadelata training algorithm	UAV-acquired multispectral data from 9 fields.

Crop Type Classification	Yang-yang et al. [63] (2020)	Classifying 31 classes of fruits and vegetables using various DL models	VGG16, VGG19, SqueezeNet, InceptionV4, DenseNet121, ResNet18, ResNet50	CropDeep dataset
	Liheng et al.[64] (2019)	Classification of 14 summer crops	Conv1D + LSTM	Landsat Level-2 dataset

### 3. CHALLENGES

Challenges in smart cities are elaborated here: (i) accuracy and robustness in computer vision and sensor network, enhancement in result with high accuracy over object detection, object recognition, object classification, segmentation, transform learning etc. are required. Robustness is a major concern in smart cities because of different geographical conditions. Atmosphere and weather conditions are different for various geographical area, like areas covered with mountains, harbour, dusty etc. so more accuracy and enhancement in technique is required to utilize services in real time. (ii) Cybersecurity and privacy are also challenging tasks in smart cities. Internet connected devices generate and transmit huge chunks of data, privacy for data which may be relevant to CCTV, medical diagnosis, fund transfer, gas station or charging station, electricity or power supply, food supply, emergency services and many more. If there is a case, criminals easily gain access to data and use for illegal activity. Hence the government and IT support system should strengthen enough to prevent cyberattack. (iii) Infrastructure, well equipped resources are required to install and utilize smart technology like Artificial Intelligent, Computer vision, IoT. (iv) Engaging the community, smart city truly exists, when citizens are engaged and actively involved in new projects and practices.

### 4. CONCLUSION

Computer Vision is used to provide better quantitative information that is unobtainable subjectively, leading to the eventual replacement of human effort. Computer Vision is a necessary and promising one for analysing the qualities and information using different convolution networks like AlexNet, ZFNet, VGG-19, ResNet etc. These model learning systems are an essential part of feature extraction. Deep learning frameworks are a cornerstone for Computer Vision and used in variety of visual understanding tasks, such as object detection, face recognition, action and activity recognition, human pose estimation, image retrieval, and semantic

segmentation. The most applicability of Computer Vision is in smart cities involving new use cases related to smart healthcare, smart transportation, video surveillance and smart agriculture. These are among the most important open issues in Smart City that attract the interest of the research community in Computer Vision.

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