Automatic Traffic Management and Emergency Vehicle Detection

Ramya Srikanteswaraa , Dr.Sarojadevi Ha, Anantashayana S Hegdeb, Puneet T Hegde b

aAssistant Professor, Nitte Meenakshi Institute of Technology, Bengaluru, India

bStudent, Department of CS&E, Nitte Meenakshi Institute of Technology, Bengaluru, India

Abstract:

Number of vehicles in the cities are growing every day, authorities are trying to solve this problem. Due to traffic congestion commuters, students, delivery agents etc are late for work, school. Traffic congestion is one of the biggest problems in metropolitan cities. Emergency vehicles for example, Ambulance and Fire-Engine cannot advance, ease of movement of these vehicles can save many lives. Traditional traffic management does not solve this problem and we need a better system which can take autonomous decisions based on the situation present. This paper proposes a Traffic management and Emergency vehicle detection system which can solve these problems. Traffic management system is designed to control the density of vehicles and to reduce traffic congestion. This paper used most recent YOLOv7 state of art algorithm which helps in identifying the objects in road with most efficiency. Correlation filters used to tally the count of vehicles present in each lane. Traffic light to each lane will be based on number of vehicles. Transfer learning is used to make use of already trained model to By Transfer learning we can use big Convolution Neural Network which is pretrained on big datasets.

**KEYWORDS: Traffic Management, Emergency Vehicles, YOLOv7, Correlation Filter, Transfer Learning, Convolution Neural Network**

* 1. Introduction

Number of vehicles increases daily in cities. Traffic problem is one of the biggest problems in Metropolitan cities, Authorities trying to solve this problem using available technologies. The unprecedented growth of city affects mainly transport system which can affect Social, Education and Economic Condition of the city. The rise of population and the number of vehicles that come on to the road everyday cannot confronted not only by building more infrastructure but making use of available resources to handle them efficiently. Because of this traffic Emergency vehicles like ambulances and Fire fighters gets stuck in traffic and making a way for it in between traffic is nearly impossible. If emergency vehicles cannot reach the destination at correct time, then lives of the people may lost. Every second is precious in these emergency situations. The traditional Traffic System which includes pre-programmed Traffic lights or Traffic Police does not solve the problem of congestion the current Traffic system, the biggest drawback is fixed time for each lane. Because of this the lane with a greater number of vehicles will get same number of times as of lane with less number vehicles. Also, even if lane has no vehicles also it gets green light. Because of this congestion may occur at some lanes. Vehicles which are in Congested side have wait for multiple green signals and because of this model time, money and natural resources are gets wasted. As technology is getting advance there is an immediate need of building an autonomous Traffic Management System which can take all these factors into consideration and allocate time for each lane dynamically based on the situation.

Due to the advancement in recent times, many authors have proposed multiple systems that can help to reduce the problem. One of the ways is using Internet of Things to solve this. RFID tags can be attached to vehicles and in the junction, it is read by RFID reader (V. Bali, S. Mathur, V. Sharma and D. Gaur, 2020). Exact count of vehicles can be obtained, also giving a unique RFID to ambulance will solve both issues. But using these sensors may not be possible in long run and sensors are easily susceptible to damage by bad weather and Cost is also high. In another paper, author has tried to solve Traffic in city of Kyiv, Ukraine by making use of artificial Intelligence (V. Cherniy, S. Bezshapkin, O. Sharovara, I. Vasyliev and O. Verenych, 2020). They have considered the all the factors in the environment that can affect the Traffic for example number of residents, workplaces, schools near that area and many other factors are taken. Based on these factors it is decided whether congestion will happen in that road or not. In the method suggested, Artificial Intelligence is used to decrease the problem of traffic congestion. Use of camera and object detection to keep track of the vehicle count will help us to formulate an algorithm which can solve the traffic congestion by allocating the green light time to each line based on count, also object detection will help us to detect emergency vehicles stuck in traffic. We have designed a robust algorithm which can allocate green signal time and help emergency vehicles to come out of the traffic and reach destination. Further number of vehicles in a particular road can give insights about the environment to traffic maintain department and based on that they formulate new rules.

Object detection can be defined as process of identifying certain objects in the input and common way of representing objects identifies is Bounding Boxes. At present main object detection systems used are 1 stage detectors and 2 stage detectors. 2 stage detectors contain two different networks which work on Region Proposal and Classification of objects. Whereas in Single Stage detectors both process is done by single network. 2 stage detectors give High accuracy but typically they are slow. R-CNN Model family is one detection algorithm of widely used Two stage object detector. It contains R-CNN, Fast R CNN (Girshick, R., Donahue, J., Darrell, T., & Malik, J. 2013) and faster R CNN (Ren, S., He, K., Girshick, R., & Sun, J. 2015) which uses Convolution Neural Networks. In One stage detector we have mainly YOLO (You only look once) family and Single Shot Detectors. After the introduction of Neural Networks, Object detection is evolving at much more speed. In real time analysis we need to make use of efficient algorithms that can give the result faster. YOLO is one of the fastest object detection algorithms. In the proposed method we are making use of YOLOv7 (Wang, C., Bochkovskiy, A., & Liao, H. 2022) algorithm for object detection.

Main goals of proposed work are as follows:

* To count the number of vehicles and to divide green signal time to each lane depending on the situation. To reduce the possibility of traffic congestion.
* When emergency vehicles are detected, make sure that it will come out of the traffic and reach destination as soon as possible.

Section 1 contains brief introduction of proposed method and background of proposed method. Section 2 contains related works and mentions various work done on the proposed topic. Section 3 contains methodology proposed to solve the problem. section 4 contains result obtained, conclusion and discusses future improvements that can be done on the model.

* 1. Literature Survey

Dr. Shailender Kumar et al. (S. Kumar, Vishal, P. Sharma and N. Pal, 2021) have made use of YOLOv4 algorithm to detect vehicles. They have made use of Kalman Filter, and Deep Sort algorithm get the count of vehicles and for enhanced result. But in bad weather or under dim light the algorithm which they have used may not give great result. Asha C S et al. (C. S. Asha and A. V. Narasimhadhan, 2018) have used YOLO algorithm to get the count of number of vehicles in road. Authors have used Correlation Filter to count the number of vehicles. But only one track is considered. S. K. Saini et al**.** (S. K. Saini and M. Singh Ghumman, 2022) proposed a smart Traffic light Control system which works in real time and efficiently allocates green light time for different lanes based on time scheduling algorithm.  Murthy Jonnalagadda et al. (M. Jonnalagadda, S. Taduri and R. Reddy, 2020) have proposed a Green Time estimation algorithm which changes in each cycle and allocates time-based vehicle count. Mr. Prashant Jadhav et al. (Prof. Prashant Jadhav, Pratiksha Kelkar, Kunal Patil, Snehal Thorat, 2016) built “Smart Traffic Control System using Image Processing” which is implemented using Mat lab programming. It uses image processing methods to extract data and allocates time for each lane. Aditi Anekar et al. (P. Viola and M. Jones, 2021) created a “Automatic Traffic Signal Management System” which uses background subtraction and mainly based on vehicle flow identification.

Although there many methods which detects the vehicles and takes decision based on vehicle count, there is no traffic management system which is based on latest YOLOv7 algorithm which is most efficient among YOLO family. Also, there is no Traffic management system which handles the emergency vehicles stuck in traffic and provides a way to come out of the traffic.

1. Proposed Work
   1. Dataset Preparation

Dataset is divided into normal vehicles and emergency vehicles. To train the model we have used 1044 images of vehicles and 1213 images of emergency vehicles. For testing purposes, 263 images of normal vehicles and 286 images of emergency vehicles are taken. Images of autorickshaws are added which is common in India. To test the model for completely unknown environment we went to Traffic junction and took videos of ambulance present in traffic. Fig. 1 contains sample images taken from vehicle dataset. Fig. 2 contains images of emergency vehicles that used to train the model.



A group of cars on a road

Description automatically generated with low confidence

Fig. 1 - Dataset

2.2 Methodology

A screenshot of a computer

Description automatically generated with medium confidence

Fig. 2 - Vehicle Count Algorithm

The proposed method combines YOLOv7 based object detection with correlation filter to get the count of vehicles. The method used earlier was based on background subtraction and didn’t produce good results. Background subtraction algorithm often fails to extract moving vehicles exactly. Convolution Neural Network (CNN) is a Deep Neural Network Architecture which is used in image analysis. It performs tasks such as object classification, segmentation, and detection. CNN can used to extract the features and classify and to check whether any emergency vehicle is present or not. Object is detected with help of applying YOLO algorithm to input and each detected object is assigned to a correlation filter-based tracker after validating the object. The problem of overlapping between two bounding boxes is solved by computing ratio of intersection over union. While counting the number of automobiles in each lane, it will be checked whether any emergency vehicle is present in that lane or not. If emergency vehicle is found in that lane, then all other lanes will be closed and open only that lane where emergency vehicle is detected. This will make the emergency vehicle pass through the traffic and reach the destination on time.

Time scheduling algorithm is designed to allocate green time to different lanes based on number of automobiles present in each lane. We have set a threshold of 20 vehicles by analysing number of vehicles that pass-through junction in allocated time (i.e., 30sec). we have Considered a Traffic cycle time of 120 seconds where each four lane has 30 seconds. If number of vehicles in any lane is more than that of threshold, then we will increase time allotment for that lane by 15 seconds. If we increase time for any lane, then we will decrease time allocated for other lanes so that total time in the cycle will be 120 seconds. We have set a condition that we can only increase time for two lanes in a cycle so that other lanes won’t be affected too much from it. From the fig. 3 we can see the possibilities of time scheduling based on vehicle counts in each lane.

Chart, bar chart

Description automatically generated

Fig. 3 – Time scheduling Illustration

1. Technologies Used
   1. Analysis of YOLO

The majority of conventional techniques, such the Viola Jones detector (Redmon, J., Divvala, S., Girshick, R., & Farhadi, A, 2015), Histogram of Oriented Gradients (HOG), and Deformable Parts Model (DPM), extract features from images, such as edges and gradients, then categorise images using this data.  But when Convolution Neural Networks started using for Object detection, it is evolving at an unprecedented speed. YOLO is a Single stage object detection algorithm. Instead of using region recommendations as used by two-stage detectors, YOLO divides the image into grids and applies sliding window technique to detect objects. Because of this YOLO algorithms can detect objects faster than others. But because of dividing the image into grids, there will be positional errors. An application like autonomous driving requires both accuracy and speed.

YOLO algorithm works by dividing the image into grids and applying object detection on each grid. Then a feature map obtained from this is used to draw a bounding box around objects. YOLO can detect multiple objects. The bounding box outputs 5 values which are, Center point coordinates (x, y), height(h) and width(w) of the object and confidence score. The objects with lower confidence score will be filtered out. His technique is called non-maximal suppression (NMS). YOLO’s architecture has 24 Convolution layers with 2 fully connected layers at the end. YOLO makes use of Intersection over Union (IOU) to make sure that bounding box surrounds the object perfectly. Intersection over union score is calculated by dividing the area of overlap by the area of union.

In 2016 Joseph Redmon et al. published “You only Look once – unified real time object detection” (Redmon, J., & Farhadi, A. 2016) more famously known as YOLO object detection algorithm. It outperformed DPM and its variants by considerable amount of margin. But if was not accurate as two stage detectors. Joseph Redmon and Farhadi published YOLOv2 (Redmon, J., & Farhadi, A. 2018) in 2017. It was trained on huge datasets like Pascal VOC and MS COCO. It outperformed various state of art algorithms like Faster R-NNN and SSD. Joseph Redmon and Farhadi in 2018 released an incremental model of YOLO i.e. YOLOv3 (Bochkovskiy, A., Wang, C., & Liao, H. 2020). The new model was built on darknet53 network. Alexey Bochkovskiy  et al. Published Yokov4 (Li, C., Li, L., et l., 2022) in 2020. YOLOv4 outperformed all the object detection algorithms when it released. It introduced many concepts like Mosaic data augmentation and Weighed Residual Connection. Just two months after the release of YOLOv4, YOLOv5 released by Glenn Jocher. It was implemented on Pytorch, eliminating the limitations of Darknet. Later YOLOv6 (Henriques JF, Caseiro R, Martins P, Batista J, 2015) introduced EfficientRep Backbone and Rep-PAN Neck. YOLOv7 authored by Alexey Bochkovskiy et al. Is the latest in the YOLO family. YOLOv7 utilizes techniques like Model reparameterization, Trainable bag of freebies to increase speed and efficiency. In the suggested plan of reparameterization, authors have determined that a layer which contains residual or concatenation connection, its RepConv should not have identity connection. Consequently, RepConvN, which lacks an identity link, can take its place.

* 1. Correlation Filter

Correlation Filters are first introduced in 2010. Correlation Filters are class classifiers which produce sharp peak in the output, primarily used to achieve accurate localization of targets. When objects are moving like vehicles in the road, it is hard to count the number of objects as objects will be in different positions in each frame. But with the help of correlation filter we can track the vehicle when they are moving also. Correlation Filter can track the objects quickly in real time but cannot guarantee same accuracy when objects appearance changes. The proposed work used Correlation Filter track the objects as it can track multiple objects in real time. Correlation Filter works by sliding the Correlation kernel and multiplying weights in the kernel with pixels of the image. Correlation filters have achieved better performance than many other tracking algorithms.  Using Correlation Filter, we can also do scale estimation which helps in further analysis of vehicles sizes.

Henriques JF et al. (DanelljanM HgerG, Khan FS, Felsberg M 2016) in 2014 introduced kernels correlation Filter (KCF) that changes the characteristics of the channel to multi channel characteristics and includes convolution Network features used in tracking which increases the filter’s capacity to appropriately distinguish between items. Danelljan et al. (Danelljan M, Häger G, Khan F, Felsberg M 2014) suggested a discriminative scale space tracker(DSST) which employs feature pyramid to tackle multi scale variation problem and proposed fDSST algorithm (Danelljan M, Robinson A, Khan F S, Felsberg M 2016). C-COT algorithm (Lukezic A, Vojir T, ˇCehovin Zajc L, Matas J, Kristan M, 2017) effectively displays spatial location which is mixture of Correlation filtering and CNN. CSR-DCF algorithm (Bo Huang, Tingfa Xu, Jianan Li, Ziyi Shen, Yiwen Chen 2019)  which is like C-COT algorithm improved robustness of the algorithm. A Transfer Learning-based Discriminative Correlation Filter (TLDCF) was suggested by BoHuang et al. (S. Boyd, N. Parikh, E. Chu, B. Peleato, J. Eckstein, et al. 2011) to prevent corrupting an updated filter and to improve the model's distinguishability. Alternating Direction Method of Multipliers (ADMM) (Y. Cao et al., 2022) was used to calculate the filters in frequency domain. A Gaussian scale mixture (GSM) model-based Bayesian correlation filter was proposed by Yuan Cao et al. (Zhuang, Fuzhen & Qi, Zhiyuan & Duan, et al., 2020). It decomposes each Correlation filter coefficient into products of positive scaler multiplier and Gaussian random variable.

* 1. Transfer Learning

Transfer learning is a popular approach in Deep learning where already learned model is reused for a new task. Fig. 4 represents how transfer learning works. In transfer learning except the last layer all the other layers are frozen so that weights cannot be modified further. It can train deep neural networks with small amount of data. The machine uses knowledge it learnt from previous problem and can reuse it for a new problem. Transfer learning works only if model is trained for neural features in first problem and its inputs size should be same in first problem and next problems. Over twenty transfer learning models were utilized by Fuzhen Zhuang et al. to analyze data from Office-31, Reuters-21578, and Amazon Reviews.

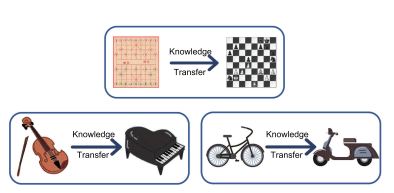


Fig. 4 – Transfer Learning

* 1. Flow of proposed Work

Fig. 5 shows the flowchart representation of proposed methodology. Input is recorded from the camera present at the junction. Number of vehicles in each lane is counted, while doing that we also check whether any emergency vehicle is present at any lane. If any emergency vehicle is present at a lane, that lane is given green signal and all other lanes will be closed for ease movement of emergency vehicle. If emergency vehicle is not present at any lane, then vehicle count in each lane is checked. If any lane has vehicle count more than fixed threshold, then additional green time will be provided for that lane based on time scheduling algorithm. In a cycle we can increase green time any two lanes only. Threshold and cycle time will be decided on the traffic condition of that junction.

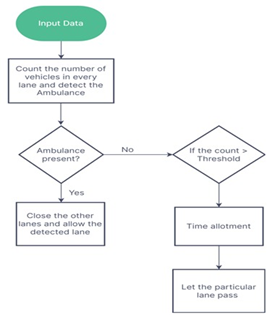


Fig. 5 – Flow chart of algorithm

1. Result and Conclusion
   1. Result Analysis

Google Collaboratory was used to train the model; it is a free environment which runs entirely on cloud. The model was trained for ten epochs. The accuracy of the model. increases with increase in number of iteration and regularization. The model's accuracy may be determined by,

A picture containing text, font, white, line

Description automatically generated

The model has attained an accuracy of 84.2% on Training set and 83.1% on Test set. Further model is tested on videos collected from traffic in which model is successfully detected emergency vehicles. Fig. 6 represents how accuracy of the model changes when epoch increases. Fig. 7 shows how model correctly identifying a ambulance present in traffic.

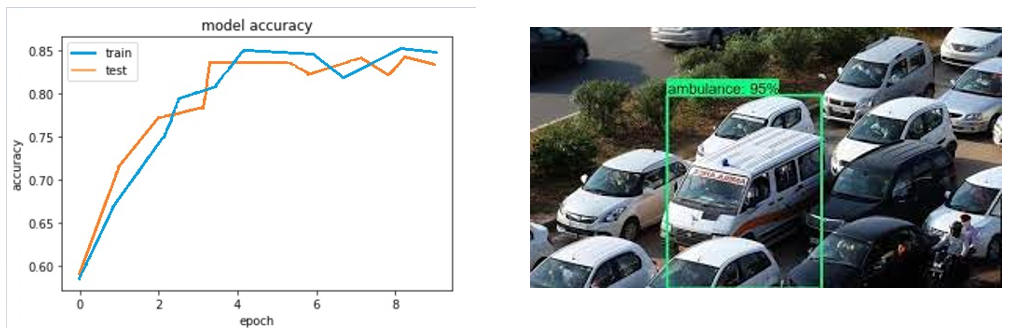


Fig. 6 - (a) Accuracy (b) Ambulance being detected

* 1. Conclusion

Traffic congestion is one the biggest problem in India, resources and time get wasted because of this. Also, emergency vehicles cannot reach destination in time. There are many efforts to solve this problem by using technologies available like IoT, Artificial Intelligence etc., But till now no system have solved both the problems. This paper proposes an intelligent solution to the problem which can be solved efficiently. We have made the best use of AI to solve this traffic congestion. This model counts number of vehicles in each lane and allocates green light based on that. If it detects any emergency vehicles like Ambulance or Fire Engines, it will give priority to that lane and all other lanes will be blocked for the ease movement of emergency vehicle.

We have built the model using YOLOv7 which was released in July 2022, most recent in YOLO family. YOLOv7 will tackle many issues which was present in the old model and introduces many concepts which improves the traditional model. In most of Traffic Management system and Object detection systems old version of YOLO are used. It is very much required to adopt best practices and methods when it comes to scientific research. This paper makes use of recent advancements, and it can also be used further to improve the model as below.

Future Improvements:

The model proposed here considers vehicle count to allocate the time for different lanes. Further we can take other factors that can affect the traffic and other enhanced implementation ways that can solve traffic congestion. Also, nowadays traffic violations are increasing, we can make a system to detect traffic violations and send details directly to traffic police. For example, we can add speed detection to the system and if any vehicle is over speeding, then actions will be taken on them. Also, a model can be built to detect whether a person wearing helmet or not. Lastly a model to detect vehicle’s number plate if it jumps a red light.

References

V. Bali, S. Mathur, V. Sharma and D. Gaur, "Smart Traffic Management System using IoT Enabled Technology," 2020 2nd International Conference on Advances in Computing, Communication Control and Networking (ICACCCN), 2020, pp. 565-568, doi: 10.1109/ICACCCN51052.2020.9362753.

V. Cherniy, S. Bezshapkin, O. Sharovara, I. Vasyliev and O. Verenych, "Modern Approach to the Road Traffic Management in Cities of Ukraine: Case Study of Kyiv Municipal Company "Road Traffic Management Center"," 2020 IEEE European Technology and Engineering Management Summit (E-TEMS), 2020, pp. 1-6, doi: 10.1109/E-TEMS46250.2020.9111757.

Girshick, R., Donahue, J., Darrell, T., & Malik, J. (2013). Rich feature hierarchies for accurate object detection and semantic segmentation. *arXiv*. <https://doi.org/10.48550/arXiv.1311.2524>

Ren, S., He, K., Girshick, R., & Sun, J. (2015). Faster R-CNN: Towards Real-Time Object Detection with Region Proposal Networks. *arXiv*. <https://doi.org/10.48550/arXiv.1506.01497>

Wang, C., Bochkovskiy, A., & Liao, H. (2022). YOLOv7: Trainable bag-of-freebies sets new state-of-the-art for real-time object detectors. *arXiv*. <https://doi.org/10.48550/arXiv.2207.02696>

S. Kumar, Vishal, P. Sharma and N. Pal, "Object tracking and counting in a zone using YOLOv4, DeepSORT and TensorFlow," 2021 International Conference on Artificial Intelligence and Smart Systems (ICAIS), 2021, pp. 1017-1022, doi: 10.1109/ICAIS50930.2021.9395971.

C. S. Asha and A. V. Narasimhadhan, "Vehicle Counting for Traffic Management System using YOLO and Correlation Filter," 2018 IEEE International Conference on Electronics, Computing and Communication Technologies (CONECCT), 2018, pp. 1-6, doi: 10.1109/CONECCT.2018.8482380.

S. K. Saini and M. Singh Ghumman, "Automated Traffic Management System Using Deep Learning Based Object Detection," 2022 International Conference on Machine Learning and Cybernetics (ICMLC), 2022, pp. 1-5, doi: 10.1109/ICMLC56445.2022.9941332.

M. Jonnalagadda, S. Taduri and R. Reddy, "RealTime Traffic Management System Using Object Detection based Signal Logic," 2020 IEEE Applied Imagery Pattern Recognition Workshop (AIPR), 2020, pp. 1-5, doi: 10.1109/AIPR50011.2020.9425070.

Prof. Prashant Jadhav, Pratiksha Kelkar, Kunal Patil, Snehal Thorat, “Smart Traffic Control System Using Image Processing” 2016, Volume 03, Issue 03, Mar2016, International Research Journal of Engineering and Technology

Aditi Anekar, Nayan Bagade, Akshata Jogdand and Mayawati Tayade, "Automatic Traffic Signal Management System", IJIR, vol. 02, no. 06, pp. 1036-1038, Jun 2016.

P. Viola and M. Jones, "Rapid object detection using a boosted cascade of simple features," Proceedings of the 2001 IEEE Computer Society Conference on Computer Vision and Pattern Recognition. CVPR 2001, 2001, pp. I-I, doi: 10.1109/CVPR.2001.990517.

Redmon, J., Divvala, S., Girshick, R., & Farhadi, A. (2015). You Only Look Once: Unified, Real-Time Object Detection. *arXiv*. <https://doi.org/10.48550/arXiv.1506.02640>

Redmon, J., & Farhadi, A. (2016). YOLO9000: Better, Faster, Stronger. *arXiv*. <https://doi.org/10.48550/arXiv.1612.08242>

Redmon, J., & Farhadi, A. (2018). YOLOv3: An Incremental Improvement. *arXiv*. <https://doi.org/10.48550/arXiv.1804.02767>

Bochkovskiy, A., Wang, C., & Liao, H. (2020). YOLOv4: Optimal Speed and Accuracy of Object Detection. *arXiv*. <https://doi.org/10.48550/arXiv.2004.10934>

Li, C., Li, L., Jiang, H., Weng, K., Geng, Y., Li, L., Ke, Z., Li, Q., Cheng, M., Nie, W., Li, Y., Zhang, B., Liang, Y., Zhou, L., Xu, X., Chu, X., Wei, X., & Wei, X. (2022). YOLOv6: A Single-Stage Object Detection Framework for Industrial Applications. *arXiv*. <https://doi.org/10.48550/arXiv.2209.02976>

Henriques JF, Caseiro R, Martins P, Batista J (2015) High-speed tracking with kernelized correlation filters. IEEE Trans Pattern Anal Mach Intell 37(3):583–596 DanelljanM HgerG, Khan FS, Felsberg M (2016) Discriminative scale space tracking. IEEE Trans Pattern Anal Mach Intell 39(8):1561–1575

DanelljanM HgerG, Khan FS, Felsberg M (2016) Discriminative scale space tracking. IEEE Trans Pattern Anal Mach Intell 39(8):1561–1575

Danelljan M, Häger G, Khan F, Felsberg M (2014) Accurate scale estimation for robust visual tracking. In: British machine vision conference, pp 1–5

Danelljan M, Robinson A, Khan F S, Felsberg M (2016) Beyond correlation filters: Learning continuous convolution operators for visual tracking. In: European conference on computer vision, pp 472–488

Lukezic A, Vojir T, ˇCehovin Zajc L, Matas J, Kristan M (2017) Discriminative correlation filter with channel and spatial reliability. In: Proceedings of the IEEE conference on computer vision and pattern recognition, pp 6309–6318

Bo Huang, Tingfa Xu, Jianan Li, Ziyi Shen, Yiwen Chen, Transfer learning-based discriminative correlation filter for visual tracking, <https://doi.org/10.1016/j.patcog.2019.107157>.

S. Boyd, N. Parikh, E. Chu, B. Peleato, J. Eckstein, *et al.* Distributed optimization and statistical learning via the alternating direction method of multipliers Found. Trends®  Mach. Learn., 3 (1) (2011), pp. 1-122

Y. Cao et al., "Bayesian Correlation Filter Learning With Gaussian Scale Mixture Model for Visual Tracking," in IEEE Transactions on Circuits and Systems for Video Technology, vol. 32, no. 5, pp. 3085-3098, May 2022, doi: 10.1109/TCSVT.2021.3101591.

Zhuang, Fuzhen & Qi, Zhiyuan & Duan, Keyu & Xi, Dongbo & Zhu, Yongchun & Zhu, Hengshu & Xiong, Hui & He, Qing. (2020). A Comprehensive Survey on Transfer Learning. Proceedings of the IEEE. PP. 1-34. 10.1109/JPROC.2020.3004555