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A Study on Real-time Object Tracking in Distributed Networks

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Abstract

In the past 15 years we have witnessed a tremendous increase in the usage of camera to capture videos. Cameras are widely used in surveillance of offices, malls, schools etc. The conventional architecture involves a cluster of cameras that communicate with a centralized server where all the processing is done. But as the network grew bigger the centralized network failed to show robustness. This instigated a need for a distributed camera network with optimized image processing algorithm to accommodate reduced computing. This paper outlines the concepts, architecture and application of this much needed distributed technology using the consensus algorithm. It also outlines the optimizations that need to be done in image processing inorder to compensate for the reduction in computing power at the nodes of the network. In this paper we also cite some recent research and outline its advantages over the traditional architecture.

Keywords: *Distributed Camera Networks, Consensus Algorithm, Real-time Image Processing.*

1. Introduction

On 24 January 1544 mathematician and instrument maker Reiners Gemma Frisius [1] of Leuven University used a custom made instrument to watch a solar eclipse, publishing a diagram of his method in the following year. This is assumed to be the first use of a camera obscure which led to the evolution of cameras. These artificial eyes that humans invented have completely changed our way of life. Somewhere around 20 years ago, a new scope of video capture became the leading research field which can rightly be termed as object tracking or recognition.

1.1 Various Accepted Definitions

Object recognition [2] is concerned with determining the identity of an object being observed in the image or an image sequence from a set of known labels. It also aims at identification of a distinguishable feature to disparate the objects when they occur in the frames of the monitored video. This method of storing the object properties to quickly match it with the image is also a challenge in recognition.

Object tracking [3] can be defined as the problem of estimating the trajectory of an object in the plane of the image as it is moving around in a scene. A tracker has to assign consistent labels to the tracked objects in different frames of a video.

Image recognition [4] means matching features of an image with a stored model of an object. A good recognition system is generic, recognises images in all conditions and has an easy learning process of obtaining reference database. There are various methods but it can be broadly classified into appearance based and geometry based algorithms.

In appearance based methods [4] appearances of a model under different orientation is captured to construct a model, and sub-images extracted from input images are matched with the constructed model. One limitation in this is that complete isolation of object is required, hence not making it very feasible.

In geometry based methods [4] each object to be recognised is represented explicitly using primitives like shape, circles and colours. These are then matched with invariant primitives extracted from the input image. The limitation in this being dependency and ambiguity in interpretation of primitive reference points. Other methods include storing local features of images/objects and checking whether input image can be seen as an extension of this stored local feature or not.

1.2 Concept of Tracking Objects

A tracking system framework typically consists of the following main components-

1) *Cameras* – They are the main eyes of the tracking system, which can be as simple as a VGA webcam to a complex PZT (Pan-Tilt-Zoom) enabled controllable camera. It's a hardware entity and sometimes can be layered with a software controller that handles the controls of the camera. This layer creates an abstraction that hides all the hardware complexities and provides a high level API that the processor can use to interact and fetch sequence of visual images as a stream.
2) *A Communication Network* – The medium through which the cameras can communicate and share data that they collect. Various architectures have been tested out in the recent years and the centralized and distributed architectures are most commonly found ones. The choice of architecture is usually based on the domain in which the tracking is done. The domain usually stipulates the network topology that is essential in determining the cost of transmitting data from one point in a network to another.
3) *A Communication protocol or Algorithm* – The agreement that the cameras follow to communicate with each other. It involves creating distinguishable features from a sequence of images and sending them over the communication network to the next node or the central server as stipulated by the protocol. Using a centralized server eliminates the complexity of the protocol required. In distributed topologies the protocol dictates where and how data should be transferred after basic processing.
4) *An optimal Image Processing Algorithm* – This is the process that will take in the sequence of images produces and create insightful data based on the analysis of colour, shape and other parameters considered by the algorithm.

The functioning of the tracking system can be considered as the collaboration of these individual entities.

2. Existing Technology

We outline various types of implementations that are part of research in the recent times to draw a conclusion of what might prove to be a good solution.

2.1 Cameras

It can often be seen in past researches that tracking systems require sophisticated cameras. But by increasing the efficiency of the image-processing algorithm, we have to integrate consumer smart cameras available in the market into the tracking networks.

Prati, Andrea, and Faisal Z. Qureshi [5] explain the need of the hour to use mobile vision available to the normal consumer. The authors investigate the topology of isolated cameras and corroborate their need to collaborate to generate more conclusive results. Their work in [5] enlists various applications that use inter-camera communications to generate feasible data that claims to be lucrative to a certain section of society. It tabulates a comparison of various kinds of cameras available and their pros and cons in influencing the modern day camera networks. It highlights the Integration issues and algorithmic optimizations that can be used to get more efficient system. Their main emphasis lies in energy efficiency of the system, which will be the major concern in the future.

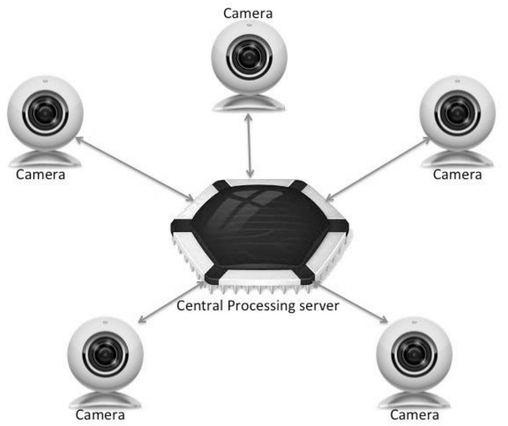
2.2 The Communication Network Topology

An optimal solution would require a smart network. A smart network [6] urges that there is a need for convergence of embedded computing, Image Sensors, Computer vision and Networks. The ubiquitous nature of cameras in our daily life has engendered the research for the best network topology for Camera. Martin Reisslein, Bernhard Rinner, Amit Roy-Chowdhury [6] have tried to put forward certain requirements that a good camera network system should have. The points laid down by the authors include the requirements that demands the network to be real-time, distributed and energy efficient.

Apart from that the software governing the system must be scalable, robust and computationally efficient. The control and coordination of the system also needs to be easily deployable and flexible with enough importance given to security and privacy. There is a need to understand the tradeoff between cost and performance of a camera network system. Instigating a new thought of research of Solar Wi-Fi powered energy efficient tracking cameras [6] which shall be capable of doing real-time 3D tracking of nearby objects.

Initially when this technology was introduced the computing power was built inside the camera. But soon researchers realized the need for more cameras and hence emerged the centralized camera architecture. A conventional centralized camera network can we visualized as shown in fig.1

Fig. 1 Example of a centralized camera network topology



Considering a scenario in which a network has a central server and a cluster of camera connected to it we can prove that there are redundant data transfers that can be avoided when the cameras are nearby.

Let **G = {V, E}** be graph representing the network and let **C** denotes the central server which is considered a part of **V**. We define **W** as the Cost function where $\mathbf{W(V_i, V_j)}$ can be understood as the cost of transmitting unit data content from $\mathbf{V_i}$ to $\mathbf{V_j}$.

- Cost of transmitting data from $\mathbf{V_i}$ to $\mathbf{V_j}$ server can be written as $\mathbf{W(V_i, V_j)}$
- Cost of Transmitting data through central server can be written as $\mathbf{W(V_i, C) + W(C, V_j)}$
- Let us assume for a case where exists a path from $\mathbf{V_i}$ to $\mathbf{V_j}$ without going to **C** using some edges in **E**

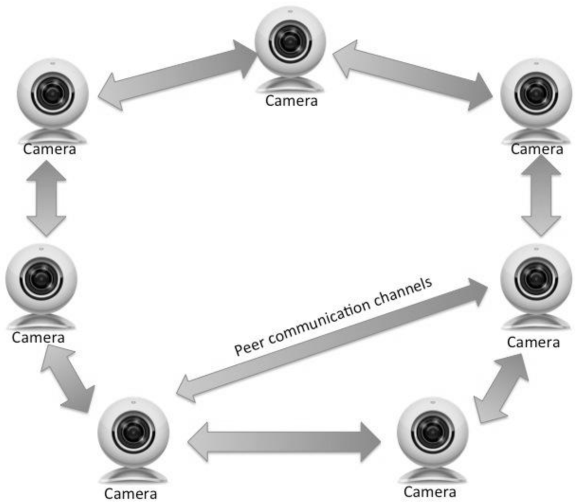
The feasibility of a centralized architecture can be calculated by comparing the path overhead that is incurred by choosing to transmit through the central server. Hence if

$$\mathbf{W(V_i, V_j) < W(V_i, C) + W(C, V_j)}$$

It can be clearly proved that we are not completely optimized to transfer unit data from $\mathbf{V_i}$ to $\mathbf{V_j}$. But in the old times the cost of computing was more and hence it was feasible to have a single processing power. In the recent decade the cost of compute has declined and this has paved way to researchers thinking about a Distributed architecture with small computing converged with the camera apparatus. This has led to the emergence of converged architecture. A lot of research has been done recently and we have tried to outline most of them in our study.

The decreasing cost of embedded cameras have also triggered the need for distributed networks. They can be easily manageable for surveillance of a region.

Fig. 2 Example of a distributed camera network topology



Distributed networks provide integration of surveillance and analysis of a target area and offer a more optimized solution for the task of sensing and tracking. Distributed Camera Networks or Smart Camera Networks deploy embedded cameras over a wide area for tracking of target objects. Each node is limited in its computational capability and there might be a limit on the bandwidth used for communication. Hence [7], the main challenge is to localize the target and track and detect targets with reliability, while the target is in motion in a wide area with a deployed camera network. Authors in [8] make an attempt to solve bandwidth issues by analysing data at the source and then only communicating filtered information to neighbouring nodes.

In [8] the authors briefly discuss a quasi-distributed framework based on sensor networks where an elected cluster head camera reaches consensus about a target based on Kalman filter and sends information to a central station, Hence it cannot be termed as completely distributed.

Another way of establishing a network as mentioned in [9] is to randomly place cameras and the first stage begins with establishing the topology of the environment i.e. the CN-complex. Each camera coverage is given by bisecting lines when field of view is overlapped and the common field of view is given by intersect points. The topology constructed from this data is similar to the actual environment and is verified by decomposition theorem.

Comparison of Network Architectures

Serial no.	Performance of Network		
	Criteria	**Centralized**	**Distributed**
1	Processing overhead	High	Nil
2	Redundancy in Data Transfer	High	Low
3	Risk of SPOF (Single point of failure)	High	Nil
4	Risk of Data loss	Low	Moderate
5	Delay in reception	High, mainly because of a busy central server.	Low
6	Risk of Data theft	High	Low

In [7] the authors suggest a system where each autonomous camera transmits data about tracked objects throughout the network. Other cameras can query this data and sign up for events related to a particular tracked object. For each tracked object a camera is assigned to maintain track of that object as the object moves, this camera can invite neighbouring cameras to form an ad-hoc network to provide local sensing about the target, as target moves to another location, more cameras can be recruited to join the ad-hoc local network.

Building the network through a 3D co-ordinate frame [8] wherein each camera positions are determined with respect to the established frame. The camera localization is achieved through LED-lit rod and DLT (Direct Linear Transformation) method. This can be useful when the cameras are not placed randomly. Maintaining tracks about objects can be done by extracting distinctive features of an object, which can be done by multiple cameras individually and later comparing these features to build targets, we can also deploy a dense network of camera nodes such that there is sufficient overlapping of FOV (field of view) so that the targets are always in the viewpoint when they move around.

Considering a scenario of tracking a moving person, there is an impression of locality involved, as the target object will be visible to more than one camera. Hence according to [7], camera nodes need only communicate with its neighbours, which are also viewing the target. So each camera should be able to compare and correlate its measurements with that of the neighbouring cameras and reach on a conclusion about the targets. As autonomous cameras perform sensing, extract information and track objects, they need to collaborate their findings in order to reach consensus about the trajectory followed by the moving target(s). Reference [8] shows that this can be achieved by MHT (multiple hypothesis tracking) as used in radar system where each source updates the track and the MHT does not consider non likely tracks and chooses the best probable track. The authors discuss about an experiment on camera networks, which used joint probabilistic data-association technique [8], where the tracks of targets as obtained by neighbouring cameras in the network were fused together using Kalman consensus filter.

2.3 The Communication Protocol or Algorithm

On top of the network topology we need a protocol that will define the rule for data transfer. Song, Bi, et al [10] discuss the requirements of a communication protocol for camera networks. It is established that the main goals for the protocol should involve

- Validity – Checking if data is valid.
- Agreement – Establishing an agreement with neighbour.
- Termination – Creating a session that can be terminated.
- Integrity – Checking for the integrity of data transferred.

By carefully analysing these requirements they propose a consensus algorithm [10] to track objects. This is the base paper of many researchers in this field. It proposes a consensus algorithm to track objects. Consensus means agreement. The neighbouring cameras exchange data by the means of agreements.

We may come across several faulty processes in a system and still expect the system to be reliable and be accurate for different unprocessed data. Such a reliability of the system can be achieved if the processes agree to some data value which is the need of computation. Reaching such a value may be defined as reaching the consensus. Similarly, in an image processing algorithm, several faulty measurements may be encountered due to estimation errors in tracking and data association as well as the effect of limited field of view which are considered to overcome in a consensus algorithm.

In [10] they prove that having a central unit to process is expensive and propose a distributed computing architecture. The paper discusses the goals of communication between the camera devices and the algorithm that is optimized to avoid redundant data transfer and bandwidth exhaustion. The Kalman Consensus algorithm proposed by the paper uses optimization on image processing and the efficiency of the PZT devices in the network. The paper presents the result of an experiment that utilized the algorithm on an area of 10000 sq ft which included 8 targets to be tracked. The Kalman

Consensus Filter is used for the fusing the data procured from neighbouring PZT.

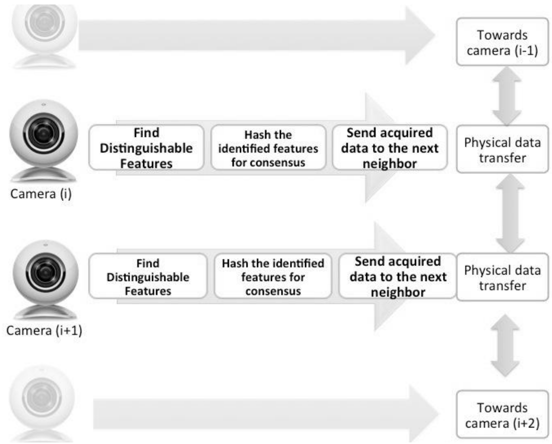


Fig. 3 Working of consensus algorithm

Furthermore Kamal, Ahmed Tashrif, Jay A. Farrell, and Amit K. Roy-Chowdhury [11] propose that the weighted average consensus is essential where each node shares information with its immediate neighbours and corrects its state by using the information sent by neighbours. This when done iteratively and averaged across the networks produces an optimal result.By proposing an Information based weighted consensus algorithm they aim to converge to the optimal centralized performance under reasonable circumstances. By comparing the convergence of different algorithms with multiple consensus algorithms at different time steps the authors establish a relationship of each parameter on the algorithms' performance. The authors claim that the the ICF (Information based Consensus Filter) does not require hand-off protocols, and require computation and communication resource similar to the less alternative algorithms. The experiments carried out by the proponents have proved that the ICF outperforms the other KCF(Kalman Consensus Filter) and GKCF (Generalized Kalman Consensus Filter) algortihms.

Kamal, Ahmed Tashrif, Jay A. Farrell, and Amit K. Roy-Chowdhury [12] propose the development of an information consensus algorithm for distributed multi-Target tracking. Often in a distributed network a situation may arise where the sensors, which are communicating neighbours, may not be observing the same target or a situation where each sensor's scope to observe is limited to a certain portion of all targets. In such a limited field of view information fusion, from various camera may lead to development of an effective information weighted consensus algorithm where each sensor reaches a consensus iteratively by obtaining information of the prior state from its network neighbours .No specific topology is needed for such a framework. The only disadvantage of such an algorithm can be that in a finite time interval the iterative process number has to be restricted because of limited bandwidth.

In a research study conducted [13] distributed maximum likelihood estimation is performed. The scenario is a centralised one with a distributed implementation. In a particular scenario, five cameras are connected in a peer-to-peer topology as C1 ↔ C2 ↔ C3 ↔ C4 ↔ C5. As a random target approaches a location where at least one camera could observe it, This first position was estimated as the average of the measurements using the average consensus algorithm and then followed by an estimation using the DMLE (Distributed Maximum Likelihood Estimation) [13] algorithm where the root mean square error of this method was reported to be the minimum.

A game-theoretic approach to camera control was presented in [20] but limited only to the area coverage problem. Each camera serves as a local decision maker by maintaining its own utility function. Each camera optimally assigns itself to a target and aims to optimise its own utility function which indirectly leads to the optimisation of a global utility function. This is achieved by an algorithm based on game theory where all targets in the area of deployment are treated as opponents. If the target is captured in an image with the desired resolution as per the requirements of the application the target losses the game and is eliminated. Cameras play together as a team and score point for each successfully acquired image at the required resolution. The consensus here is described by the notion of Nash equilibrium which is described by the choice of targets and is a function of time because of the dynamic nature of the targets .If all the targets in the field of deployment are being tracked by the cameras and no further information can be obtained by a particular camera by deciding to track a particular target at some other resolution then Nash equilibrium is said to be reached. This was expanded on in [21] to a distributed tracking and control approach. It required the camera control and tracking to independently run and in parallel.

To sum it up arriving at consensus can be thought as a message passing system wherein each camera passes the information it obtained, thereby tracking the object as it passes through a network of cameras. Normally cameras have overlapping field of views, using the above process the cameras will be able to approximate the positions of the objects more accurately.

In Order to get a holistic view of the environment being monitored we need to arrive at a consensus image taking into account the various frames sent by the neighbouring cameras. The algorithm proposed by Ermis, Erhan Baki, et al [14] involves arriving at a consensus through pixel level correspondences whenever an unusual activity takes place. The difficulties of orientations, zooming and dynamic nature of the cameras are also addressed. The algorithm takes into account of unsupervised cameras and communication bandwidth and is robust. According to [14] upon testing the algorithm performed well in case of disoriented cameras while the usual SIFT (Scale Invariant Feature Transform) method failed.

2.4 An Optimal Image Processing Algorithm

This is considered the main part of the tracking system and is usually directly responsible for the success of the system. In the past studies various approaches were undertaken and compared to find the most optimal tracking algorithm.

Zoidi, Olga, Anastasios Tefas, and Ioannis Pitas [15] present the task of identifying the unique features of the object and to track in between the frames. Keeping track of the object in successive frames does this. The object changes or modifications are then learned in order to accommodate to changing appearances of the object. The algorithm doesn't perform well in case of occlusions and the speed of processing is considerably low and cannot be used in real life applications.

Reference [16] suggests that the task of detection can be done by projecting ellipsoid on the plane and then doing background subtraction. Tracking is done by keeping track of variables that represent object state and then performing Bayesian estimation and conveying the information to other neighbouring cameras. In order to speed up the process of processing a GPU has been used.

Chang, Chi-Jeng et al. [17] propose and outline the advantages of the FPGA (Field Programmable Gate array), which has an integrated architecture to overcome the complexity different hardware units present for consecutive iterations of image acquirement, convolution and sorting. After the pixels are obtained from an image sensor, they are filled in a row of a matrix. Then selected coefficients are obtained to initiate the convolution process. Succeeding this process pixels are filled in another **NxN** matrix. Better quality images are obtained once the Maheshwari sorting is performed on the obtained pixels. Another advantage of this process is that the presence of hardware oriented FPGA instead of traditional series microprocessors, which accounts for a faster image acquirement time.

In [18] the authors provide a comprehensive evaluation of the various facial recognition techniques in image processing. Relative performance checks of various methods are performed under different conditions of light, orientation, pose and partial occlusion, facial expression and presence of glasses, facial hair and a variety of hairstyles. The paper suggests that it is not possible to predict the best technique in an outright manner since there is a lack of uniformity in the methods of their evaluation. Under a given circumstance a defined test set may be used to determine which techniques are competitive in which domain.

Yun, Yixiao et al. [19] proposed a tracking scheme to include multi view tracking Learning on Riemannian Manifolds by Combining Geometric Constraints. The tracking scheme consists of two major parts: 1) multi-view Maximum Likelihood (ML) tracking; 2) online-learning of object appearances on the Riemannian manifold. These two processes are performed in an alternative fashion.

Mohedano et al. [22] proposed a centralized 3D tracking method in multi-camera environments. 2D tracks that are gathered from all the cameras of the system are combined to estimate 3D trajectories using Bayesian association. Though the performance was good we prefer using Distributed network for robustness and scalability.

Yue Wu et al. [25] proposes method of creating an entire scene from images taken from different cameras.The first stage compares two images (reference and sensed) and try to find out the correspondence set which has highest number of matches of pixels. This is done using Fast scale consensus (FSC) algorithm. The second stage improvises the result by increasing matching the keypoint to the appropriate neighbour using the Iterative selection of correct matches algorithm (ISCM). So we will be having a better correspondence set. This set is again run with Imprecise Points Removing Algorithm (IPRA) to eliminate the correspondence whose transformation error is beyond certain pixels. Results show that the method is robust, efficient and accurate compared to other algorithms.

Ref [26] describes internet of things (IoT) as an entity where major data and information will be stored and linked by real life objects. The objective is to capture meaningful data from agreement by different objects. IoT consists of three layers namely 1) Sensing layer which involves capturing data through sensor nodes, 2) Application layer which basic functions and the 3) Network layer which involves communication.

The authors describe the architecture of IoT based on services where each node/edge provides or demands services. In such an architecture we require agreement from various nodes which will lead to a Consensus Decision Making. The nodes will require to reach consensus when nodes 1) Access same piece of data or 2) Provide a service in which collaboration from many nodes is required. Suggested solution is that each node reach a Local Consensus based on communication with immediate nodes (cluster) and then a Global Consensus is reached based on the findings of al clusters.

3. Conclusions and Future Research

The most recent developments in the field of object tracking are demanding for a more dynamic and efficient working mechanism. This paper does a survey of various existing technologies in the field of object tracking, camera networks and consensus algorithm.

The processing of an image can be improved in two ways i.e. hardware or software. We have seen that the usage of FPGA or a GPU can increase the speed significantly. Even though the usage of previous frames leads to better approximation the processing rate is reduced. So appropriate tradeoffs should be made depending on the situation. The optimization of the image processing is the need of the hour and can eliminate the need of high computing at the nodes of our proposed distributed network.

In the networking part, Network discovery and maintenance still remains tough to achieve. We have seen various methods. Some use a coordinate system and some mutual signaling. We tried to ascertain their pros and cons. The main challenge here is to establish a dynamic network and a robust one as mentioned in [8]. The new research field for creating self-configurable smart camera networks is illustrated by SanMiguel, Juan C., et al. [23], which can be a very good future enhancement to the camera networks.

Tracking doesn't make sense until we arrive at a consensus view of the environment. One particular way is to pixel level correspondences iteratively. But the iterative way becomes a disadvantage in a network where the response time has to be very low. Taking into consideration of what has been so far we need to develop and fasten the algorithms.

The main challenge that the tracking system will face is that of security. As explained in [24] the security breaches that can happen in the visual sensory networks can cause huge damage, as the data is extremely sensitive and should always remain confidential

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References

[1] History of the camera. (2015, February 19). In Wikipedia, The Free Encyclopedia. Retrieved 20:11, February 19, 2015

[2] Yilmaz, Alper, Omar Javed, and Mubarak Shah. "Object tracking: A survey."Acm computing surveys (CSUR) 38.4 (2006): 13.

[3] Yang, Ming-Hsuan. "Object recognition." In Encyclopedia of Database Systems, pp. 1936-1939. Springer US, 2009.

[4] Matas, Jiri, and Stepan Obdrzalek. Object recognition methods based on transformation covariant features. na, 2004.

[5] Prati, Andrea, and Faisal Z. Qureshi. "Integrating Consumer Smart Cameras into Camera Networks: Opportunities and Obstacles." Computer 47.5 (2014): 45-51.

[6] Reisslein, Martin, Bernhard Rinner, and Amit Roy-Chowdhury. "Smart camera networks [guest editors' introduction]." Computer 47.5 (2014): 23-25.

[7] Shirmohammadi, Babak, and Camillo J. Taylor. "Distributed target tracking using self localizing smart camera networks." Proceedings of the Fourth ACM/IEEE International Conference on Distributed Smart Cameras. ACM, 2010.

[8] Bi Song; Chong Ding; Kamal, A.T.; Farrell, J.A.; Roy-Chowdhury, A.K., "Distributed Camera Networks," Signal Processing Magazine, IEEE, vol.28, no.3, pp.20,31, May 2011 DOI: 10.1109/MSP.2011.940441

[9] Lobaton, Edgar, et al. "A distributed topological camera network representation for tracking applications." Image Processing, IEEE Transactions on 19.10 (2010): 2516-2529.

[10] Song, Bi, et al. "Tracking and activity recognition through consensus in distributed camera networks." Image Processing, IEEE Transactions on 19.10 (2010): 2564-2579.

[11] Kamal, Ahmed Tashrif, Jay A. Farrell, and Amit K. Roy-Chowdhury. "Information weighted consensus filters and their application in distributed camera networks." Automatic Control, IEEE Transactions on 58.12 (2013): 3112-3125.

[12] Kamal, Ahmed Tashrif, Jay A. Farrell, and Amit K. Roy-Chowdhury. "Information consensus for distributed multi-target tracking." Computer Vision and Pattern Recognition (CVPR), 2013 IEEE Conference on. IEEE, 2013.

[13] Kamal, Ahmed Tashrif, Jay A. Farrell, and Amit K. Roy-Chowdhury. "Consensus-based distributed estimation in camera networks." Image Processing (ICIP), 2012 19th IEEE International Conference on. IEEE, 2012.

[14] Ermis, Erhan Baki, et al. "Activity based matching in distributed camera networks." Image Processing, IEEE Transactions on 19.10 (2010): 2595-2613.

[15] Zoidi, Olga, Anastasios Tefas, and Ioannis Pitas. "Visual object tracking based on local steering kernels and color histograms." Circuits and Systems for Video Technology, IEEE Transactions on 23.5 (2013): 870-882.

[16] Limprasert, Wasit, Andrew Wallace, and Greg Michaelson. "Real-time people tracking in a camera network." Emerging and Selected Topics in Circuits and Systems, IEEE Journal on 3.2 (2013): 263-271.

[17] Chang, Chi-Jeng, Pei-Yung Hsiao, and Zen-Yi Huang. "Integrated operation of image capturing and processing in FPGA." IJCSNS International Journal of Computer Science and Network Security 6.1 (2006): 173-180.

[18] Swaminathan, A., N. Kumar, and M. Ramesh Kumar. "A Review of Numerous Facial Recognition Techniques in Image Processing." (2014).

[19] Yun, Yixiao, I. Y. Gu, and Hamid Aghajan. "Multi-view ML object tracking with online learning on riemannian manifolds by combining geometric constraints."Emerging and Selected Topics in Circuits and Systems, IEEE Journal on 3.2 (2013): 185-197.

[20] B. Song, C. Soto, A. K. Roy-Chowdhury, and J. A. Farrell, "Decentralized camera network control using game theory," in Proc. Workshop ICDSC, 2008, pp. 1–8.

[21] C. Soto, B. Song, and A. K. Roy-Chowdhury, "Distributed multi-target tracking in a self-configuring camera network," in Proc. IEEE Conf. Comput. Vis. Pattern Recog. 2009, pp. 1486–1493.

[22] R. Mohedano and N. Garcia, "Robust multi-camera 3d tracking from mono-camera 2d tracking using bayesian association," IEEE Trans. Consumer Electronics, vol. 56, no. 1, pp. 1-8, 2010.

[23] SanMiguel, Juan C., et al. "Self-reconfigurable smart camera networks."Computer 47.5 (2014): 67-73.

[24] Winkler, Thomas, and Bernhard Rinner. "Security and Privacy Protection in Visual Sensor Networks: A Survey." ACM Computing Surveys (CSUR) 47.1 (2014): 2

[25] Yue Wu, Wenping Ma, Maoguo Gong, Linzhi Su, Licheng Jiao, "A Novel Point-Matching Algorithm Based on Fast Sample Consensus for Image Registration " Geoscience And Remote Sensing Letters, IEEE, Vol. 12, No. 1, January 2015

[26] Shancang Li, George Oikonomou, Theo Tryfonas, Thomas M. Chen, and Li Da Xu , "A Distributed Consensus Algorithm for Decision Making in Service-Oriented Internet of Things", IEEE Transactions on Industrial Informatics, Vol. 10, No. 2, May 2014.