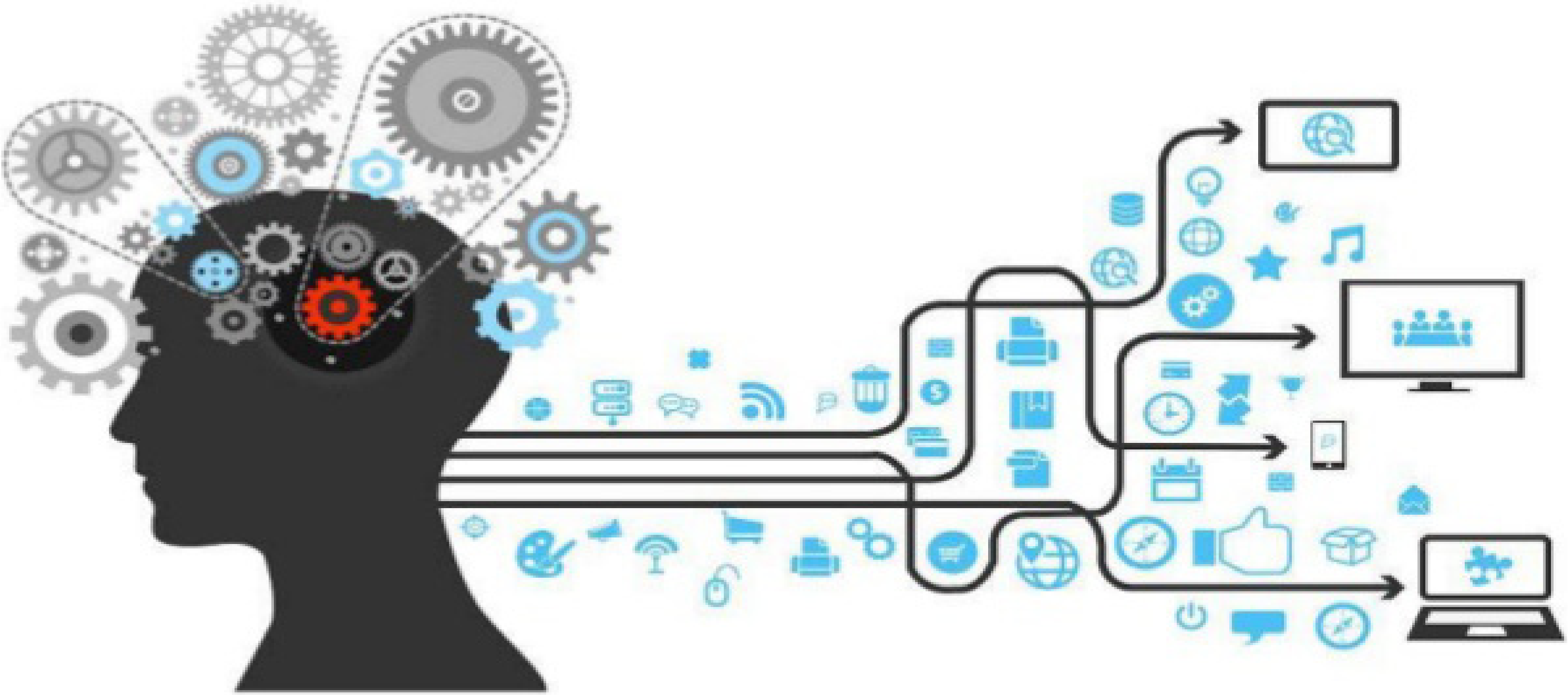
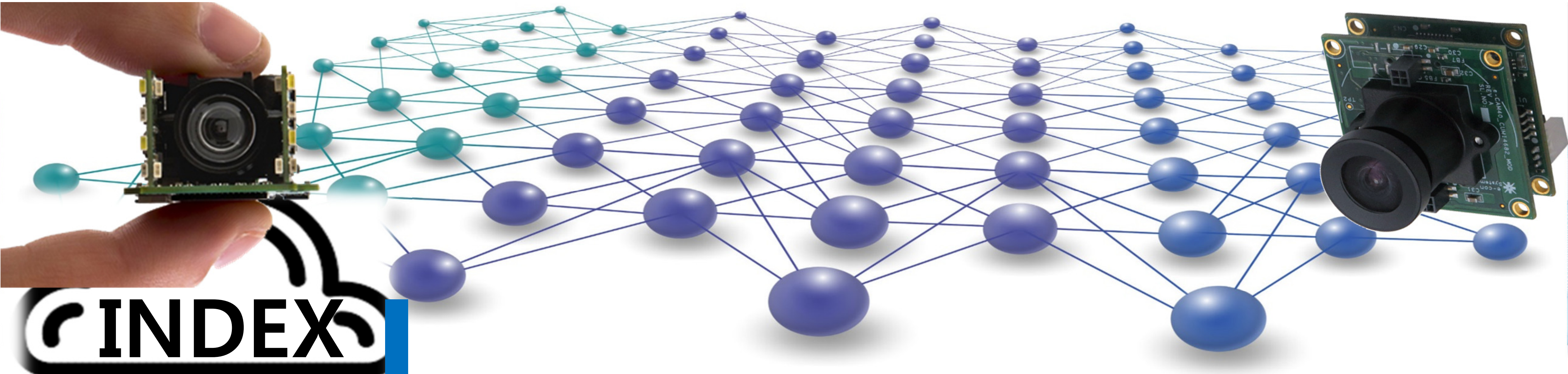


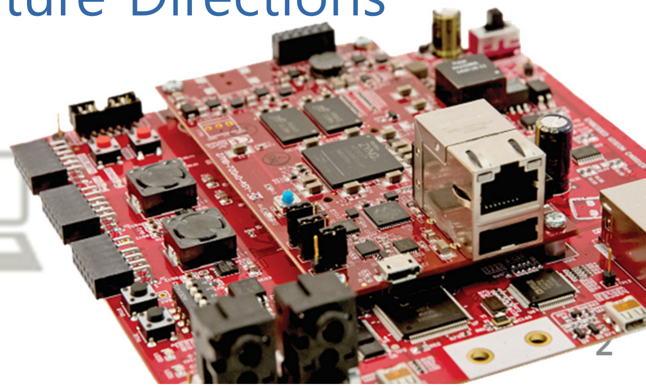
Efficient Deep Learning Methods for IoT Applications: Current Challenges and Future Directions

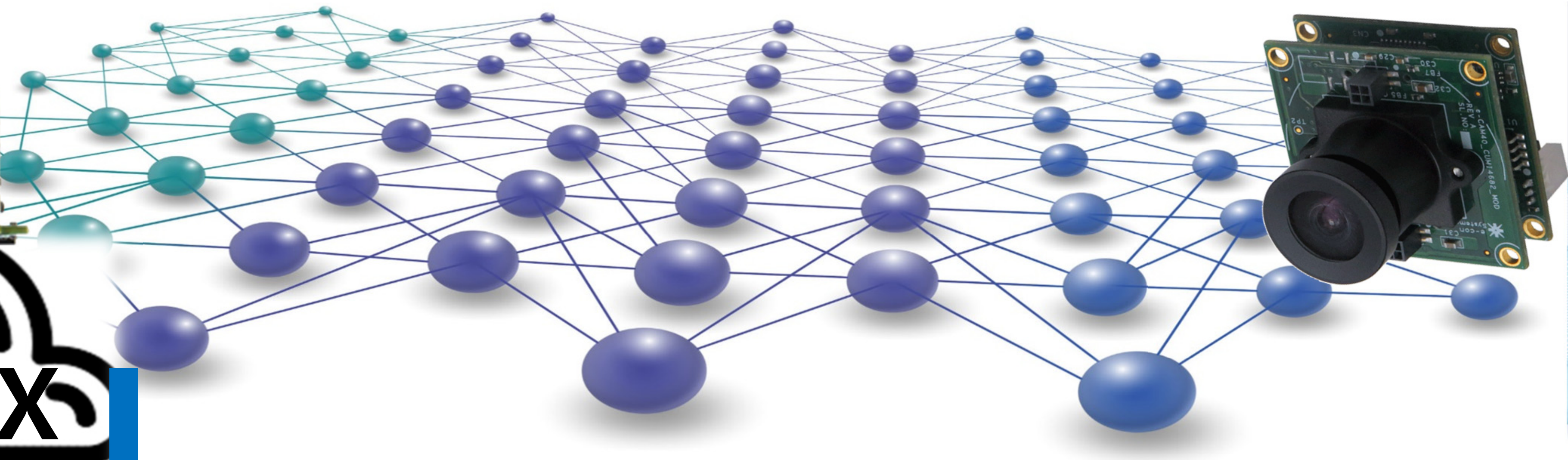
08. 07. 2021
Muhammad Sajjad

WINSYS 2021, 18th International Conference on Wireless Networks and Mobile Systems



Main Contents





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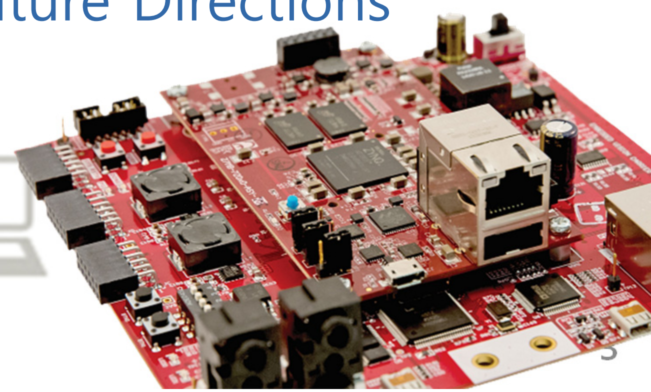
3. Efficient Deep Learning Methods for IoT Applications
4. Current Challenges and Future Directions



1. Speaker's Introduction

Muhammad Sajjad

- ERCIM Research Fellow at NTNU
- Associate Professor, Department of Computer Science, Islamia College University, Pakistan
- Head of Digital Image Processing Lab
- muhammad.sajjad@icp.edu.pk
- +92-333-9319519

Research Interests

① **Embedded Vision**
- Smart Cities Security
- Autonomous Driving

② **Image and Video Analysis**
- Video Summarization
- Action Recognition

③ **Medical Image Analysis**
- Medical Image Encryption
- Tumor Segmentation/Classification

Publication Record

Publication Record	75+
As lead /Corresponding-author	32+
As co-author	43+
Total citations	2458+
Total impact factor	180+
MS/PhD Students in Supervision	14/5
Participation in Research Projects	8
Professional and Research Experience	12

Research Projects

① **Improvement in Birth Success, Health and Safety of Cows using Smart Neck Collar for Livestock**

② **Raspberry Pi Assisted Face Recognition Framework for Enhanced Law-Enforcement services in Smart**

③ **Generic and Feature-based opinion summarizer for online product reviews using unsupervised**

④ **Road Safety for Kids based on Virtual Reality Interaction Physical Space**

2. Research Team

Current DIP Lab Members (Digital Image Processing Lab)

Imran Uddin
(Ph.D.)
(2018-2022)

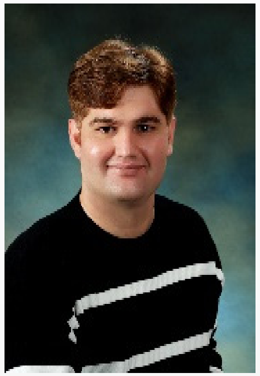
Siraj
(Ph.D.)
(2018-2022)

Hikmat Yar
(Master)
(2017-2019)

Altaf Hussain
(Master)
(2017-2019)

Adnan Hussain
(Master)
(2020-2022)

Muhammad Waqas
(Master)
(2020-2022)

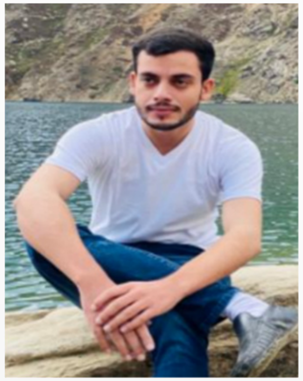


Muhammad Irfan
(MS 2018-2020)
(Researcher)

Afnan Khan
(Bachelors)
(2016-2020)

Asad Faraz
(Bachelors)
(2016-2020)

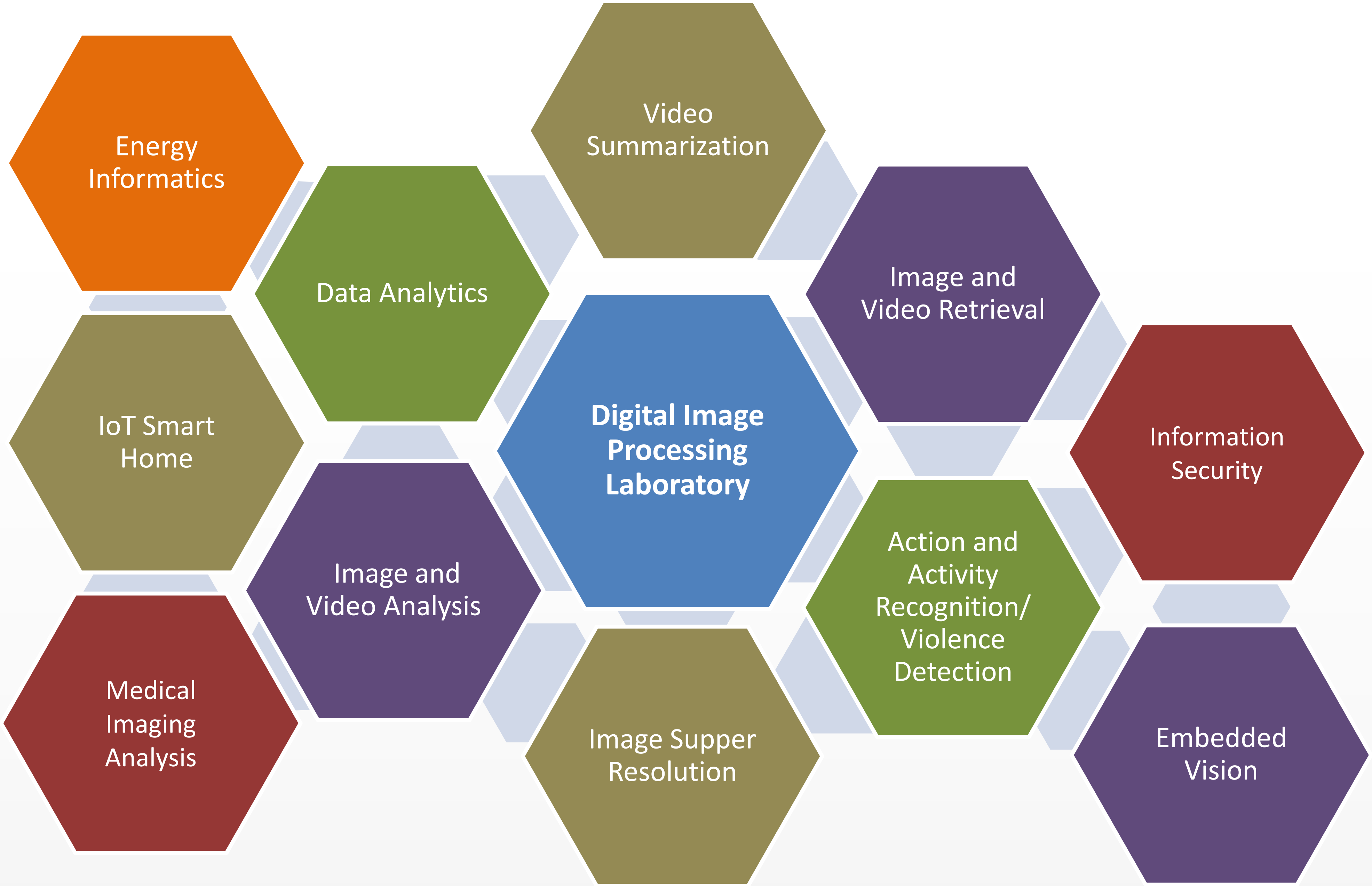
Muhammad Munsif
(Bachelors)
(2016-2020)

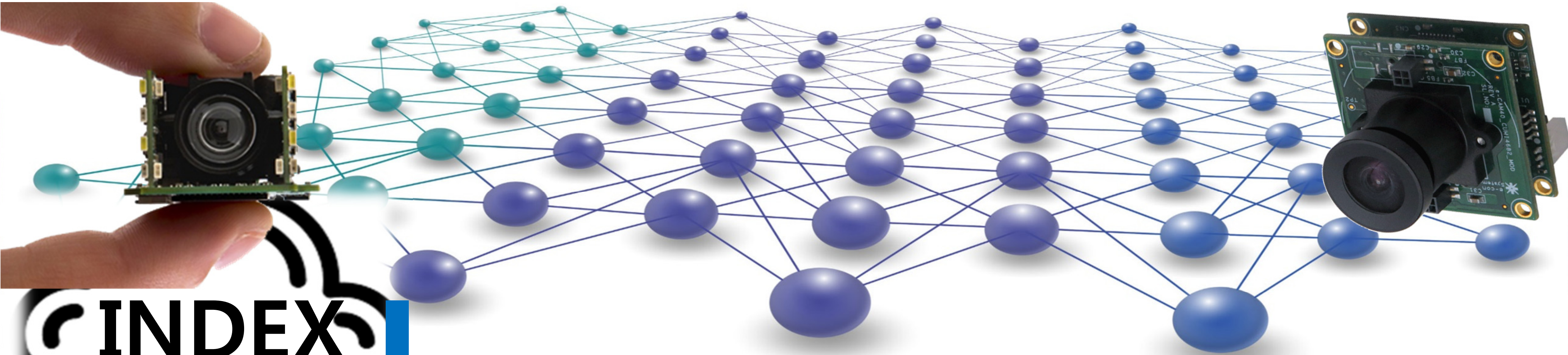


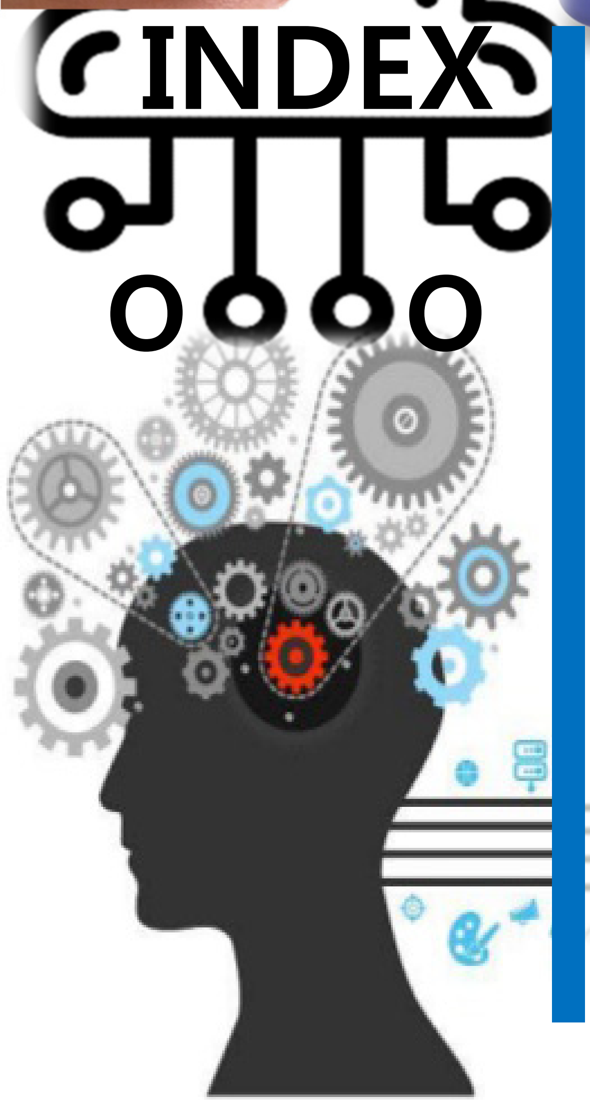
Sarer Ul Amin
(Bachelors)
(2016-2020)

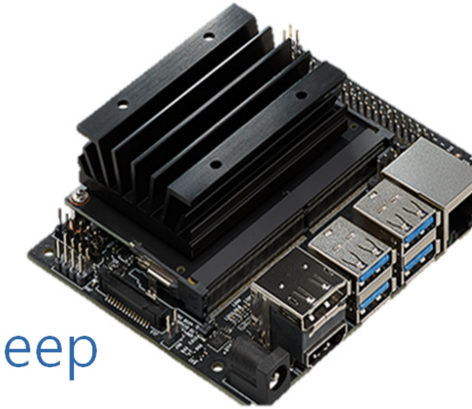
Abbas Khan
(Master)
(2020-2022)

3. Joint Research Areas



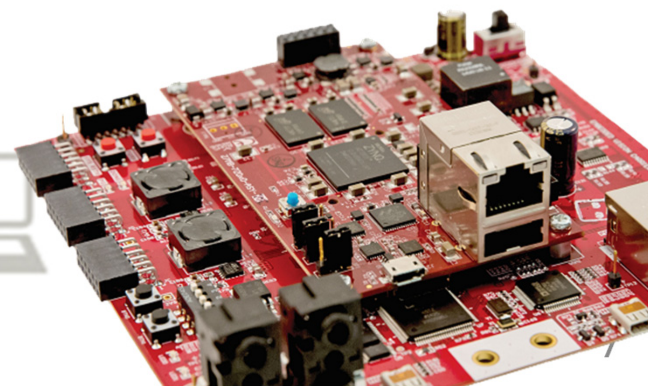






II. Introduction

1. Conventional Machine Learning vs Deep Learning
2. Deep Learning in IoT Environment



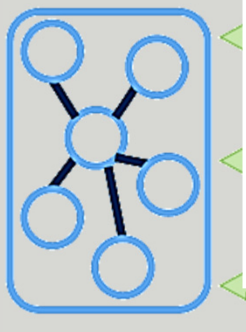
1. Conventional Machine Learning vs Deep Learning

- Deep learning is a subfield of machine learning. While both fall under the broad category of artificial intelligence.

Conventional machine learning

- Machine learni
data using ha
decisions base
etc.

- Machine learni
time for training



Conventional machine learning basic working pipeline

Deep learning

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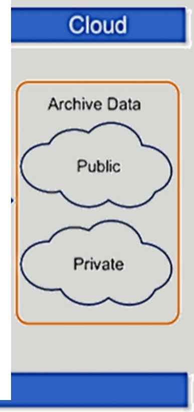
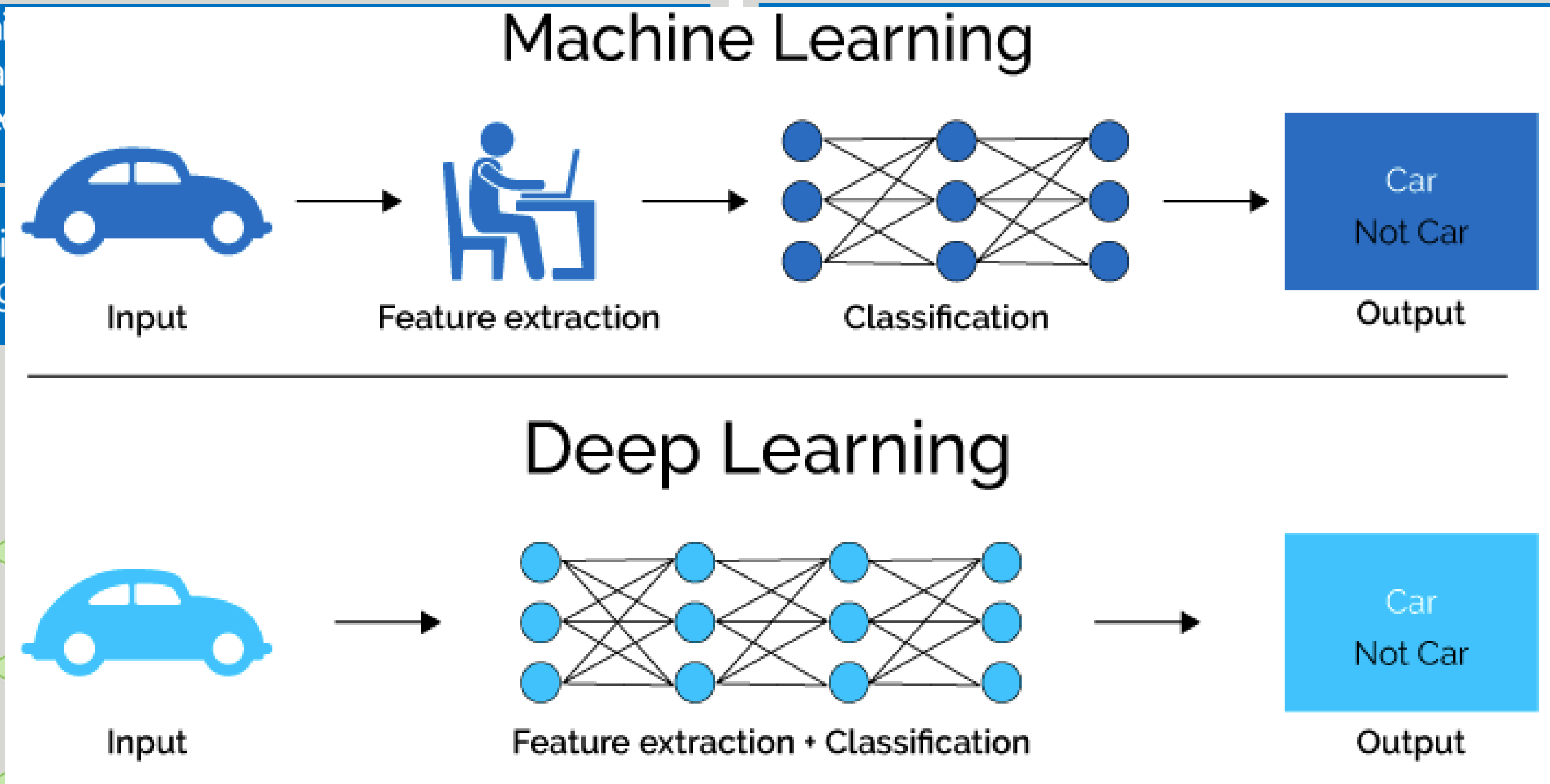


Deep learning basic working pipeline for cloud training

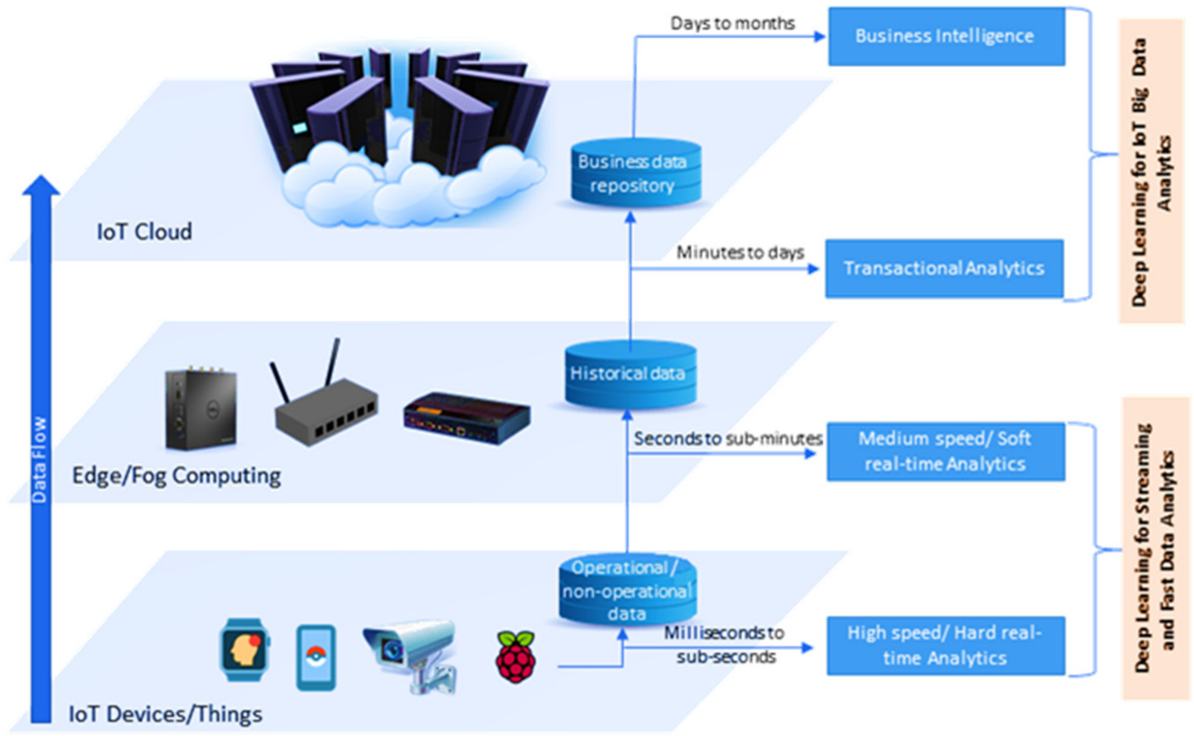


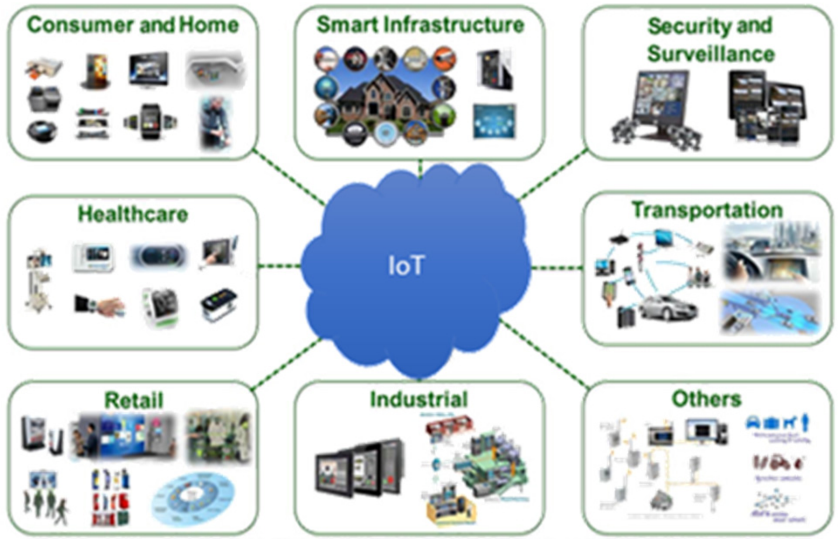
2. Deep Learning in IoT Environment

- IoT devices uses lightweight deep models for on-boarding and fast data processing
- Huge volume data is passed to the cloud for intelligent processing

Data Flow in IoT Environment

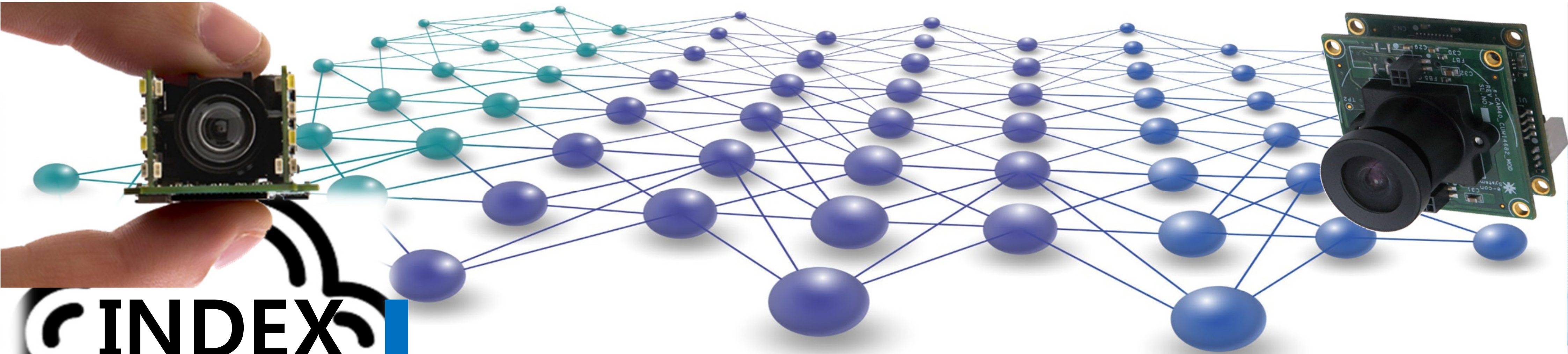
- IoT devices such as Raspberry Pi captures various types of data
- Fog computing process data to address challenges including real-time processing
- Big data is passed to cloud computing for intelligent processing





IoT Application Domains

- Factories or industries, including operation management
- Cities, including public safety, health, and traffic control
- Healthcare, including monitoring and managing illnesses
- Energy, including the smart grid



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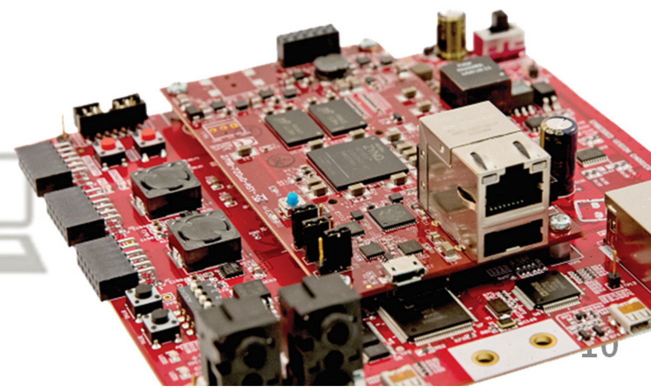
III. Efficient Deep Learning Methods for IoT Applications

1. IoT Based Smart City Security
2. Video Summarization in IoT Environment
3. IoT Based Medical Image Analysis
4. Embedded Vision

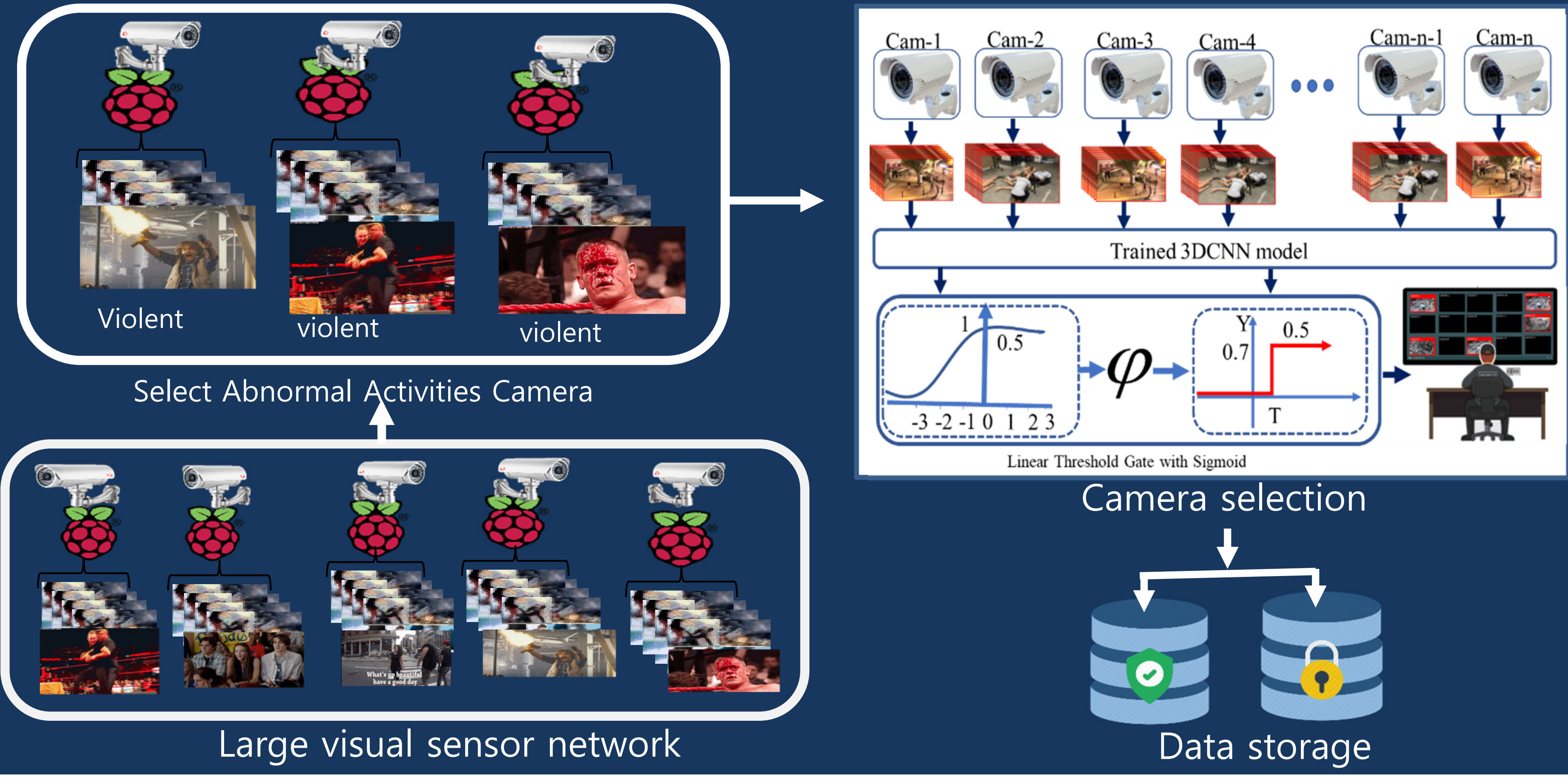


1. Camera Prioritization

Anomaly Based Camera Prioritization in Large Scale Surveillance Networks

- An energy-efficient camera prioritization framework that intelligently adjusts the priority of cameras in a vast surveillance network using feedback from the activity recognition system.
- The proposed system performs well compared to state-of-the-art violent activity recognition methods in terms of efficient camera prioritization in large-scale surveillance networks.

Main Theme



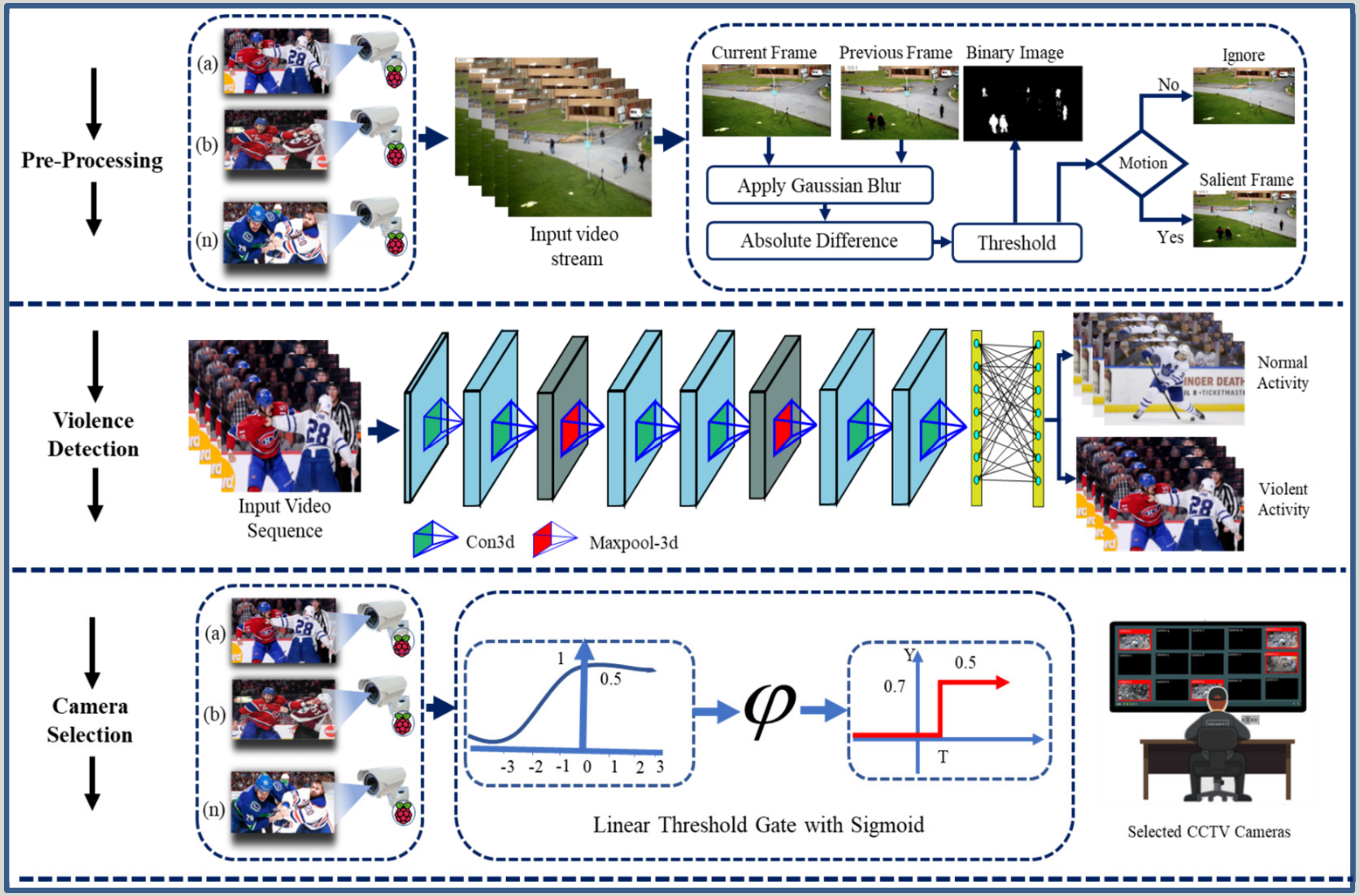
1. Camera Prioritization

Main contributions

- A novel camera prioritization framework is proposed for economical hardware devices (e.g. the Raspberry Pi) based on violent activity recognition in large-scale WVSNs. Salient motion is the key feature for activity recognition. A lightweight frame differencing technique is incorporated to extract frames containing salient motion, thus ensuring the efficient utilization of resources.

- Human activity consists of a sequence of motion patterns in consecutive frames, meaning that both spatial and temporal features need to be learned for this task. A novel lightweight 3DCNN architecture over resource-constrained devices is proposed, which outperforms other state-of-the-art techniques in terms of accuracy on benchmark datasets.

- A novel linear threshold gate sigmoid (LTGS) method is used to priorities cameras based on violent activity in large-scale WVSNs by exploiting both the metadata and the probabilities predicted by the proposed 3DCNN model, thereby reducing the dependency on human monitoring, the energy required, and the bandwidth consumption.



2. Deep-ReID: Deep Features and Autoencoder Assisted Image Patching Strategy for Person Re-identification in Smart Cities Surveillance

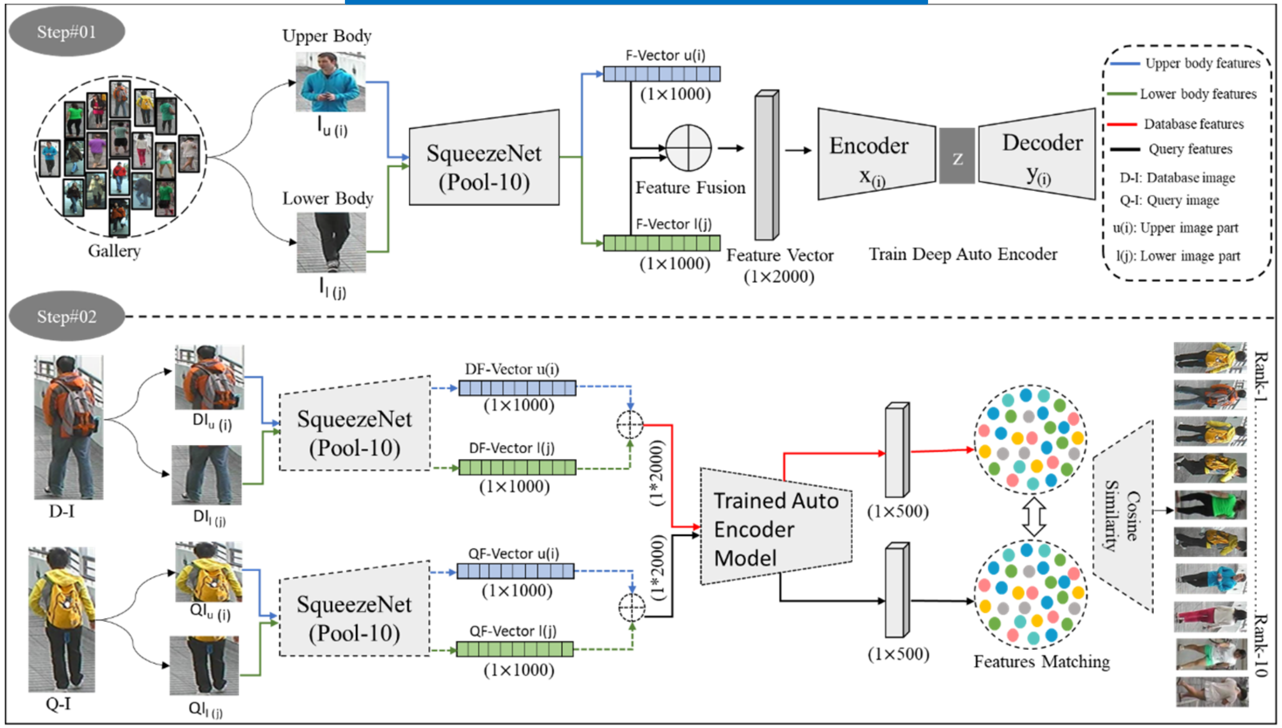
Main Contributions

- Computationally efficient framework that incorporates stacked autoencoder with convolutional neural network Squeeze-Net model.
- The filtering strategy in the proposed framework reflects the inclusion of only salient pixels in the final output. We suppress the pixels with less amount of information and consider only highly activated pixel values.

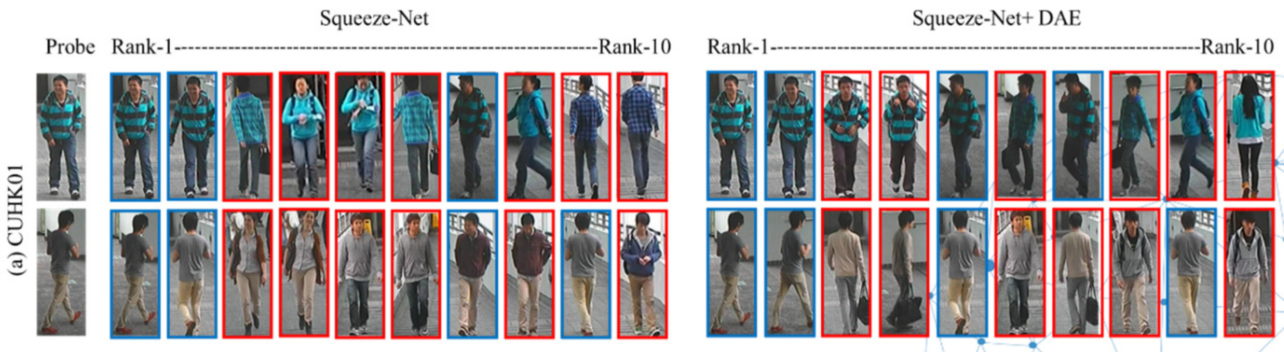
Results

- Improved 3%, 5%, and 4% Rank-1 accuracies for Market1501, CUHK01, and VIPeR datasets, respectively.
- Achieve real-time processing of standard 30 frames per second.

Framework



Results



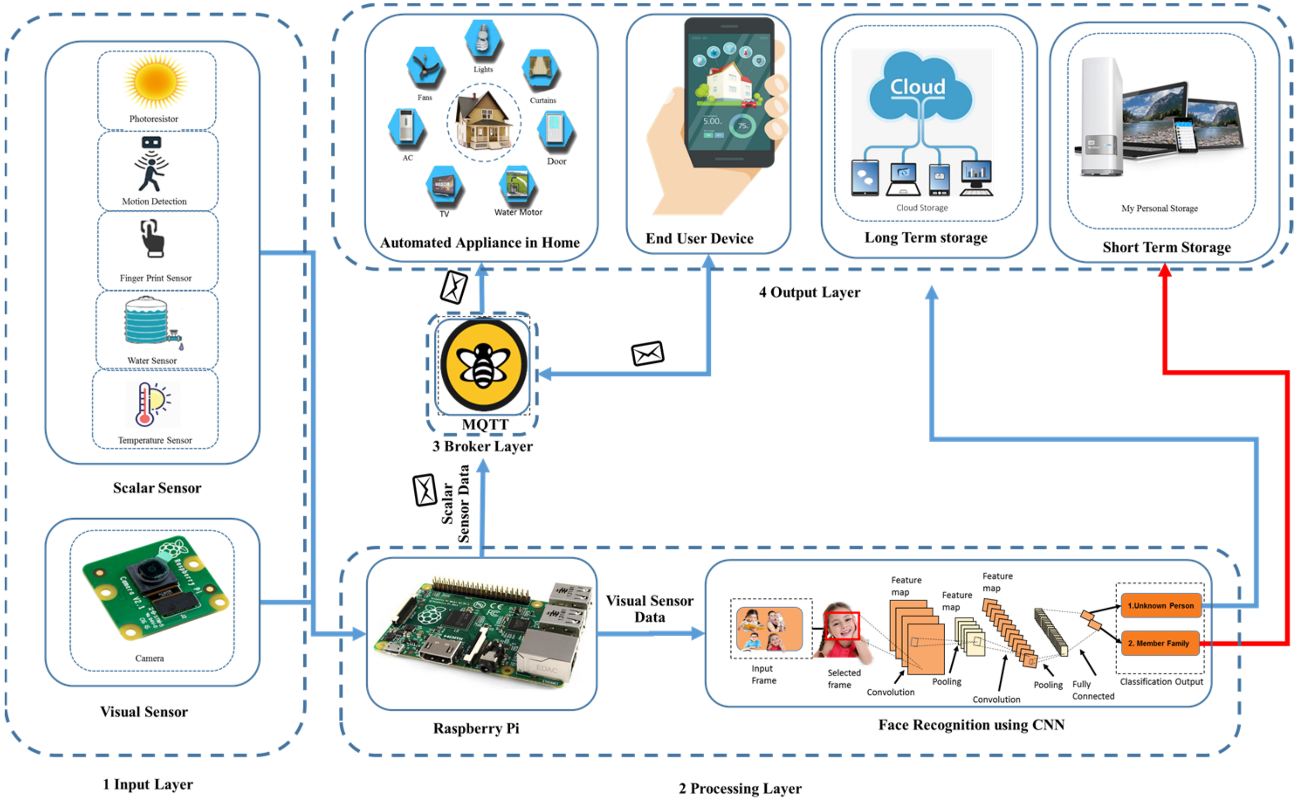
3. Towards Smart Home Automation using IoT Enabled Edge Computing Paradigm

An intelligent framework for Cost, Effective, Automatic, Secure and Engegry Efficient Smart Home:

- IoT and edge-based computing paradigm based framework to control the entire home by finger-tips, the framework is responsible to reduce the electricity usage and make home even more secure. In this framework an edge computing concept is used to process all the sensors data using Raspberry Pi on the edge and for storage purpose a device named My-Personal Cloud are used and sending average data only once in a day to cloud centers for further analysis.

Main contributions

The main contribution of the proposed work is to develop an integrated system for smart home, to control home appliances automatically and remotely via smart phone or PC, provide safe and secure environment and reduce energy consumption. The proposed system automatically works based on environmental sensors while the stream of visual sensor passed through a security filter to improve the privacy of the user. The proposed system makes use *of IoT and edge-based computation paradigm* to enable large scale data production and analysis via local systems thereby reducing the bandwidth and computation cost. The system provides a neat package and a full control over all devices via the internet that can be controlled from all over the globe. The solution is a hybrid between intelligent computational model and a secure repository for all the sensitive data generated from the sensors installed in the system.



Limitations

- No appropriate mechanism for health-care and fall detection in home
- Energy efficiency, automation, and no sensors data fusion mechanism

4. Activity Recognition Using Temporal Optical Flow Convolutional Features and Multilayer LSTM

Motivation

- Human monitoring for identification of different activities is tiresome.
- 24/7 fashion surveillance required salient information selection.

Method Description

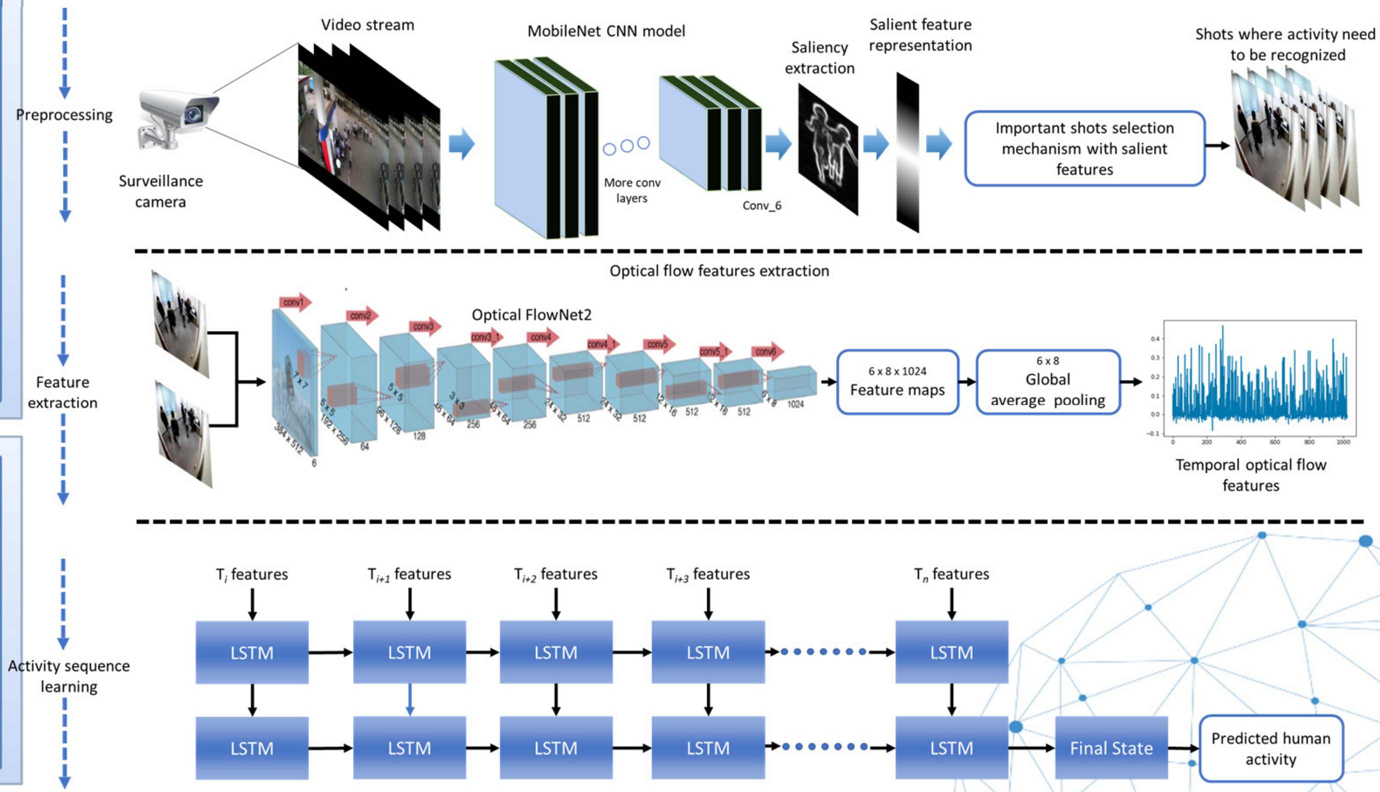
- Only salient frames selection for processing using MobileNet CNN model.
- CNN based temporal optical flow features for sequence representation.
- Multi-layer LSTM network for activity sequence learning.

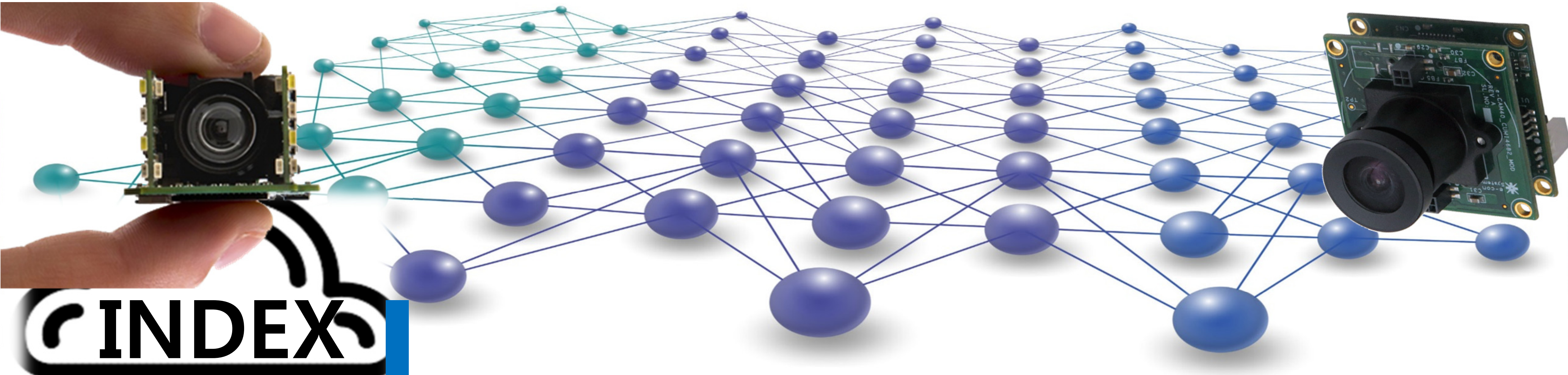
Results

- Improved 3% accuracy from state-of-the-art.
- Achieve real-time processing of standard 30 frames per second.

https://github.com/Aminullah6264/Activity_Rec_ML-LSTM

Salient regions selected from video surveillance stream





III. Applications of Deep Learning in IoT

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2. Video Summarization in IoT Environment
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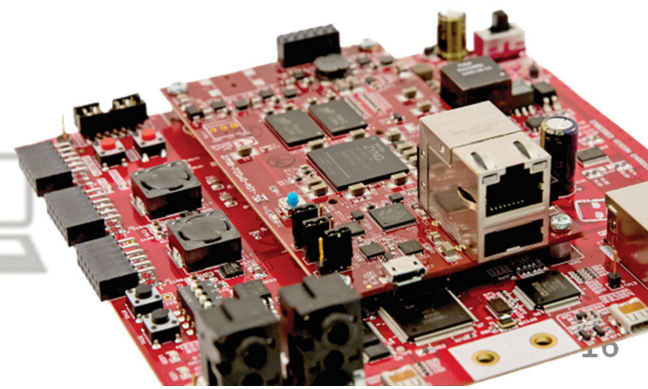
4. Embedded Vision



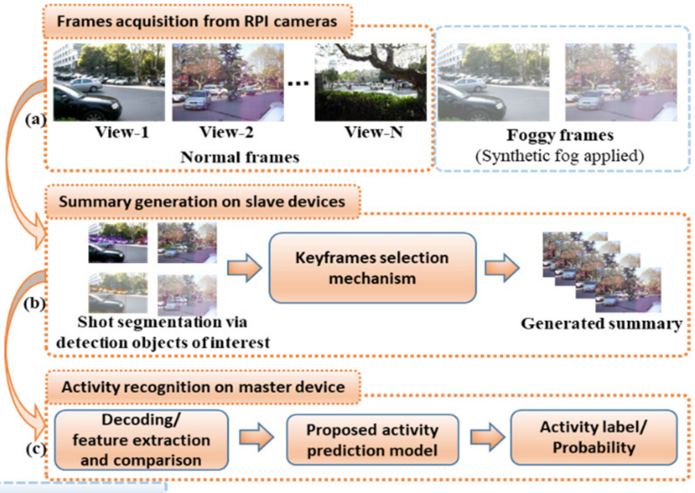
1. Video Summarization in IoT Environment

Multi-View Summarization and Activity Recognition Meet Edge Computing in IoT Environments

- An edge intelligence-based video summarization and activity recognition framework that combines artificial intelligence with Internet of Things (IoT) devices to perform multimedia data prioritization as well as further useful analysis such as activity recognition.

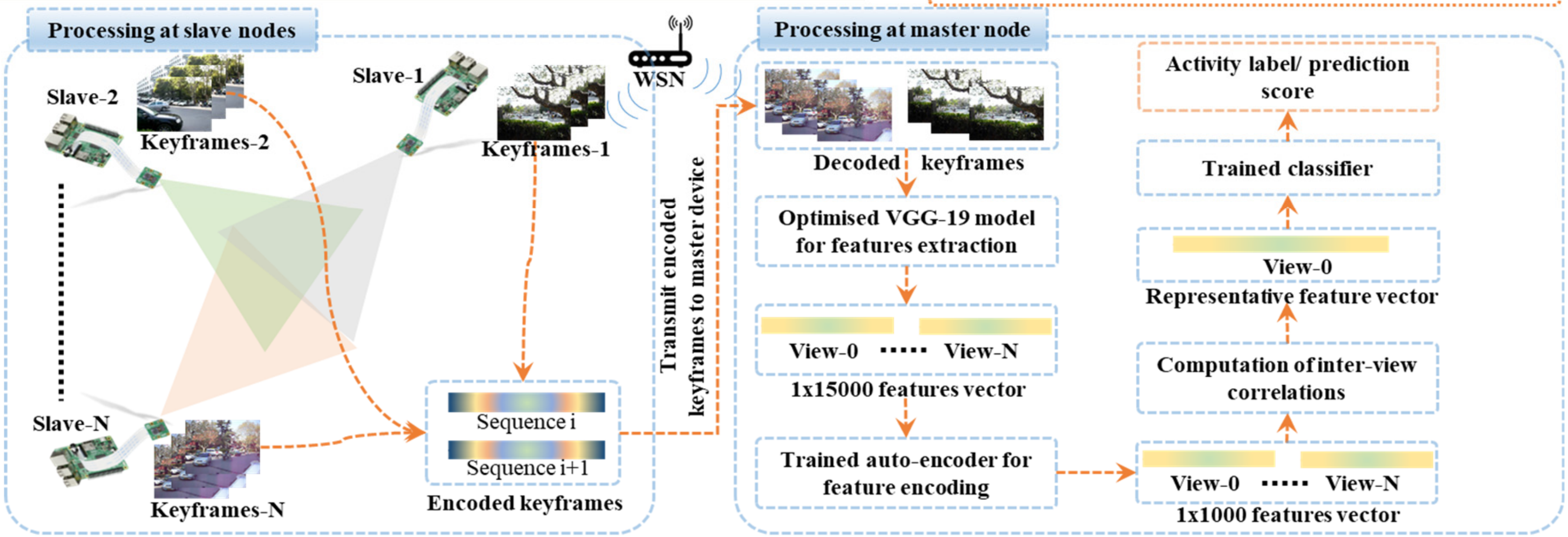
Main contributions

- VS algorithm functional over resource-constrained devices, which reduces the time complexity and gives higher accuracy than existing approaches.
- An adoptable framework to many type of scenarios such as foggy surveillance environment.
- The presented framework has various flavors based on trade-offs among transmission time, the quality of keyframes, and the accuracy of the activity recognition model with computationally variant classifiers.



Limitations

- No defogging strategy prior to object detection.
- Activity recognition for only single-view cameras.
- No alert generation and sharing mechanism in IoT network.



2. Intelligent Embedded Vision for Summarization of Multiview Videos in IIoT

Motivation

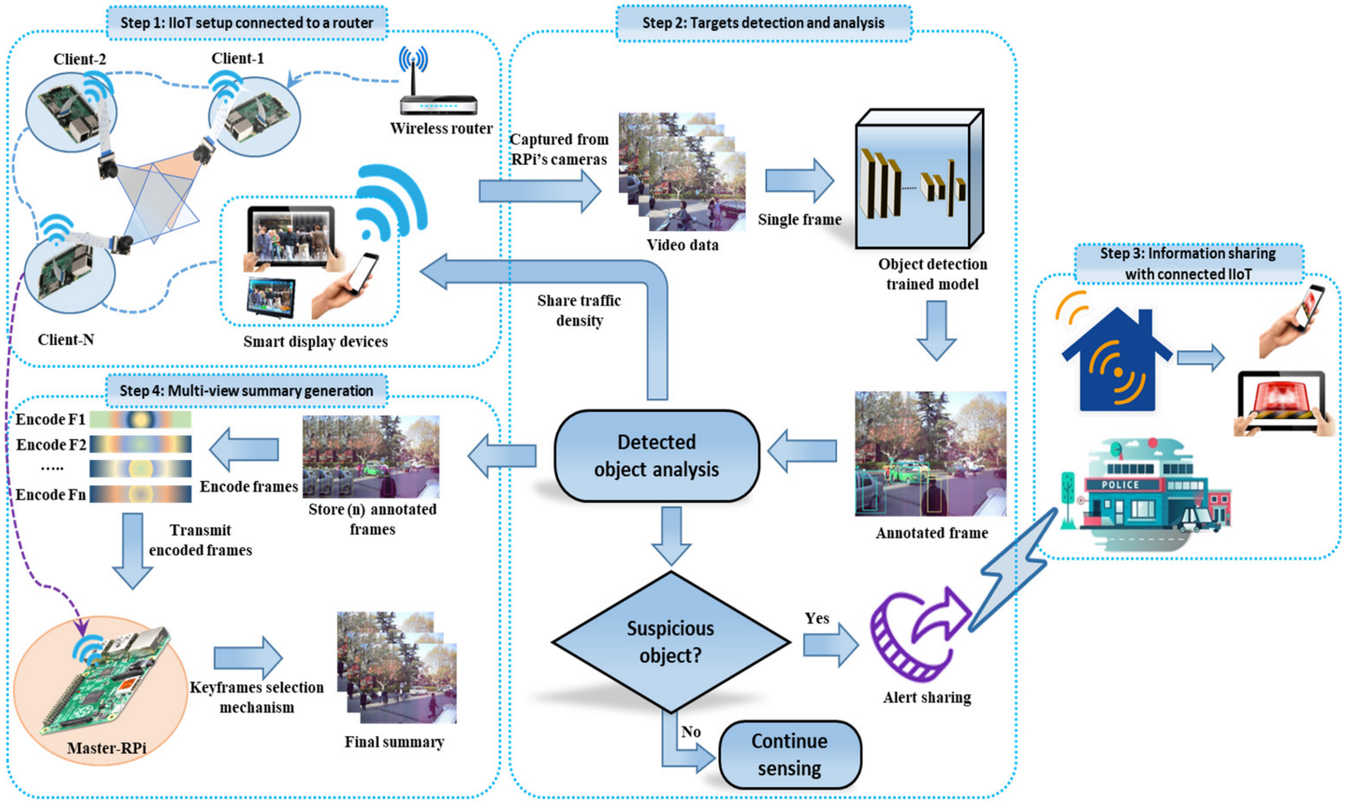
- Single-view surveillance has limited coverage.
- Multi-view video summarization (MVS) over resource constrained devices is needed for smart cities.

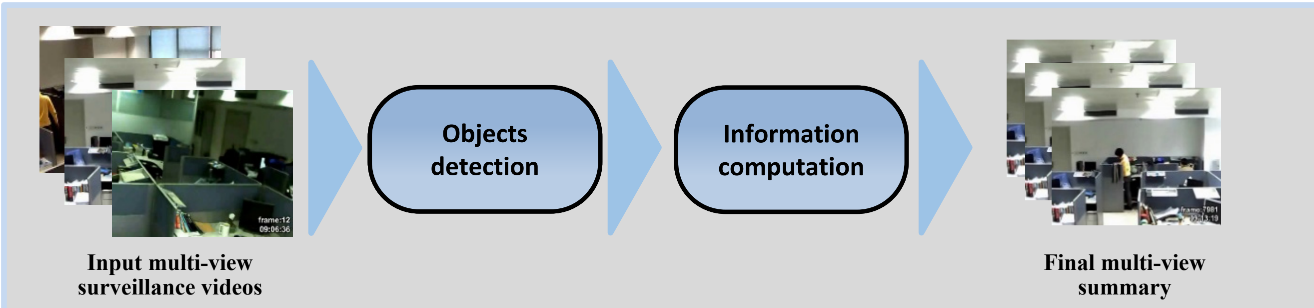
Method Description

- Suspicious objects detection over embedded devices.
- Reducing frames size before transmission over IIoT network to save resources.
- Novel entropy based information computation mechanism.

Results

- Increase of 0.1 in F-measure on Office MVS dataset.
- Encoding frames with 0.2~0.25 MB smaller size for wireless transmission.





https://github.com/tanveer-hussain/Embedded-Vision-for-MVS

2. Video Summarization in IoT Environment (2)

Fog computing enabled cost-effective distributed summarization of surveillance videos for smart cities

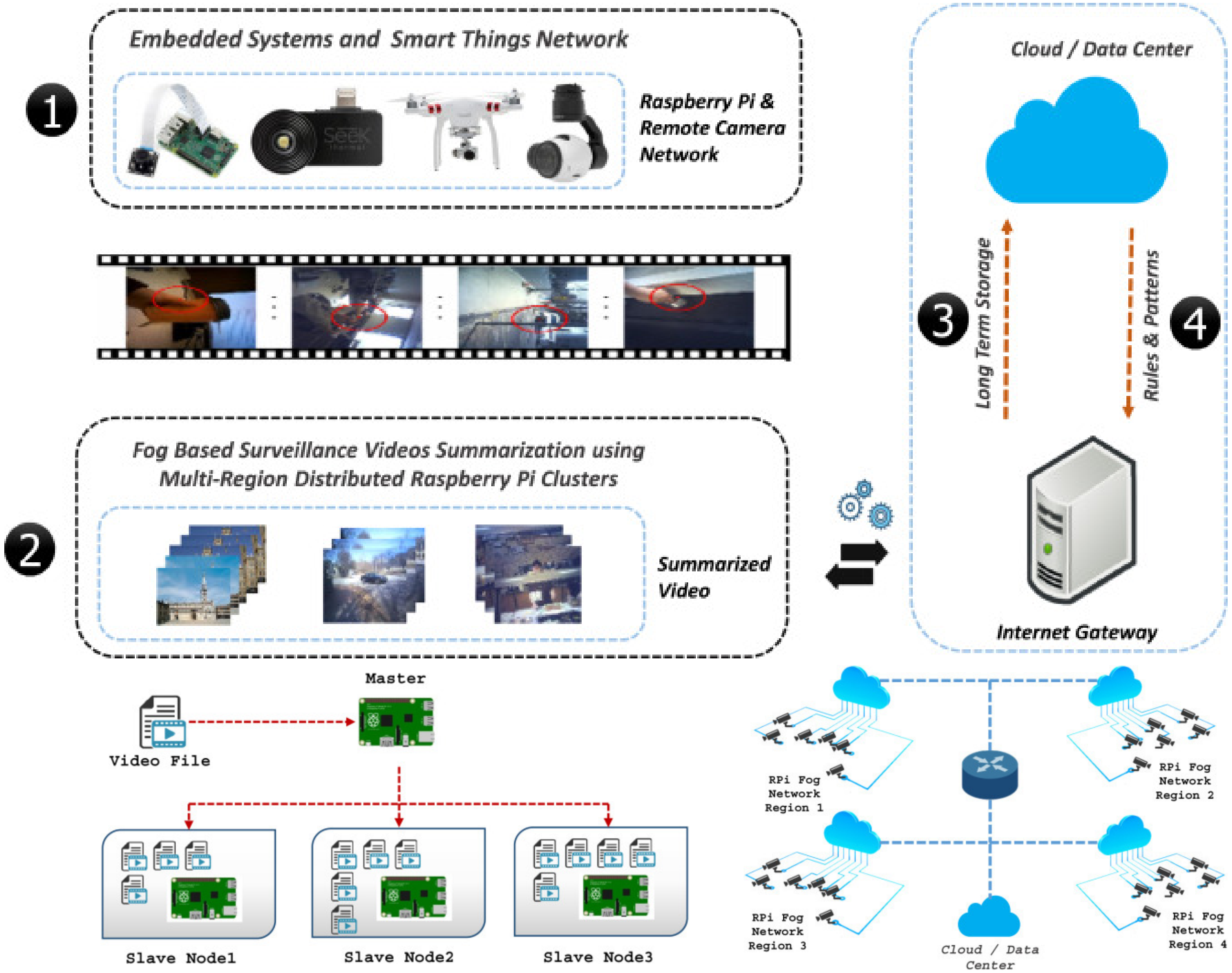
- A novel resource efficient framework for distributed video summarization over a multi-region fog computing paradigm.

Main contributions

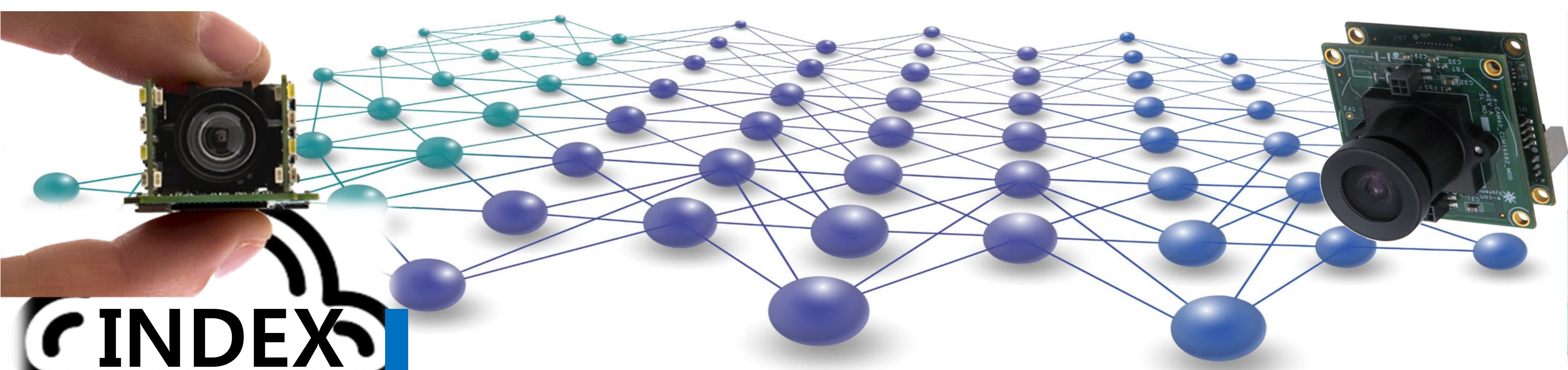
- We propose a novel fully distributed multi-region *Fog computing enabled framework for surveillance videos summarization without having to use a centralized cloud server.* To the best of our knowledge, no such solutions exists yet.

- The fog computing platform is built on low-cost, low-powered Raspberry Pi clusters, orchestrated with Apache Spark and Hadoop for distributed storage and speedy summarization of surveillance video streams.

- The proposed framework not only replaces the need for any centralized server, but it also significantly reduced the bandwidth consumption of a centralized and costly cloud-based solutions.



→Fog computing based video summarization frame for IoT environment



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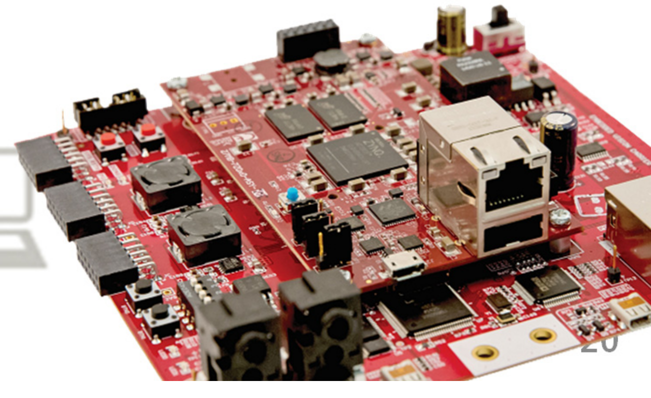
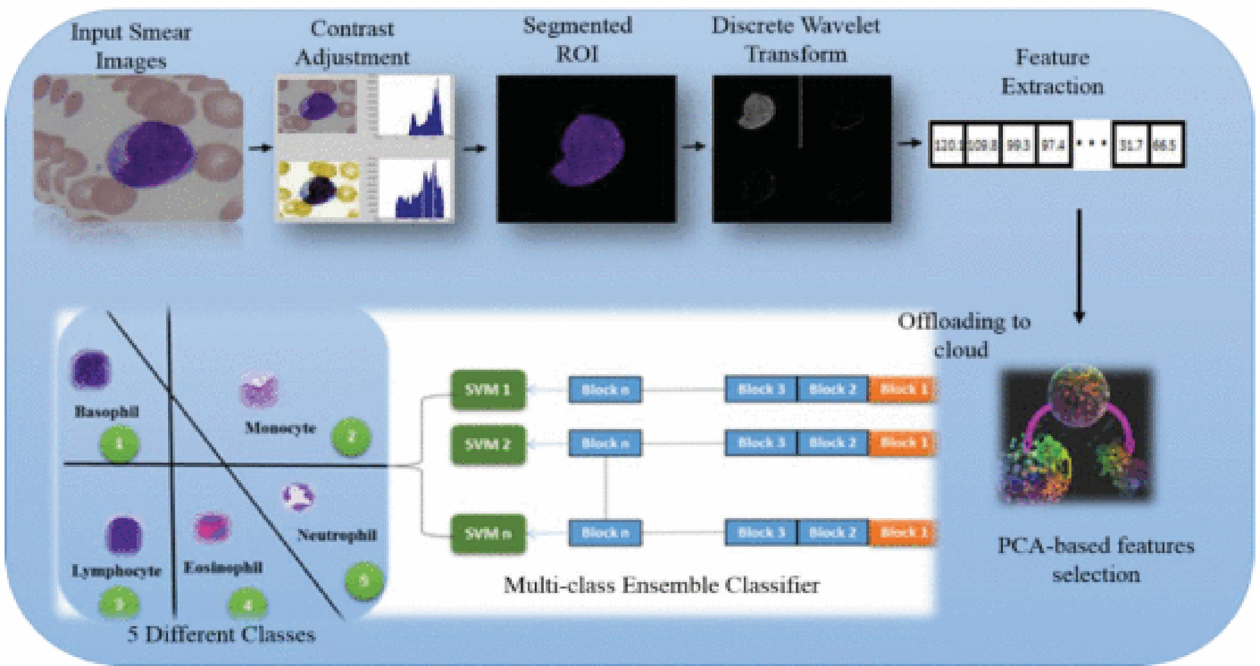


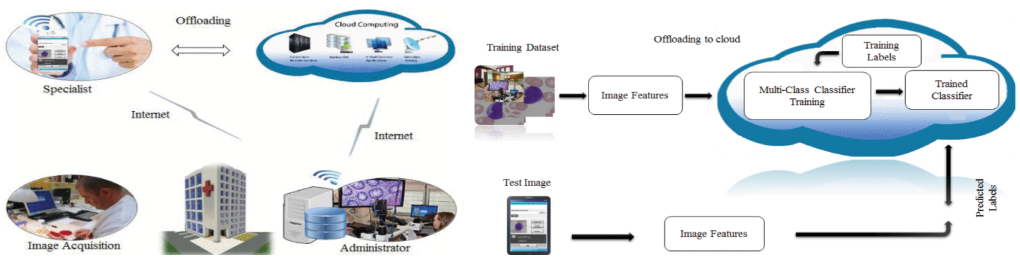
3. IoT Based Medical Image Analysis (1)

Leukocytes Classification and Segmentation in Microscopic Blood Smear: A Resource-Aware Healthcare Service in Smart Cities

- A smartphone-based cloud-assisted resource aware framework for localization of WBCs within microscopic blood smear images using a trained multi-class ensemble classification mechanism in the cloud



→Proposed leukocytes segmentation and classification framework



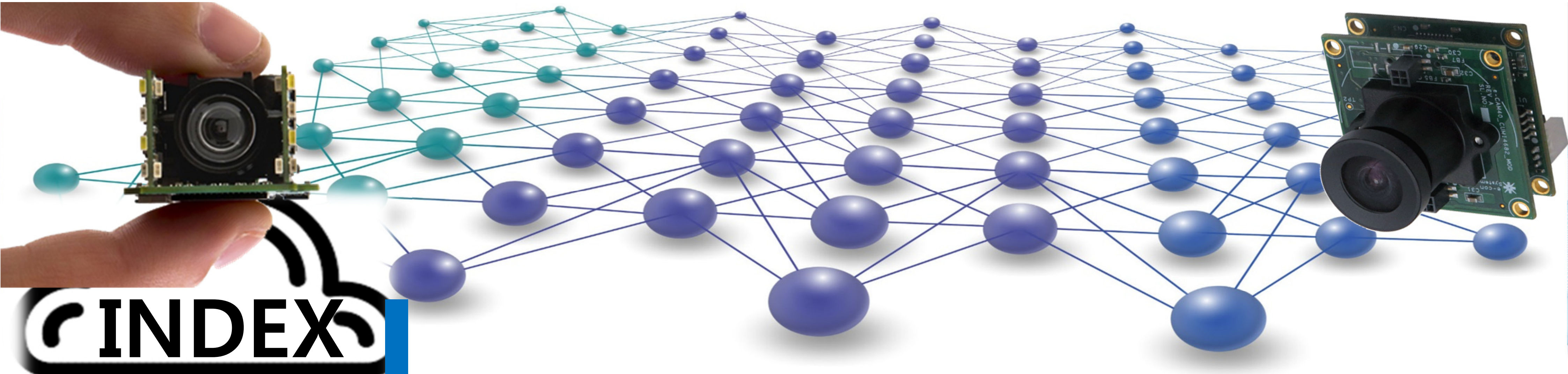
→Training information exchange on a cloud server.

Main contributions

- A novel smartphone based cloud assisted system is proposed for leukocytes classification and segmentation in blood smear images, helping haematologist in diagnosing various diseases more efficiently with better accuracy.

- Reduce internet bandwidth cost by offloading image features to the cloud to train a multi-class classifier, instead of sending an entire diagnostic image dataset.

- For efficient and effective segmentation, a color K-means clustering algorithm is incorporated into the proposed framework, providing better segmentation results compared to other state-of-the-art schemes.



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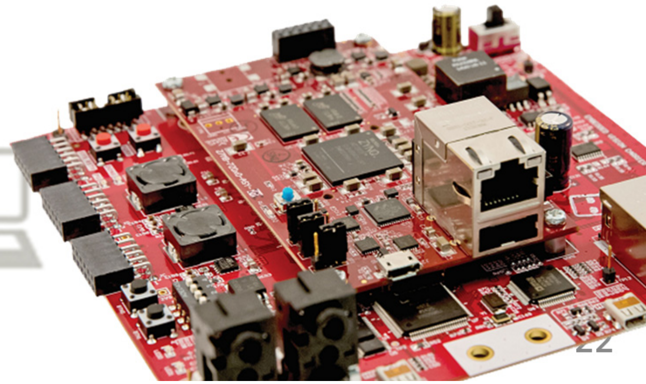
5. Demo video



4. Embedded Vision (1)

An Efficient and Scalable Simulation Model for Autonomous Vehicles With Economical Hardware

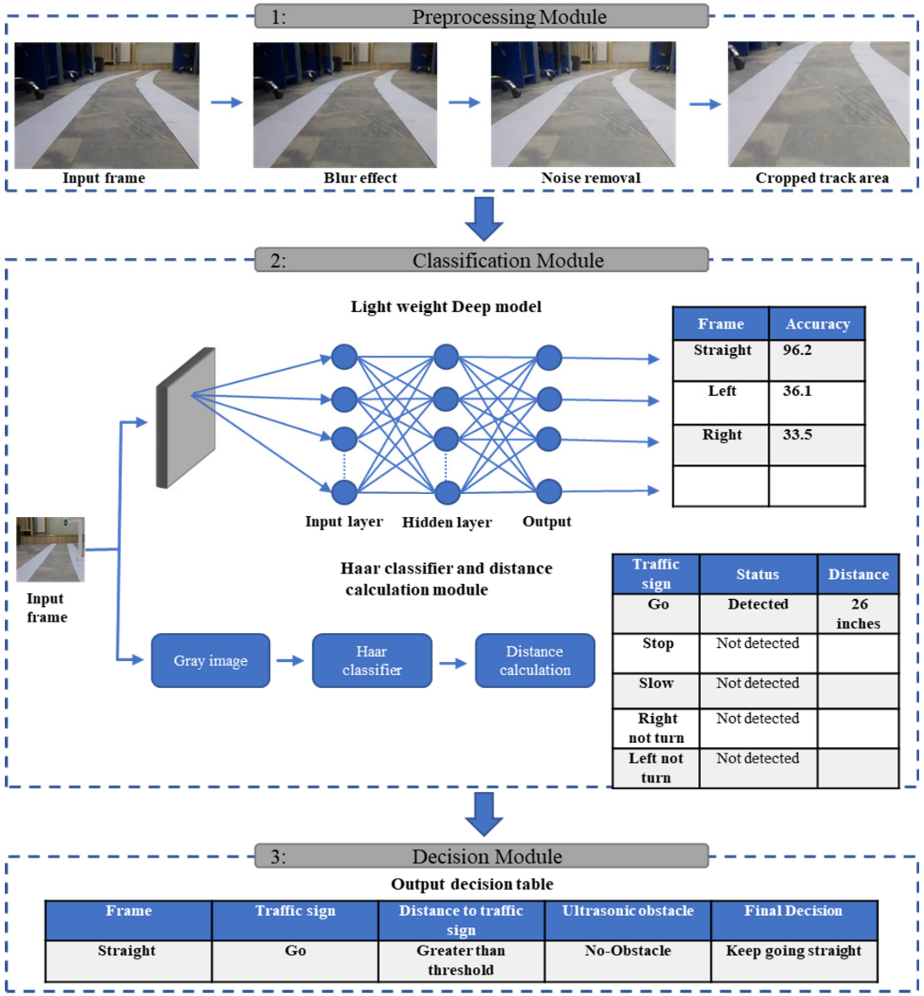
- A monocular vision and scalar sensor-based model car is designed and implemented to accomplish autonomous driving on a specified track by employing a lightweight deep learning model

Main contributions

- A Raspberry Pi based framework for a self-driving model car is proposed that moves on pre-defined track recognizing various traffic signs.

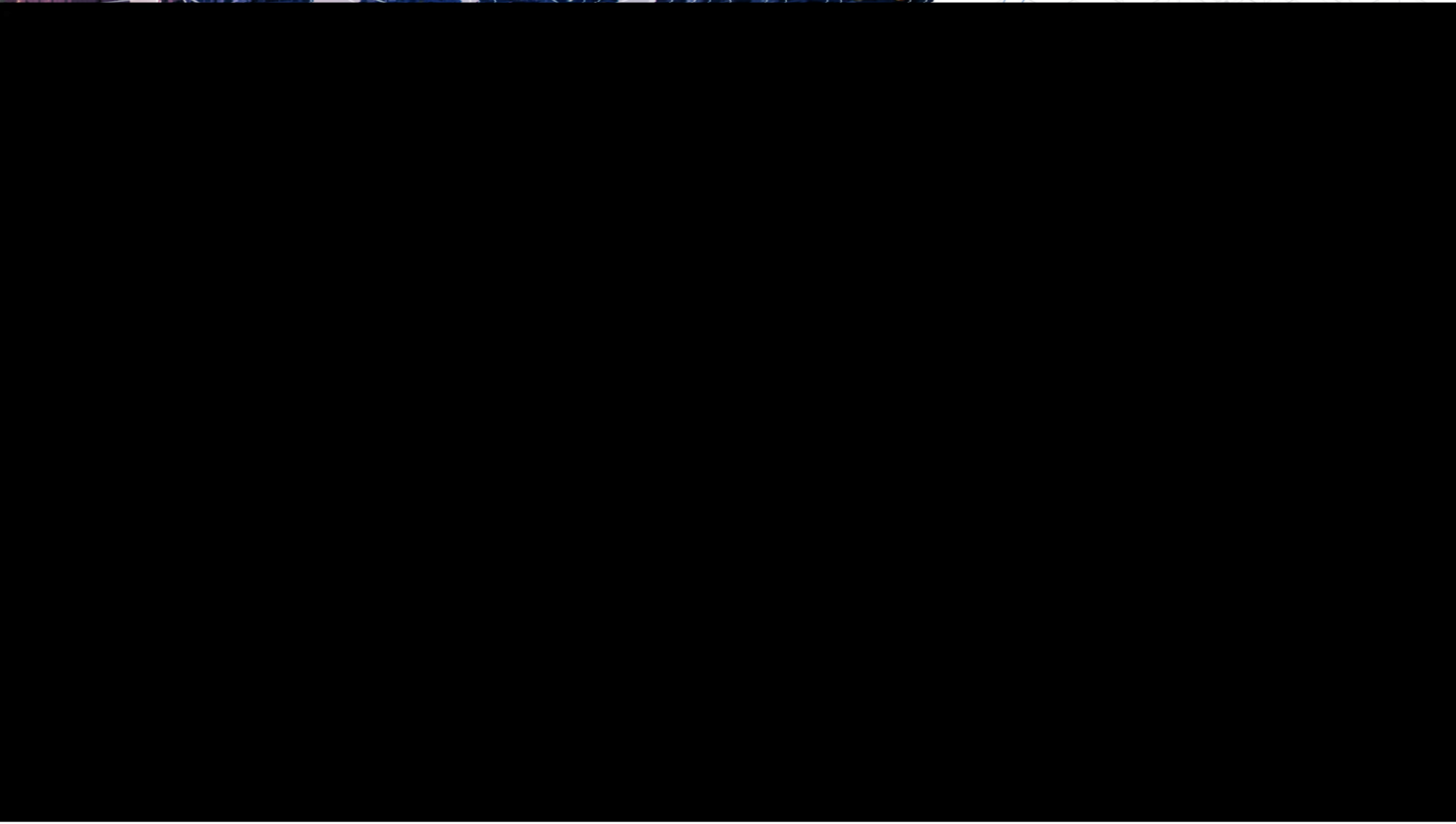
- Raspberry Pi is used as an independent processing unit to handle visual and scalar data in real time, without reliance on a centralized server for model loading and processing.

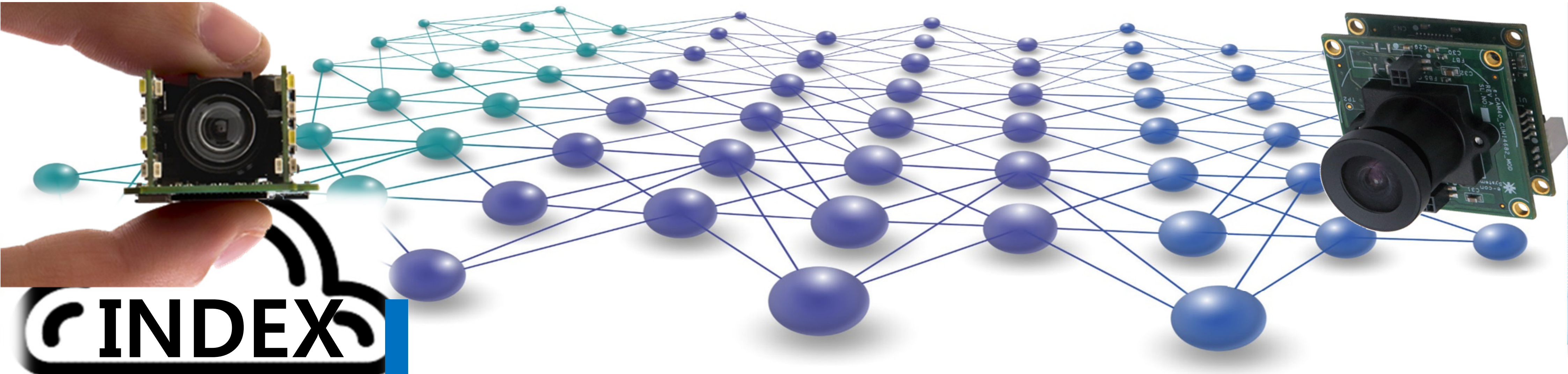
- Deep Neural Network (DNN) models require a high end processing unit for execution in real time. Therefore, a lightweight deep model has been proposed for resource constrained devices, which is executed in real time for autonomous manoeuvring.

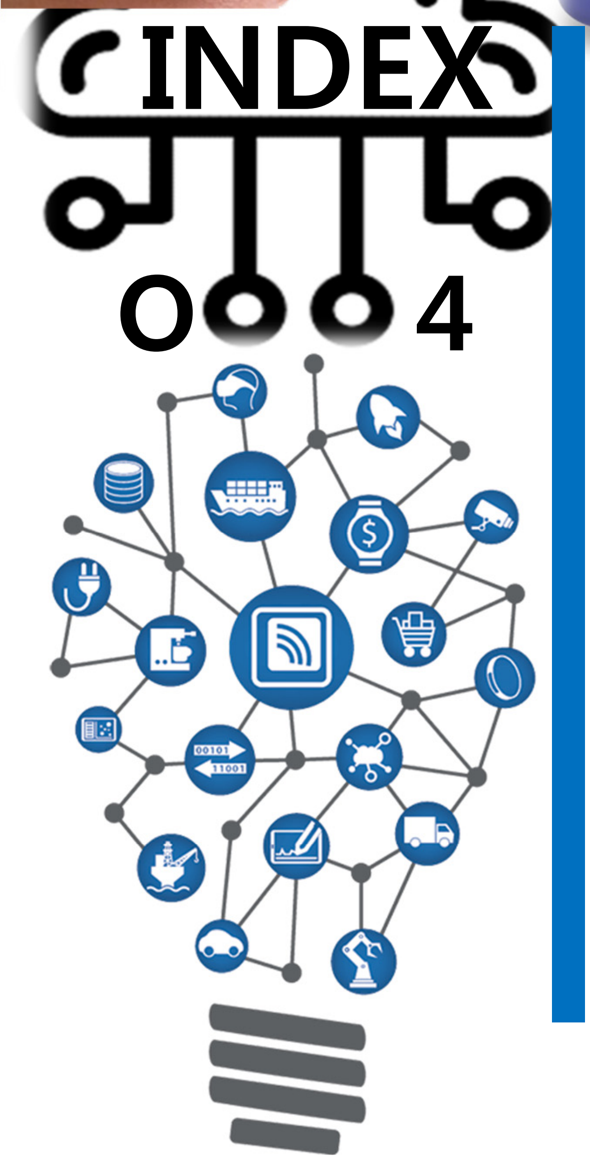


Framework for self-driving using resource constrained device.

5. Demo

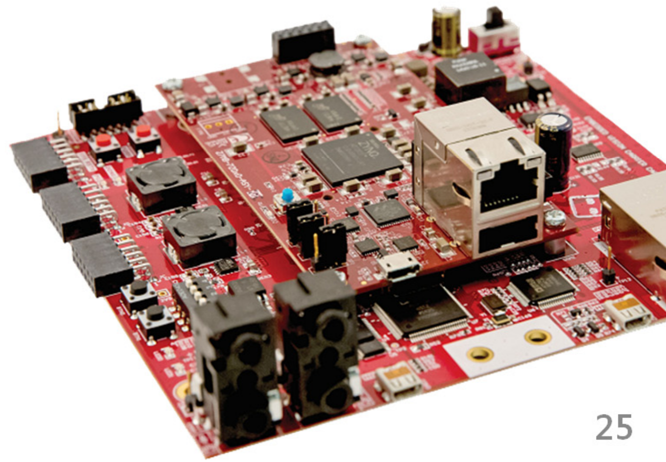






IV. Challenges & Future Directions

1. Major Challenges
2. Future Directions



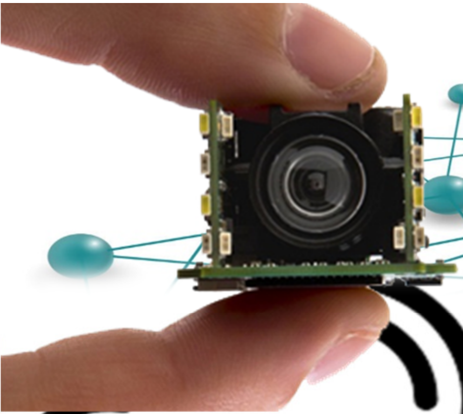
1. Current Challenges

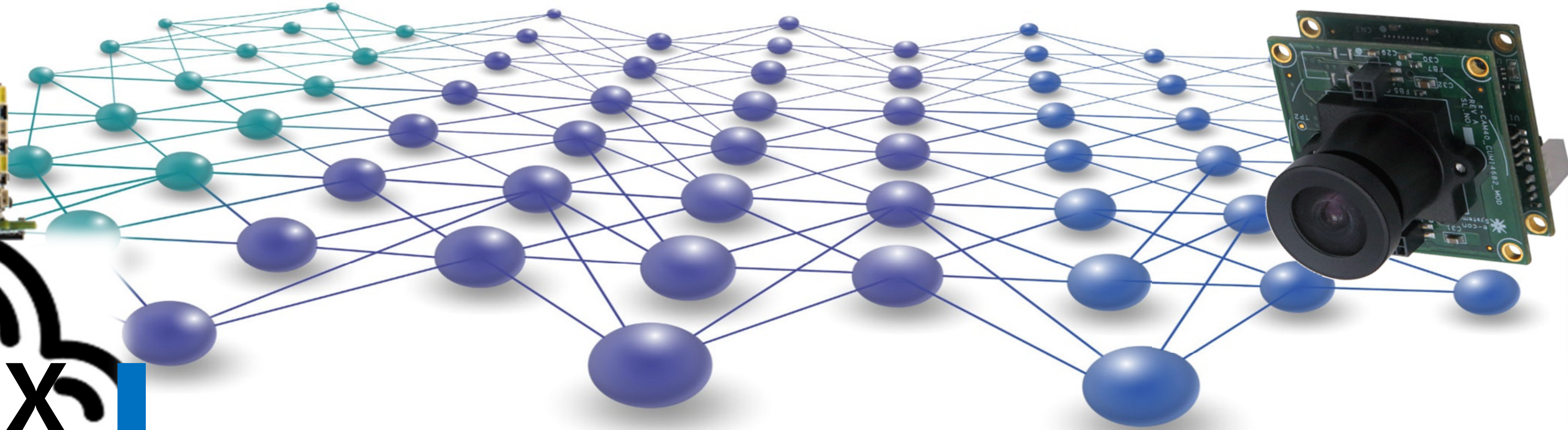
Complexity

- Gathering and Cleaning of Data in environment consist of different visual/scaler sensors
- Integration and interoperability
- Data fusion
- Complicated tasks will be handled on camera/sensors hardware while batch processing will be handled by high-end hardware.

Deep Learning

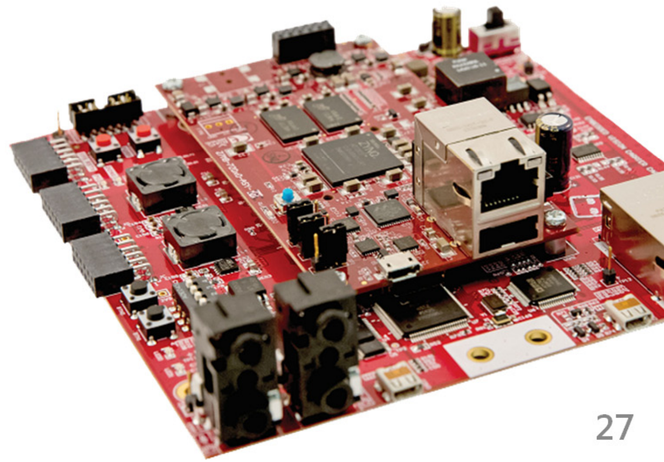
- Deep embedded vision based applications are expected to be reliable and has full feature-set of deep learning libraries
- Current deep learning libraries are not fully compatible with low-powered, low-resource hardware and often requires tricky manipulation.
- Versions complication buzz





IV. Challenges & Future Directions

1. Major Challenges
2. Future Directions



2. Future Directions

- Beside the tremendous achievements of the deep learning in IoT, there still exists certain barriers in the advancement of the technology. In Future, Deep learning based IoT will cover the following areas

- IoT Security
- Industrial Internet of Things (IIoT)
- Predictive Maintenance Analysis
- IoT in Healthcare
- Automotive IoT
- Aerospace IoT
- IoT in Smart Homes/city, agriculture etc

- Further, current IoT devices have limited resource in term of processing and power that further limits the performance of IoT devices in real-time.

- The performance of deep learning models are heavily depended on the training data (more data results good performance). Diverse data is required in order to train a generic model.

Thank you
Q&A