MADANAPALLE INSTITUTE OF TECHNOLOGY & SCIENCE

(UGC-AUTONOMOUS INSTITUTION)

Affiliated to JNTUA, Ananthapuramu & Approved by AICTE, New Delhi

NAAC Accredited with A+ Grade, NIRF India Rankings 2024 - Band: 201 - 300 (Engg.)

NBA Accredited - B.Tech. (CIVIL, CSE, CST, ECE, EEE, MECH), MBA & MCA

A Report on

IEEE CASS SEASONAL SCHOOL TITLED "NEUROMORPHIC COMPUTING AND LOGIC IN MEMORY COMPUTING USING NON-VOLATILE MEMORY DEVICES"

Organized by

Department of Electrical & Electronics Engineering (EEE) in association with IEEE Student Chapter, MITS Madanapalle

23/09/2024 to

25/09/2024

Chief Convener: Dr. AV Pavan Kumar, Professor and Head, Department of EEE, MITS.

Convener: Dr. Nehru Kandasamy, Professor, ECE

Resource Person/Speaker: Details attached below

Attendees: 71 members (National and International)

Venue: Seminar Hall **Time: 10:00 AM**

Resource Person/ Speaker:

S.no	Eminent keynote Speaker details	University
1	Dr Kim Tae Hyoung	Associate Professor, School of Electrical and Electronic Engineering, Nanyang Technological University, Singapore
2	Dr FONG, Xuanyao Kelvin	Assistant Professor, Electrical and Computer Engineering, National University of Singapore, Singapore
3	Dr. Thomas Kämpfe	Group Manager Integrated RF & AI Fraunhofer IPMS (Center Nanoelectronic Technologies CNT) An der Bartlake 5, 01109 Dresden, Germany
4	Dr Damien QUERLIOZ	**Research Director, CNRS** Adjunct Professor, Université Paris-Saclay Centre de Nanosciences et de Nanotechnologies 10 Boulevard Thomas Gobert, 91120 Palaiseau, France
5	Dr. Catherine Schuman	Assistant Professor, Department of Electrical Engineering and Computer Science University of Tennessee, United Kingdom
6	Dr. Merlyne De Souza	Professor, Department of Electronic and Electrical Engineering University of Sheffield, United Kingdom
7	Dr. Shubham Sahay	Assistant Professor, Department of Electrical Engineering Indian Institute of technology Kanpur India
8	Dr Sakthivel R	Professor, School of SENSE, VIT university, Vellore
9	Dr. Shady Agwa	Research Fellow, Centre for Electronics Frontiers CEF, University of Edinburgh, United Kingdom
10	Dr. Laura Bégon-Lours	Assistant Professor @ETH Zurich, Researcher in Material for AI Hardware Zurich

Participants: 71 members from National and International

Venue: Seminar Hall A, Madanapalle Institute of Technology and Science

Time Schedule in Indian Standard Time:

1. Dr FONG, Xuanyao Kelvin, Assistant Professor, Electrical and Computer Engineering, National University of Singapore, Singapore.
   Date: 23/9/2024, Meeting Time: 11 AM – 12.30 AM IST
2. Dr Kim Tae Hyoung, Associate Professor, School of Electrical and Electronic Engineering, Nanyang Technological University, Singapore.
   Date: 23/9/2024, Meeting Time : 2 PM – 3.30 PM IST

3. Dr Damien QUERLIOZ Research Director, CNRS Adjunct Professor, Université Paris-Saclay Centre de Nanosciences et de Nanotechnologies 10 Boulevard Thomas Gobert, 91120 Palaiseau, France
   Date: 23/9/2024, Meeting Time: 4 PM – 5 PM IST
4. Dr. Shubham Sahay Assistant Professor, Department of Electrical Engineering Indian Institute of technology Kanpur India
   Date: 24/9/2024, Meeting Time: 10 AM – 11.30 AM IST
5. Dr. Merlyne De Souza, Professor, Department of Electronic and Electrical Engineering, University of Sheffield, United Kingdom
   Date : 24/9/2024 , Meeting Time : 2 PM – 3 PM IST
6. Dr. Thomas Kämpfe, Group Manager Integrated RF & AI, Fraunhofer IPMS (Center Nanoelectronic Technologies CNT) An der Bartlake 5, 01109 Dresden,Germany
   Date : 24/9/2024, Meeting Time: 3.30 PM – 4.30 PM
7. Dr . Sakthivel Ramachandran, Professor, School of Electronics, Vellore Institute of Technology
   Date : 25/9/2024, Meeting Time: 10.30 AM– 11.30 AM IST
8. Dr. Catherine Schuman,Assistant Professor, Department of Electrical Engineering and Computer Science University of Tennessee, United Kingdom
   Date : 25/9/2024, Meeting Time : 1.30 PM- 2.30 PM IST
9. Dr. Shady Agwa,Research Fellow, Centre for Electronics Frontiers CEF, University of Edinburgh, United Kingdom
   Date : 25/9/2024 Meeting Time: 3 PM – 4 PM IST
10. Dr. Laura Bégon-Lours, Assistant Professor, ETH Zurich
    Date: 25/9/2024 , Meeting Time: 5.30 PM to 6.30 PM

IEEE CASS Seasonal School Lecture Video Recorded Link :

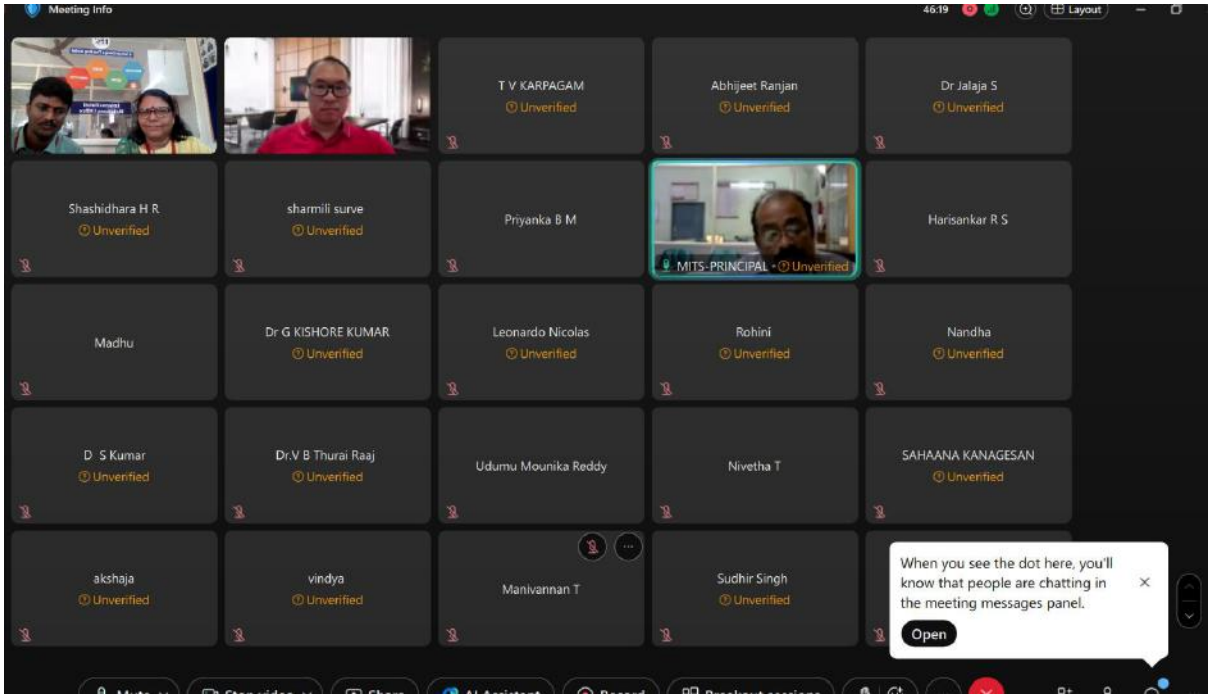
IEEE CAS Seasonal School Video Recordings

Background :

The session was attended by Undergraduate students, Graduate students, Research scholars, Industry Persons and faculty memebers from the IEEE memebrs, non IEEE members, Electronics department, Nanotechnology department and Semiconductor industry peoples, providing deep understanding of the technological advancements shaping the neuromorphic computing and logic in memory computing.

Detailed Summary of the Event

The seasonal school began with warm welcome address delivered by Dr. Nehru Kandasamy, Professor, ECE and Special address by Dr.C.Yuvaraj, Principal , Madanapalle Institute of Technology and Science. Mrs. Vijayalakshmi ,Assistant Professor, International relationship manager introduced the chief guest Dr. Kelvin Fong , NUS to the participants .



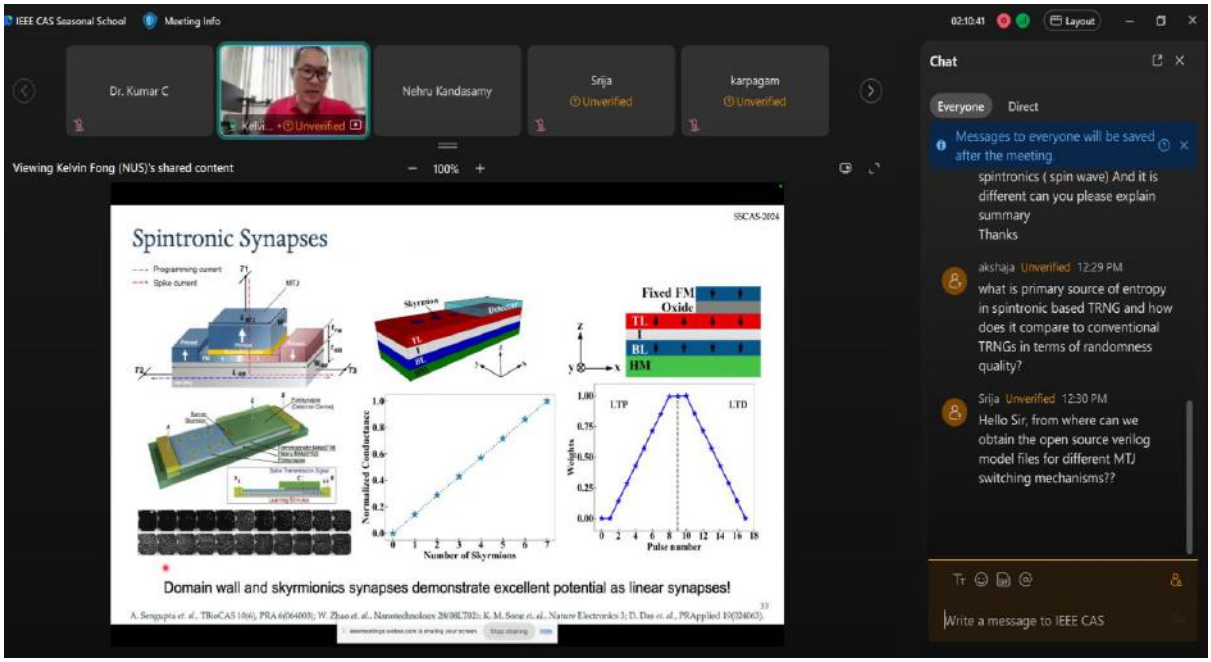
Session 1:

Date & Time : 23/9/2024, 11.00 AM – 12.00 PM IST

Topic: Logic In Spintronic Memories

Dr. FONG, Xuanyao Kelvin, Assistant Professor, Electrical and Computer Engineering, National University of Singapore, Singapore. He was delievered the keynote address with brief background of the spintronic memories.

- Spintronic Synapses
- Spintronic Based True Random Number Generator



<u>Session 2</u>

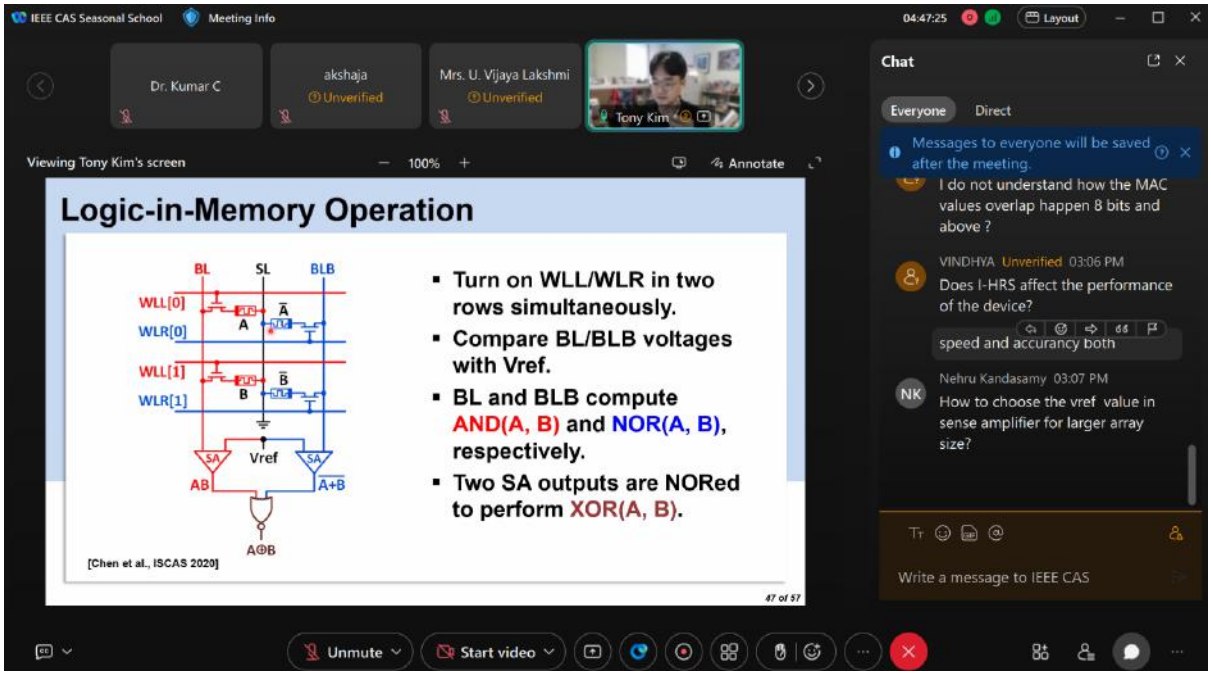
Date & Time : 23/9/2024 , 2.00 PM – 3.30 PM IST

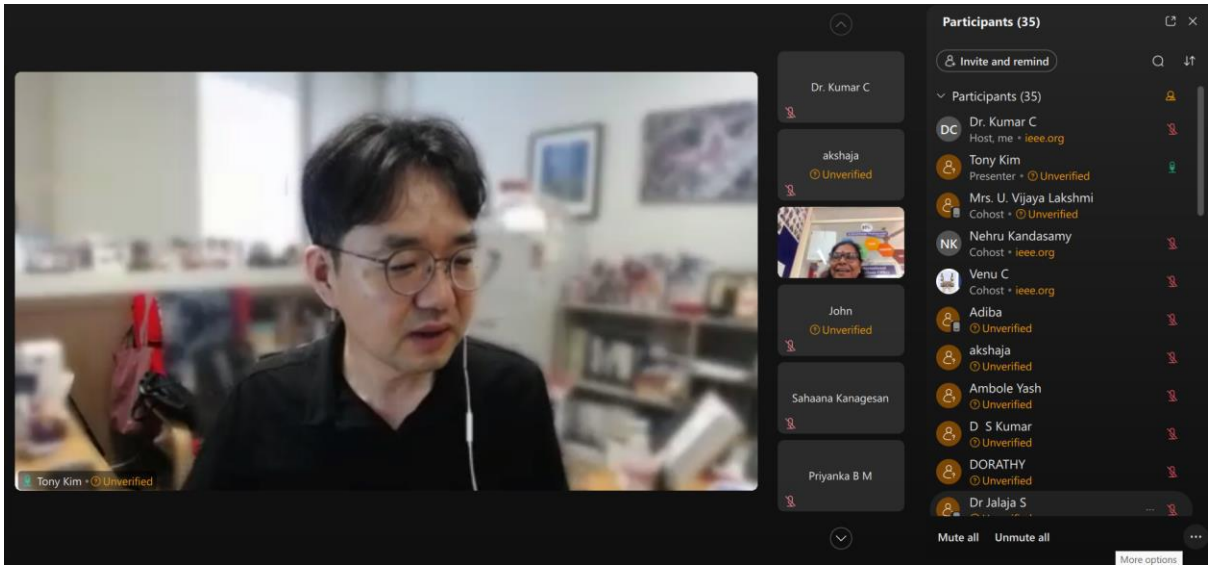
Topic: ReRAM based Compute In Memory

Dr Kim Tae Hyoung, Associate Professor, School of Electrical and Electronic Engineering, Nanyang Technological University, Singapore.

Prof Kim Tae Hyoung addressed the following points

- Machinelearning for edge devices
- ReRAM for Vector Matrix Multiplication
- ReRAM – Emerging NVM Technology





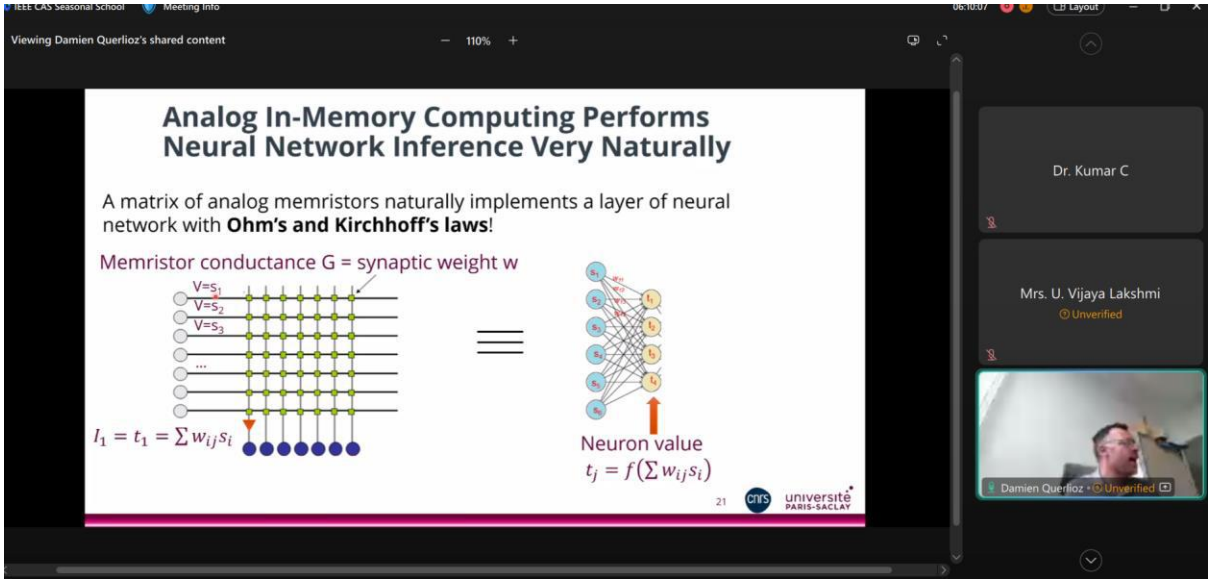
Session 3

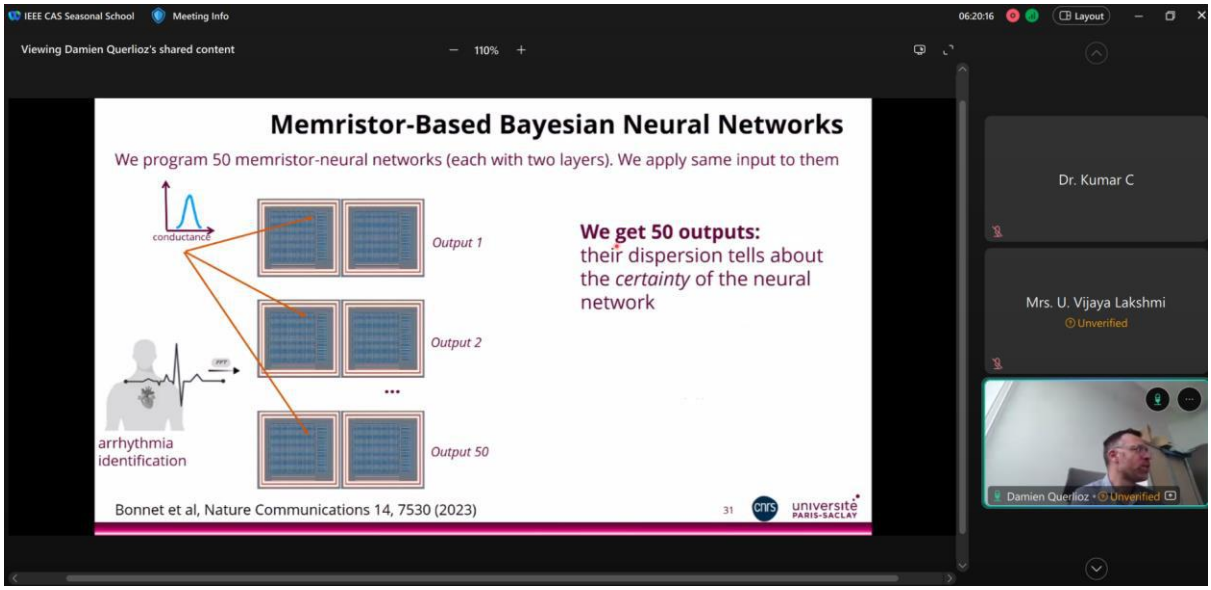
Date & Time : 23/9/2024 4.00 PM – 5.00 PM IST

Topic:Toward Energy Efficient Efficient and Trustworthy Embedded AI: The In Memory Computing Approach

Dr Damien Quarlioz, CNRS, France summerized his talk with the following points.

- **Toward Energy Efficient and Trustworthy Embedded AI**
- **Multiplication within the sense amplifier**
- **Analog In Memory Computing**





Session 4

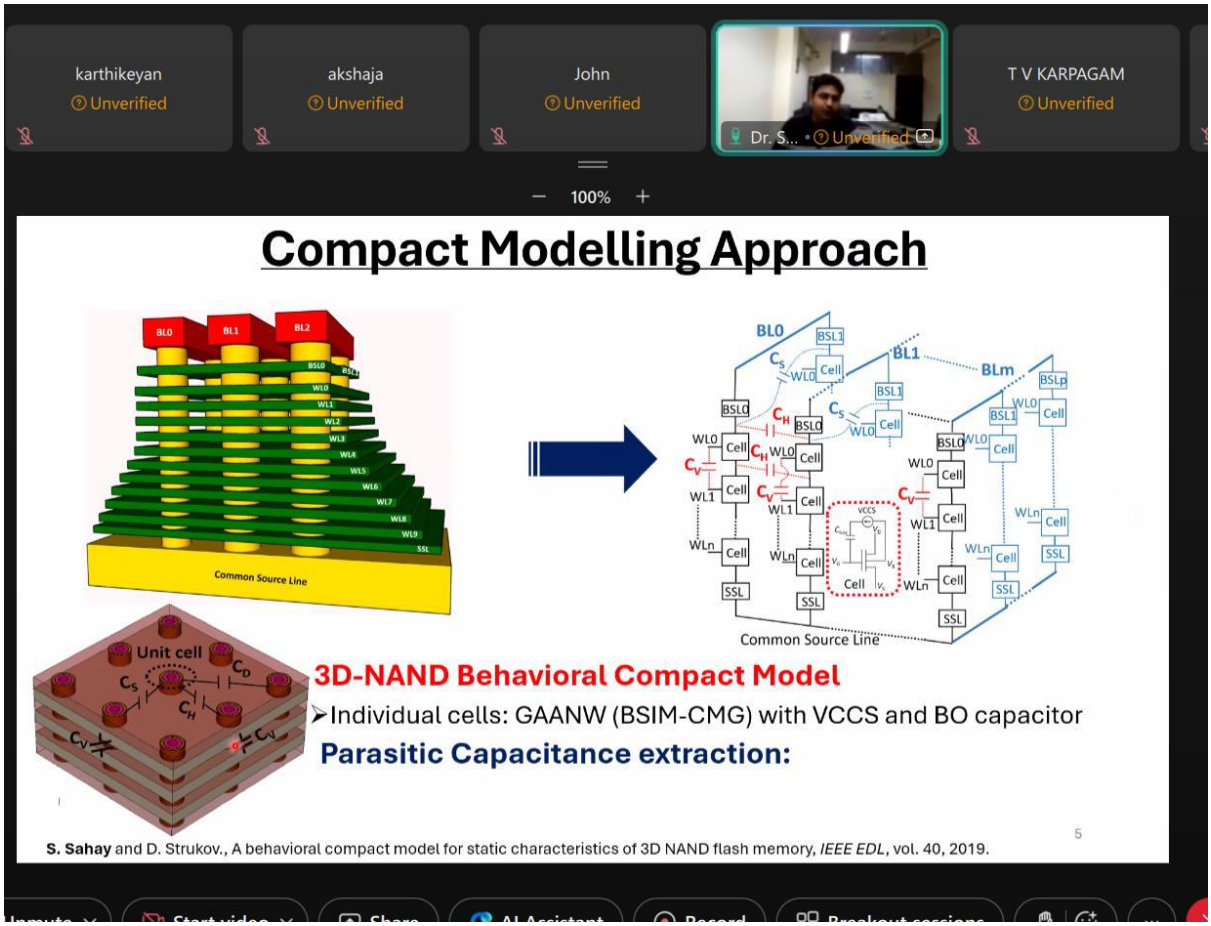
Date & Time : 24/9/2024 10.00 AM – 11.30 AM IST

Topic:Energy Efficient Neuromorphic Circuits and Systems based on 3D NAND Flash Memory

Dr. Shubham Sahay Assistant Professor, Department of Electrical Engineering, Indian Institute of technology Kanpur, India

He was presented the following insightful key points in 3D NAND Flash

- **3D NAND Flash Compact Modelling Approach**
- **3D NAND VMM Accelerator**
- **3D NAND Inference Processor**



Session 5

Date & Time : 24/9/2024 2.00 PM – 3.00 PM IST

Topic:Physical Reservoir Computing using a Solid Electrolyte TFT

Dr. Merlyne De Souza Professor, Department of Electronic and Electrical Engineering, University of Sheffield, United Kingdom

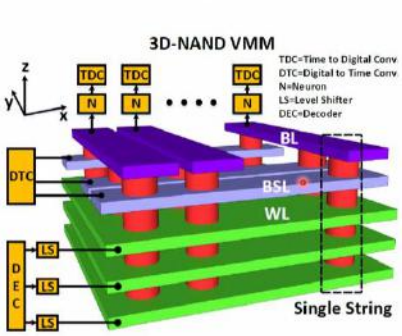
Prof Merlyne De Souza was delivered keynote related to reservior computing using electrolyte TFT

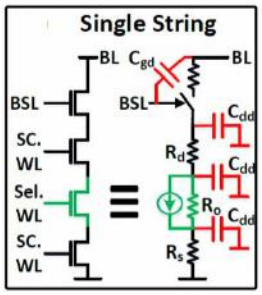
IEEE CAS Seasonal School | Meeting Info

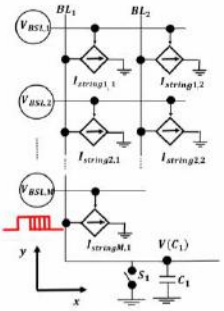
Dr. Kumar C | Priyanka B M | akshaja (Unverified) | John (Unverified) | Dr. S... (Unverified)

Viewing Dr. Shubham Sahay's screen — 100% — Annotate

3D-NAND VMM Accelerator







Allows usage of **COMMERCIAL** 3D-NAND flash for VMM without any modification

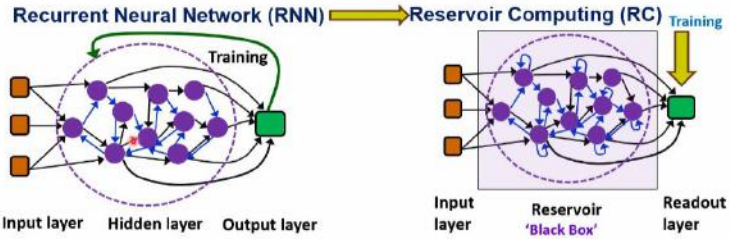
M. Bavandpour, **S. Sahay** et. al. "Mixed-Signal Vector-by-Matrix Multiplication Circuits based on 3D-NAND Memories for Neurocomputing. DATE 2020.

Dr. Kumar C | Meri... (Unverified) | Srija (Unverified) | John (Unverified) | Syed Manzoor Qasim (Unverified) | Mrs. U. Vijaya Lakshmi (Unverified)

...erlyne's applications — 100%

The University Of Sheffield.

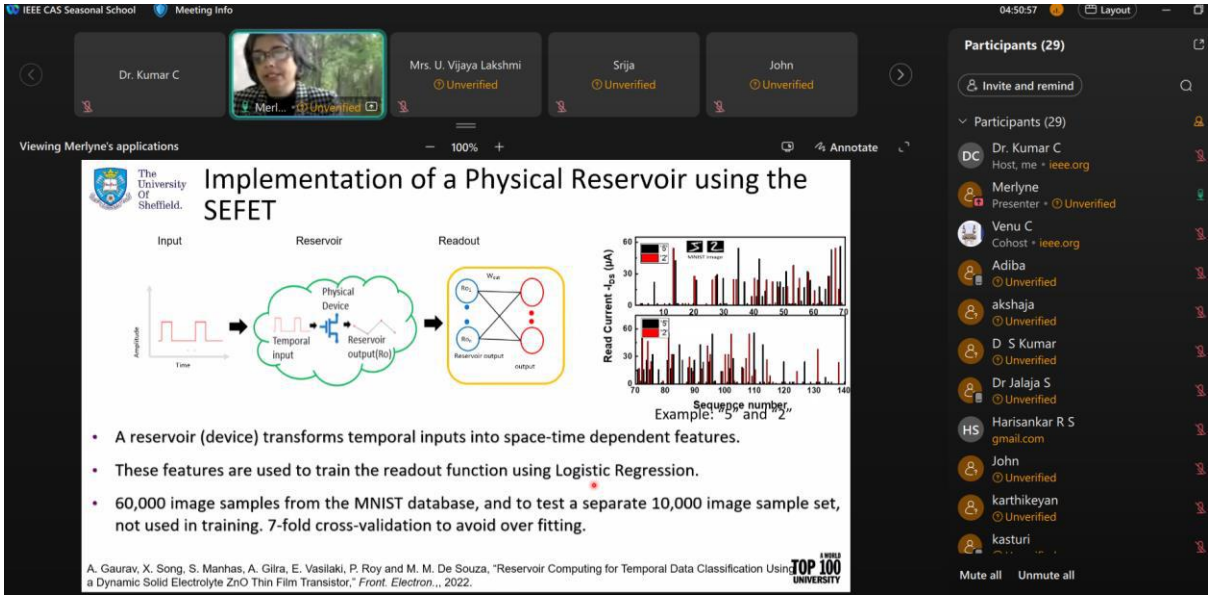
From RNN to Reservoir Computing Networks



- Weight management of each Neuron results in very high complexity and expense of training.
- Network instability and less effective learning.

- Only the readout layer is trained resulting in significant cost reduction.

TOP 100 UNIVERSITY



Session 6

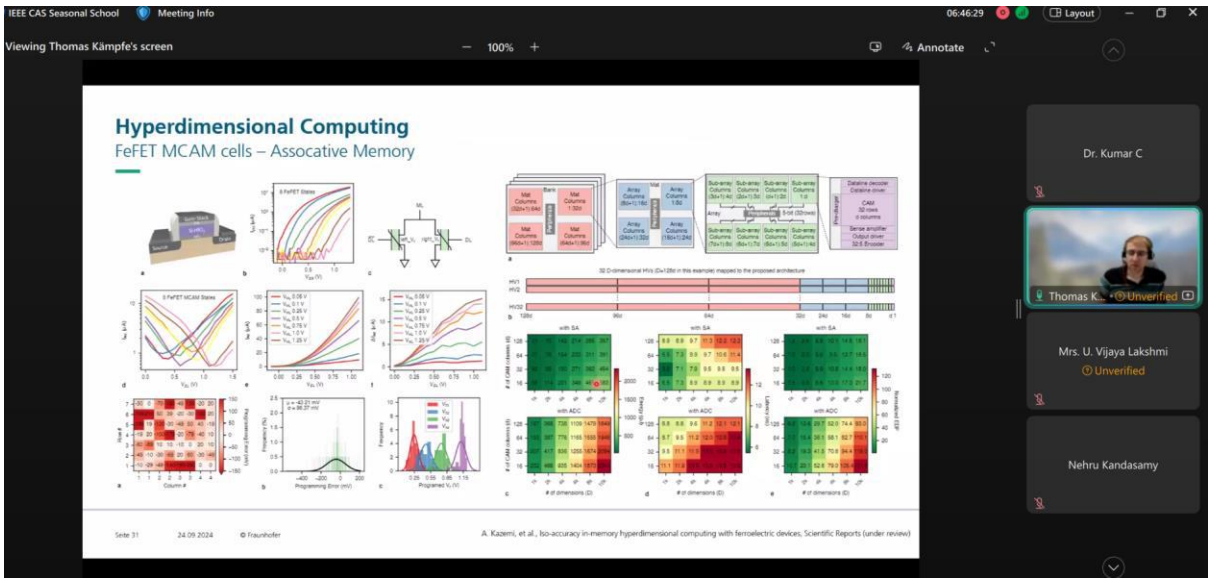
Date & Time : 24/9/2024 , 3.30 PM – 4.30 PM

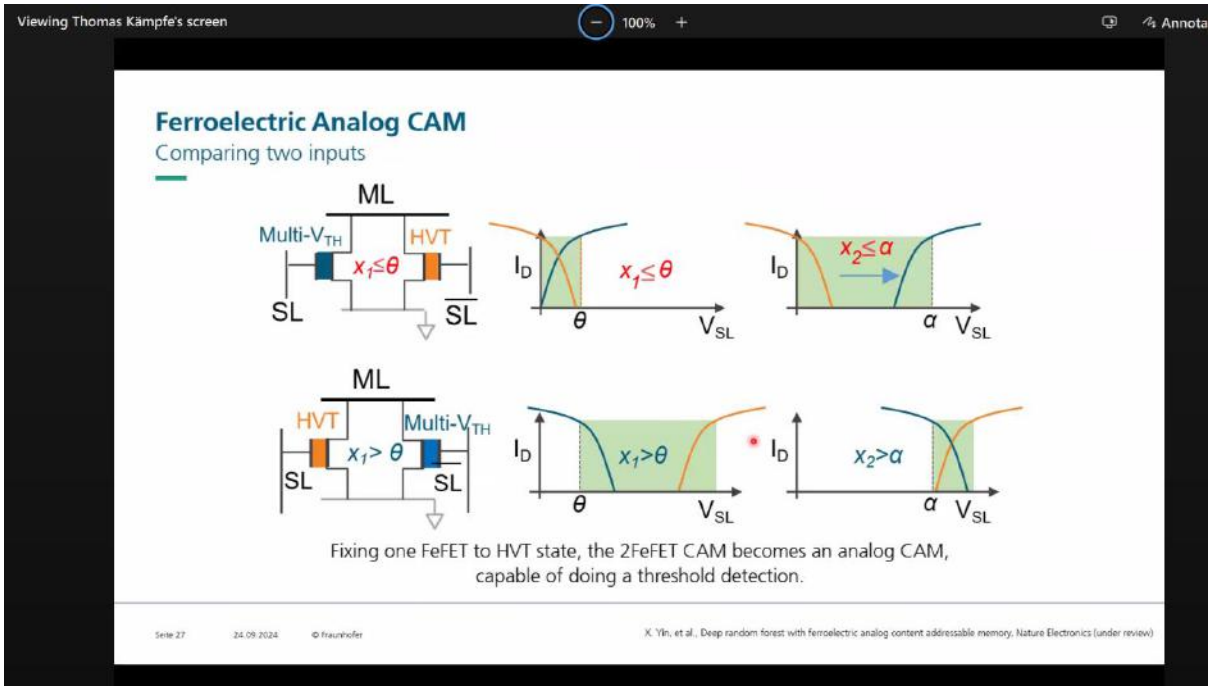
Topic : Ferro Elecronics :From Memory to Neuromorphic Computing

Dr. Thomas Kämpfe Group Manager, Integrated RF & AI, Fraunhofer IPMS (Center Nanoelectronic Technologies CNT) An der Bartlake 5,01109 Dresden, Germany

Dr. Thomas Kampfe mainly address the different FEFET memory cell , Fefet based CAM and Fefet for Neuromorphic computing. He was discussed the following points

- Neuromorphic computing accelerators
- FEFET Technologies
- Compute in Memory Chip
- Ferroelectric Analog CAM





Session 7

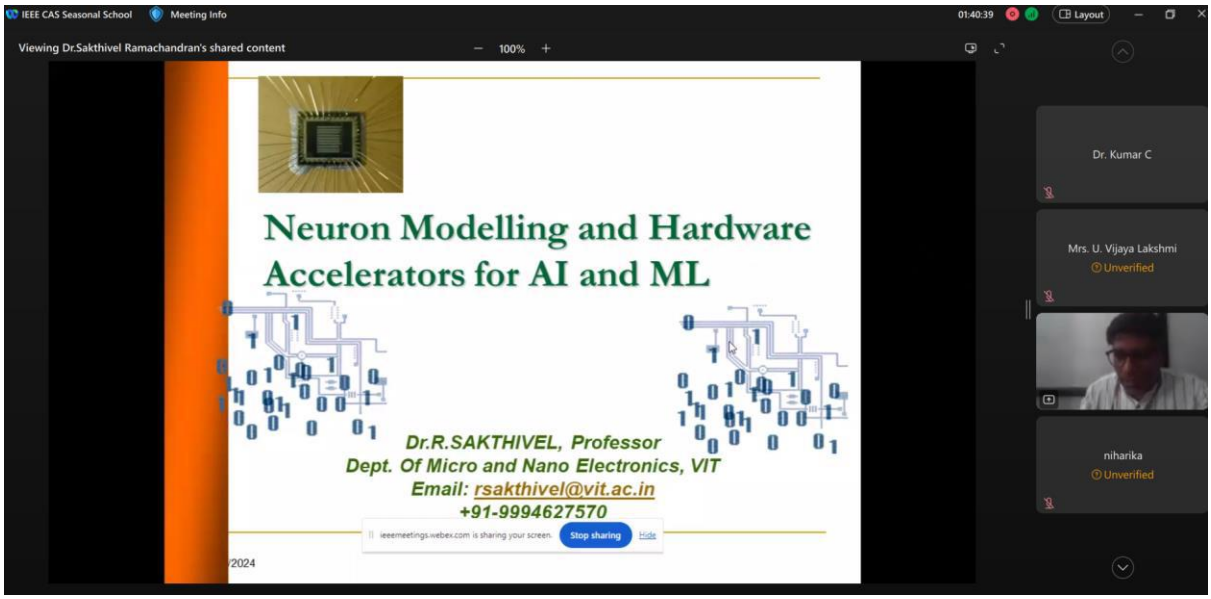
Date & Time :25/9/2024, 10.30 AM– 11.30 AM IST

Topic:Neuron Modelling and Hardware Accelerator for AI and ML

Dr. Sakthivel Ramachandran, Professor, School of Electronics, Vellore Institute of Technology , Vellore

He was addressed about the following points

- Neural versus Digital Computing
- Multilayer Perceptrons
- Hebb's Learning Rule
- Training vs Inference



Session 8

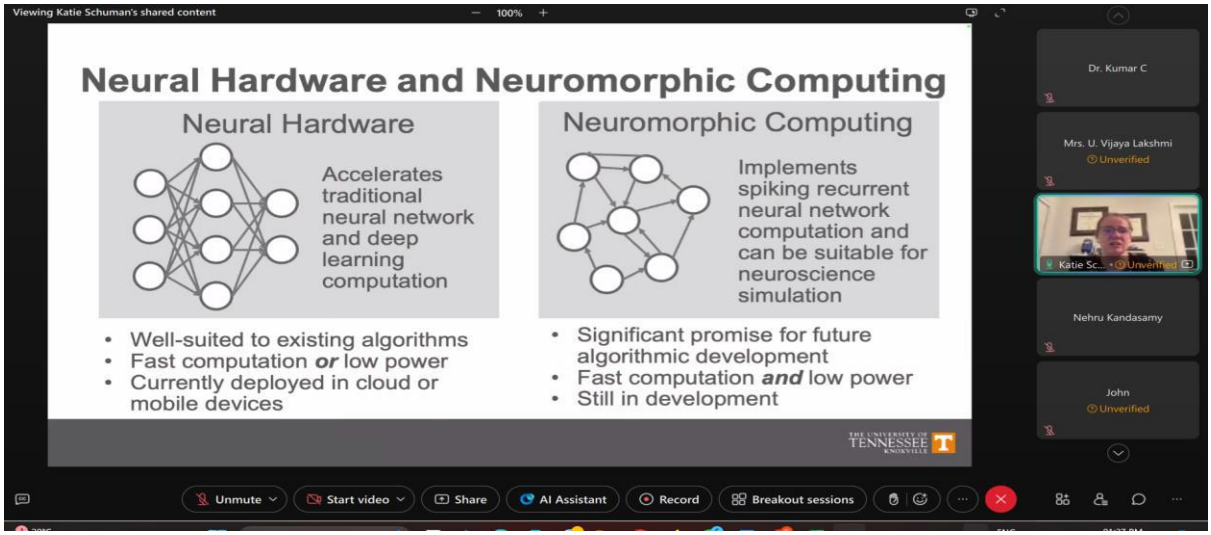
Date & Time : 25-09-2024, 1.30 PM- 2.30 PM IST

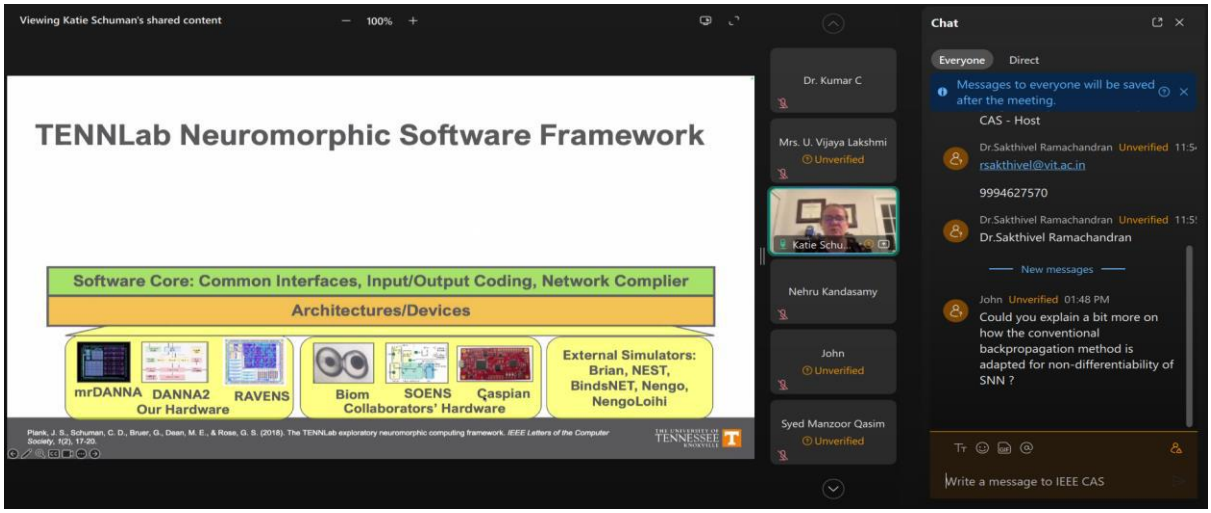
Topic: Spike based Neuromorphic Computing for Next Generation Computer Vision

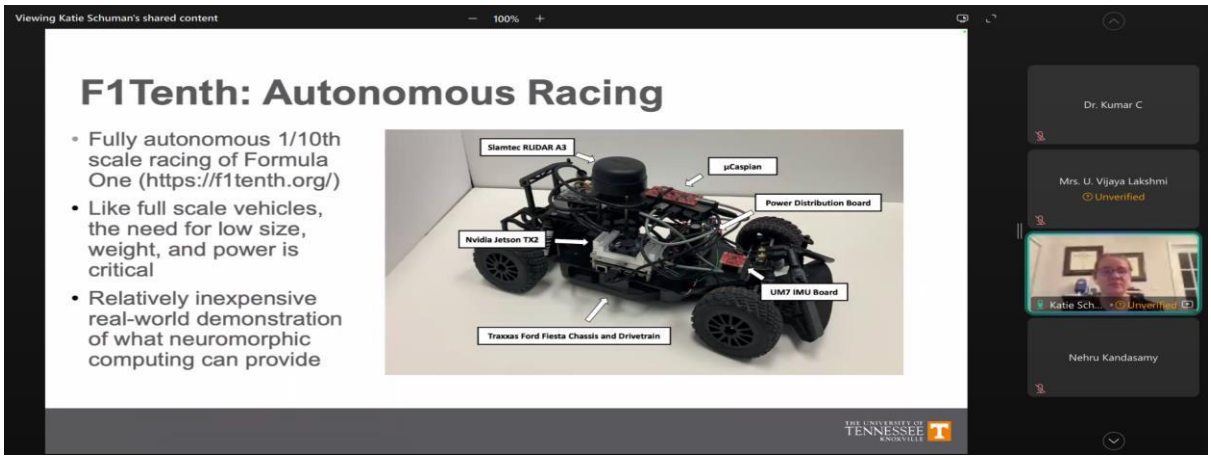
Dr. Catherine Schuman, Assistant Professor, Department of Electrical Engineering and Computer Science , University of Tennessee, United Kingdom

Prof Catherine Schuman has discussed about spiking neural networks, algorithm and Neuromorphic computing .

- Algorithm for Neuromorphic computing systems
- Spiking Neural Networks







Session 9

Date & Time : 25.09.2024, 3 PM – 4 PM IST

Topic: Digital In Memory Stochastic Computing Architectures

Dr. Shady Agwa, Research Fellow, Centre for Electronics Frontiers CEF, University of Edinburgh, United Kingdom

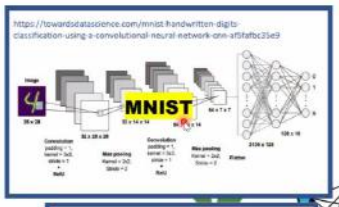
He has enlightened the following points in his presentation.

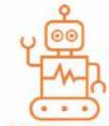
- AI Vision
- Analog In Memory Computing
- Digital in Memory Computing
- In Memory Stochastic Computing

IEEE CAS Seasonal School | Meeting Info | 06:02:26

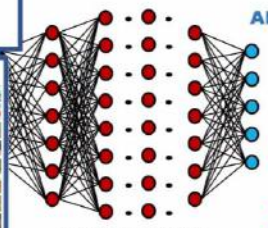
Viewing Shady Agwa's shared content | 100%

The AI Invasion!




AI Robotics

AI Social Media


Neural Networks

AI Business

3

IEEE CAS Seasonal School | Meeting Info | 06:18:16 | Layout

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Brain-Inspired Prescription!

- ✓ Gigantic Dense Memory
- ✓ Massive Parallel Processing
- ✓ Memory & Computation are Tightly Coupled
- ✓ Simple Data Representation (Spikes I_III_II_III_)
- ✓ Specialized & Approximate Computation
- ✓ High Resiliency

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Dr. Kumar C

Nehru Kandasamy

John
Unverified

IEEE CAS Seasonal School | Meeting Info | 06:31:23 | Layout

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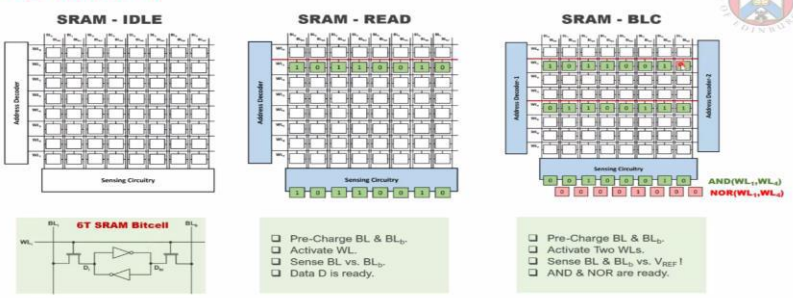
Digital IMC!



- Pre-Charge BL & BLb.
- Activate WL.
- Sense BL vs. BLb.
- Data D is ready.

- Pre-Charge BL & BLb.
- Activate Two WLs.
- Sense BL & BLb vs. VREF !
- AND & NOR are ready.

© S. Jeloka, N. B. Akesh, D. Sylvester, and D. Blaauw. A Configurable TCAM/BCAM/SRAM Using 28nm Push-Rule 6T Bit Cell. Symp. On Very Large-Scale Integration Circuits (VLSIC), Jun 2015.

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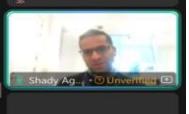
Dr. Kumar C



Nehru Kandasamy

John
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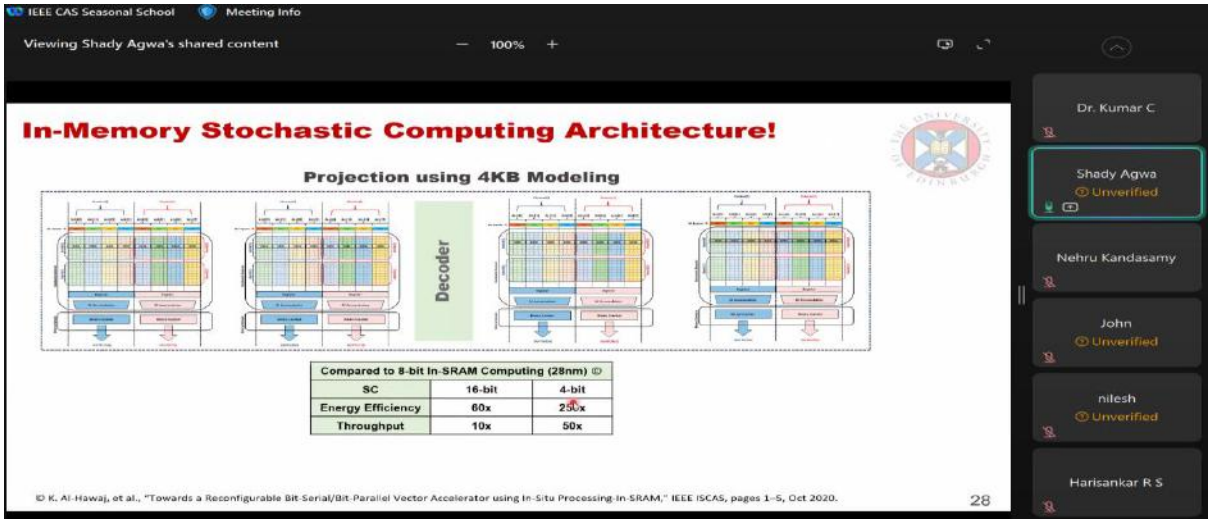


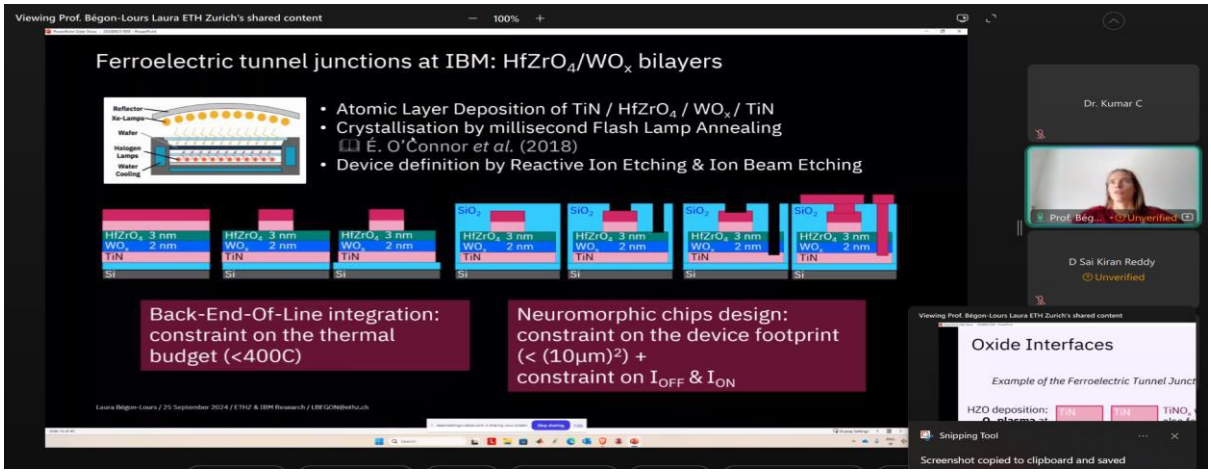
Session 10

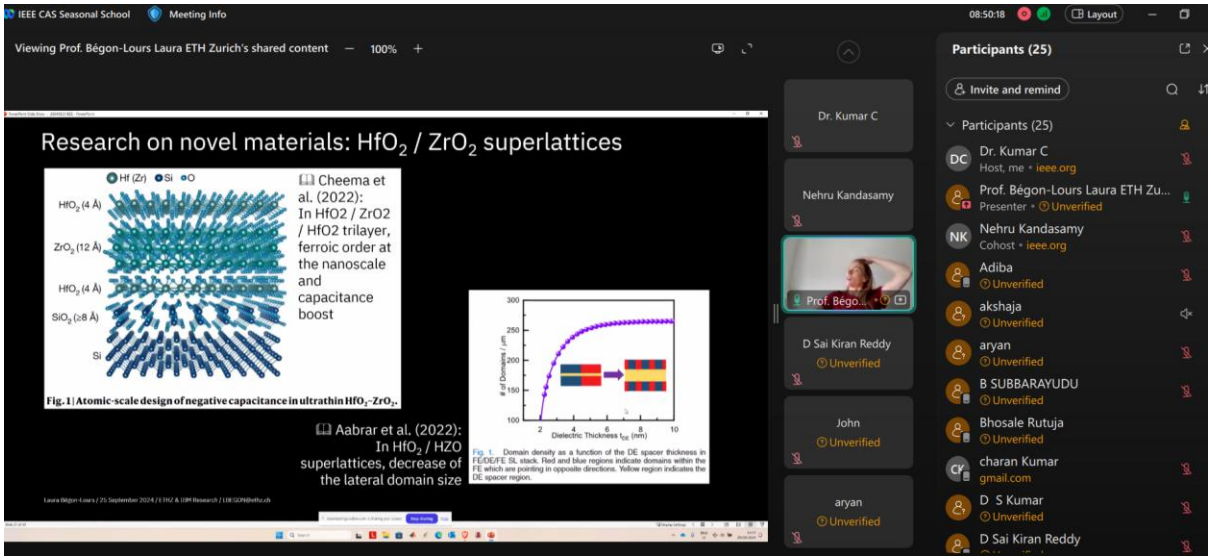
Date & Time : 25.09.2024, 05.30PM to 06.30PM (IST)

Topic: Ferroelectric Hafnia Superlattices for Bio Inspierd Computing

Dr. Laura Bégon-Lours, Assistant Professor, ETH Zurich

She was addressed about CMOS integration of HZO, the novel HfO_2 / ZrO_2 superlattice synaptic weights , the novel HfO2 / ZrO2 superlattice FeCAPs , multi level 1T-1R and 1T-1C expermental works.




IEEE CAS Seasonal School
Meeting Info
08:50:18
Layout
Viewing Prof. Bégon-Lours Laura ETH Zurich's shared content
100%
Research on novel materials: HfO_2 / ZrO_2 superlattices
Hf (Zr) Si O
HfO_2 (4 Å)
ZrO_2 (12 Å)
HfO_2 (4 Å)
SiO_2 (≥8 Å)
Si
Cheema et al. (2022): In HfO2 / ZrO2 / HfO2 trilayer, ferroic order at the nanoscale and capacitance boost
Fig. 1 | Atomic-scale design of negative capacitance in ultrathin HfO_2–ZrO_2.
Aabrar et al. (2022): In HfO_2 / HZO superlattices, decrease of the lateral domain size
Dielectric Thickness t_{DE} (nm)
Fig. 1. Domain density as a function of the DE spacer thickness in FE/DE/FE SL stack. Red and blue regions indicate domains within the FE which are pointing in opposite directions. Yellow region indicates the DE spacer region.
Laura Bégon-Lours / 25 September 2024 / ETHZ & IBM Research / LBEGON@ethz.ch
Participants (25)
Invite and remind
Dr. Kumar C
Host, me • ieee.org
Prof. Bégon-Lours Laura ETH Zu...
Presenter • Unverified
Nehru Kandasamy
Cohost • ieee.org
Adiba
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aryan
Unverified
B SUBBARAYUDU
Unverified
Bhosale Rutuja
Unverified
charan Kumar
gmail.com
D S Kumar
Unverified
D Sai Kiran Reddy
Unverified
John
Unverified

IEEE CAS Seasonal School
Meeting Info
08:29:50
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Viewing Prof. Bégon-Lours Laura ETH Zurich's shared content
100%
Ferroelectric Hafnia Superlattices for Bio-Inspired Computing.
Laura Bégon-Lours*[1,2], Ruben Hamming-Green [4,5], Mattia Halter [1,2], Stefan Slesazeck[3], Elisabetta Morabito[2], Donato Francesco Falcone[2], Beatriz Noheda [4,5], Bert Jan Offrein[2]
1. Integrated Systems Laboratory, ETH Zurich – D-ITET, Zurich, Switzerland
2. IBM Research Zurich, Rüschlikon, Switzerland.
3. Namlab Gmbh, Dresden, Gemany
4. Zernike Institute for Advanced Materials, University of Groningen, Groningen, Netherlands.
5. CogniGron - Groningen Cognitive Systems and Materials Center, University of Groningen, Groningen, Netherlands
*LBEGON@ethz.ch
Acknowledgements:
This work is funded by H2020 FREEMIND (840903), ULPEC (732642), BeFerroSynaptic (871737), UNICO (ANR-19-CHR3-0006), ALMOND (SNF 198612), COGNIGRON
The authors acknowledge the Binnig and Rohrer Nanotechnology Center (BRNC)
ETH zürich
IBM
Dr. Kumar C
Prof. Bég...
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Nehru Kandasamy
D Sai Kiran Reddy
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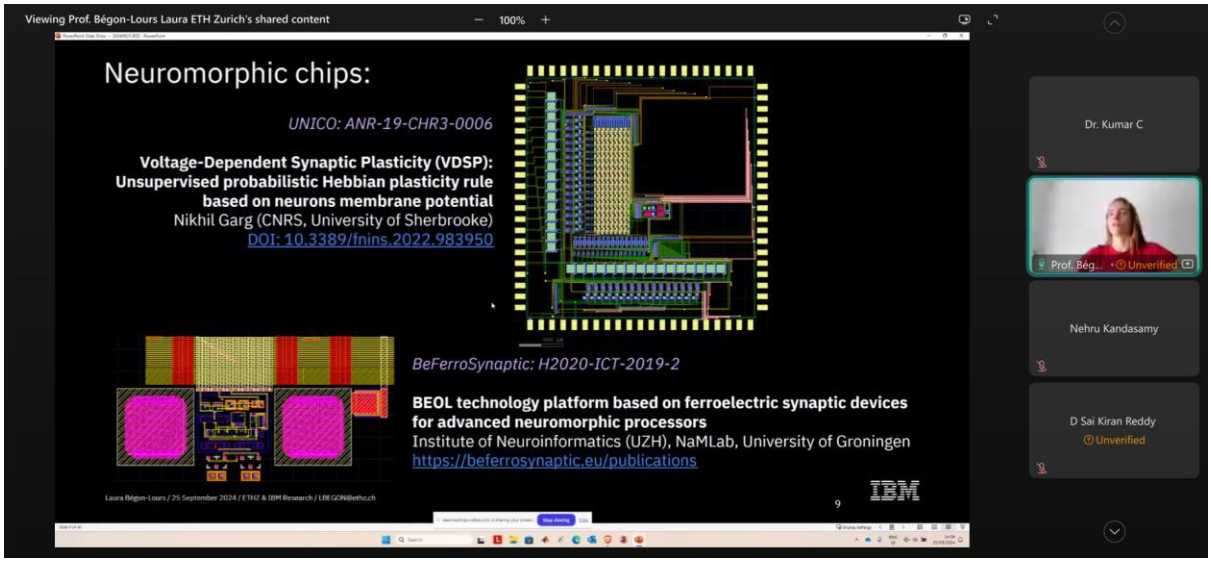
Viewing Prof. Bégon-Lours Laura ETH Zurich's shared content
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Neuromorphic chips:
UNICO: ANR-19-CHR3-0006
Voltage-Dependent Synaptic Plasticity (VDSP): Unsupervised probabilistic Hebbian plasticity rule based on neurons membrane potential
Nikhil Garg (CNRS, University of Sherbrooke)
DOI: 10.3389/fnins.2022.983950
BeFerroSynaptic: H2020-ICT-2019-2
BEOL technology platform based on ferroelectric synaptic devices for advanced neuromorphic processors
Institute of Neuroinformatics (UZH), NaMLab, University of Groningen
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IEEE CASS SEASONAL SCHOOL ON

Neuromorphic Computing and Logic In Memory Computing using Non Volatile Memory Devices

23rd - 25th September 2024

Certificate of Participation

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This is to Certify that T. Nandha Kumar of University of Nottingham Malaysia has Participated IEEE Circuits and Systems Society Seasonal School on "Neuromorphic Computing and Logic In Memory Computing using Non Volatile Memory Devices" Sponsored by IEEE CASS, Organized by the MITS IEEE Circuits and Systems Society Student Branch Chapter, Department of Electrical and Electronics Engineering in Association with IEEE Hyderabad Section during 23rd - 25th September 2024

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The IEEE CASS seasonal school was concluded with vote of thanks to participants , circuits and systems society chair and resource persons by Dr. C. Kumar , Assistant Professor, Madapalle Institute of Technology and Science.

Course Outcomes :

At the end of the IEEE CASS Seasonal School all the Participants are able to understand the

- Basics of Neuromorphic Computing & Logic In Memory Computing
- Algorithm , device physics and Hardware/software integration of novel non volatile memory devices
- Real time applications uing Non Volatile memory devices

Report Submitted by:

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