JUMP

Joint University Microelectronics Program

Proposers' Day Workshop

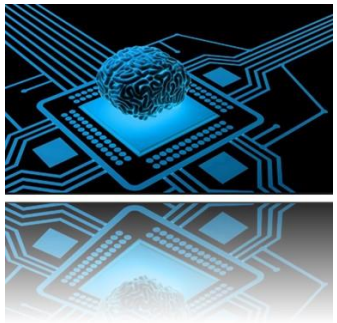
Monday, January 23, 2017

@srcJUMP, #JUMPpdw

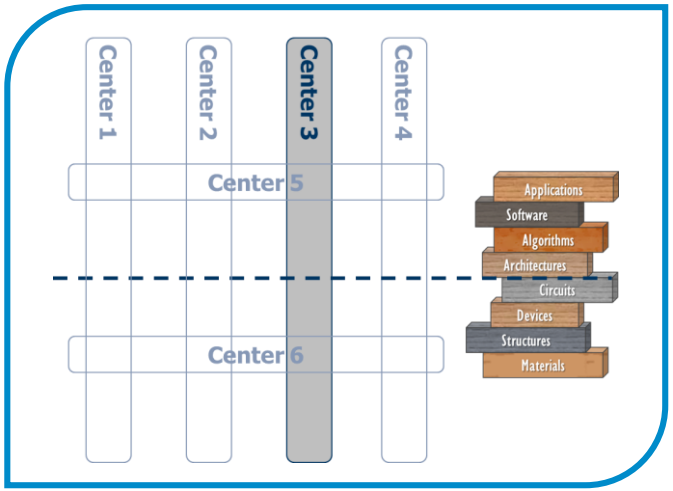
JUMP

Joint University Microelectronics Program

Cognitive Computing



Vertical Research Center



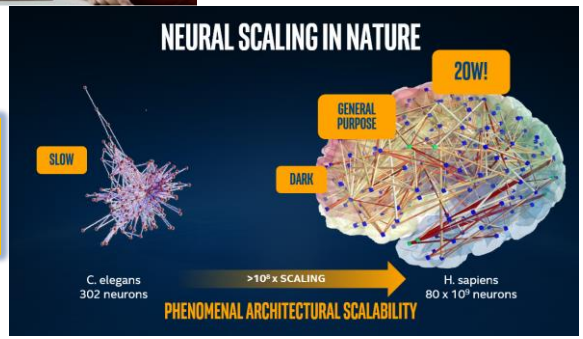
Mandy Pant

Academic Research Director

Intel Corporation

Center Motivation

- Today's deep learning is still limited
- Deep understanding of distributed architectures with brain like capabilities to optimize available resources
- Current technologies do not scale to "brain-like" levels in terms of energy and performance



Create systems for boosting economic competitiveness and contributing to social good

Research Considerations

- Seeking **novel solutions** for cognitive systems that can
  - Learn at scale
  - Perform reasoning and decision making with purpose
  - Interact with humans naturally
- Explore alternatives to von Neumann model like
  - Stochastic computing
  - Approximate computing
  - Bio/brain-inspired models such as neuromorphic computing

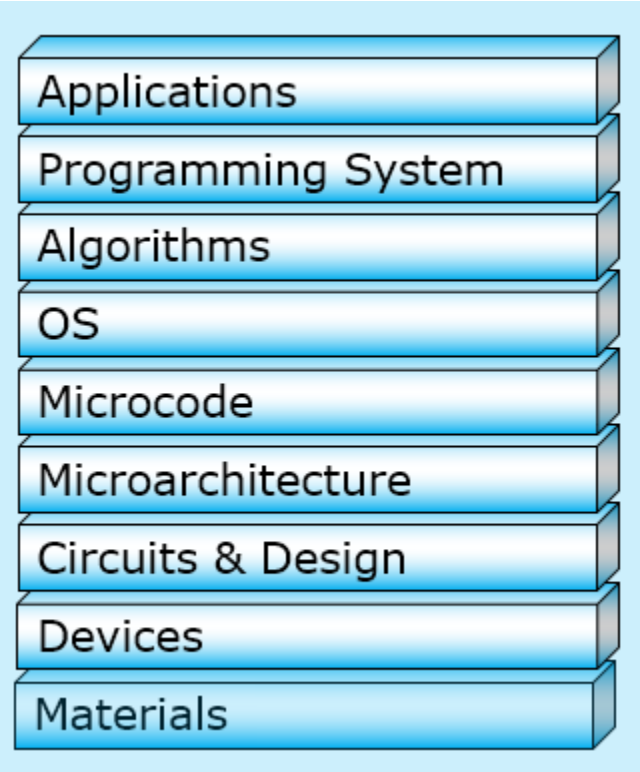
➢ **A full-system approach required to achieve goals**

- Include technology advances for fundamental leaps in performance, capabilities, and energy efficiency through improvements in programming paradigms, algorithms, architectures, circuits, and device technologies

Grand Challenge: Proposers expected to define a grand challenge in the Cognitive Computing space that the Center will address

Theme Requires

- Creating systems that, without explicit objectives, operate in natural world on their own
  - Exploration of multiple approaches for building machine intelligent systems with both cognitive and autonomous characteristics using von-Neumann, non-von-Neumann or combination of both
- **Fundamental improvements must be demonstrated** in performance, capabilities
  - Energy efficiency through breakthroughs (from devices to programming models)
- Benchmarking to prove potential of novel system
  - More than 100x better than traditional computing for same task
  - Demonstration of complete scalable compute system (with validation)
- **Research must span a gamut** of materials and devices, circuits and architecture, algorithms and programming theory
  - Cross-disciplinary effort



Possible Research Tasks

Advancements in Cognitive Capabilities (1)

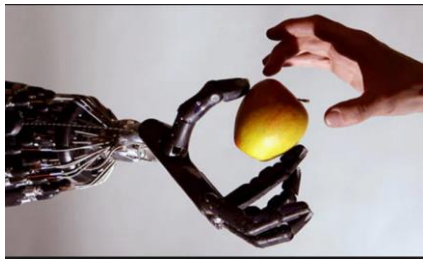
Research tasks of interest <u>includes but are not limited to:</u>

- **Knowledge generation, reasoning, prediction, planning, decision making:**
  - Create insights, actionable intelligence, knowledge, wisdom and machine assisted decision from raw sensor data
  - Anomaly detection for prediction, decision making, planning
  - **Architectures to accelerate tactical decision-making**
    - Computation on encrypted data to support safety of scalable decision making systems
- **Learning and perceiving:**
  - Pursue breakthrough advances in sensing technologies for cognitive systems
  - Develop universal algorithms using e.g. context-aware learning applicable **to a wide range of cognitive workloads**
    - Develop perception algorithms (which enable understanding of the environment), authentication enablers, and learning enablers
  - Develop hardware (architectures/circuits/ technologies) and software to realize said universal learning system

Possible Research Tasks

Advancements in Cognitive Capabilities (2)

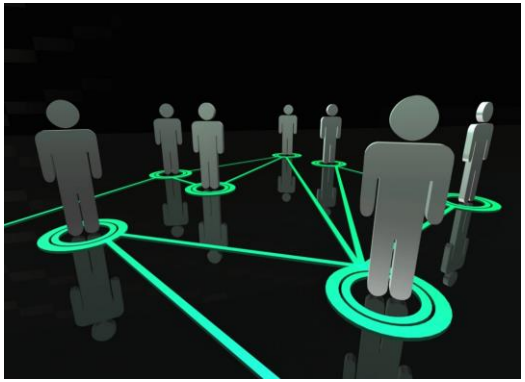
- **Learning and perceiving (cont.):**
  - Explore **fundamental limits and capabilities** of existing machine learning algorithms, for instance, deep neural network, for cognitive workloads
  - Develop new architectures and algorithms that allow hitting required test accuracy with **significantly reduced training set**
    - Handle big data and distributed analytics
    - Develop algorithmic and hardware speedup for sparse coding
    - Develop highly efficient inference systems
    - Develop energy-efficient, low-cost techniques for cognitive workloads



- **Human-Machine Interface:**
  - Develop **seamless Human-Machine Interface** for autonomous systems
  - Develop seamless Human-Machine Interface/collaboration for **sensing and feedback** (haptic, audio, vision, etc.) with high accuracy in HW and SW levels

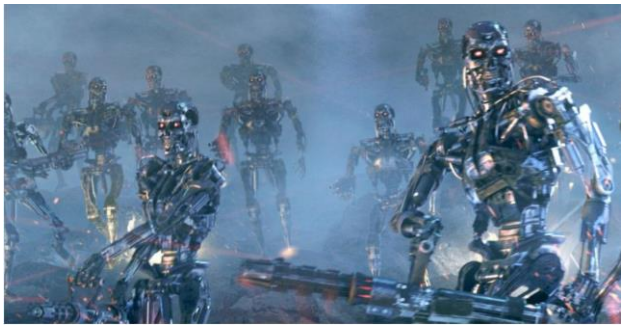
Possible Research Tasks

Advancements in Cognitive Capabilities (3)



- **Network of cognitive sub-systems:**
  - Develop architectures for **resilient self-optimizing and self-healing networks, memories and compute elements** for connecting billions of devices in intelligent systems
  - Develop **society-scale** applications and intelligent data collections systems, which can interact with local cognitive and autonomous machine intelligence systems to optimize decision support

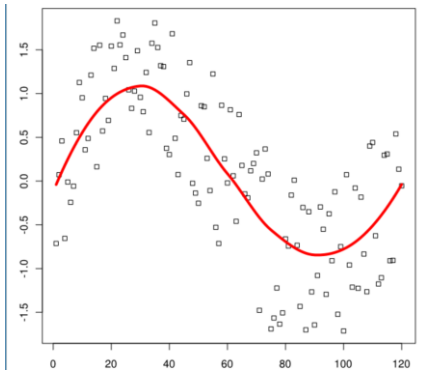
- **Other Important Aspects:**
  - Develop **programming paradigms and languages** that enable the cognitive capabilities
  - Investigate nature of **malicious and/or destructive AI systems**



Possible Research Tasks

Non-traditional Computing - 1

- **Non-traditional computing** embracing variations/randomness can provide significant benefits in energy, delay, error rate or enable scalable architectures on erroneous hardware layers
  - **Statistical computing**
  - **Approximate computing**
  - **Stochastic computing**
  - **Shannon inspired computing**
- Applications:
  - Cognitive/non-cognitive, logic based examples
    - Computation in projected spaces (increased and reduced dimensionality)
    - Application of Restricted isometry and dimensionality reduction for computing and sensing
    - Computing for classification and clustering



<u>Research tasks include but not limited to</u>

- Theoretical thrusts to address
  - Computational complexity (time and memory) of stochastic and random computing
  - Complexity of associate processors
  - Scalability
- Computing at variable accuracy covering both HW and SW
- Computing with device and hardware dynamic variations
- Statistical error correction
- Algorithmic noise tolerance
- Compressive sensing paradigms

Possible Research Tasks

Non-Traditional Computing - 2

- **Non-traditional computing** founded on neuromorphic/neural networks theory can significantly advance energy efficiency, accuracy, scalability, and latency in cognitive computing
  - Neural networks
  - Neuromorphic/Brain-inspired (check definition; difference)
- Applications
  - Cognitive, non-cognitive, logic based examples

Research tasks include but not limited to:

- Develop the **computational theory** for various neural nets/neuromorphic/brain-inspired computing methods (*enables applications to be implemented on h/w*)
  - Computational Complexity (time and memory)
  - Self-Learning
  - Scalability
- Develop energy-efficient low-cost techniques
- Develop new architectures and algorithms that would enable improved accuracy using significantly reduced training
- Develop **reconfigurable networks** suitable for a class of NN applications (ANN, RNN, CNN, etc.)
- Develop **materials and devices** designed and optimized for neural network applications, such as artificial neurons and synaptic memory devices
- Mimic actions of a neuron through new memory elements and circuits,
- New topologies like spiking neural-nets and inference augmented neural-nets
- Develop compressive paradigms for classifiers and computing for classification and clustering

Possible Research Tasks

Integration of non-traditional methods

- **Demonstrate practical mechanisms for integration and verification of any new non-traditional methods with Von Neumann (traditional) systems to support realistic, complex workflows**

Research tasks include but not limited to:

- The theoretical basis and support for non-traditional methods
- Breadth of applicability of proposed non-traditional methods
- Integration into relevant workloads and systems.
- Resiliency and reliability of proposed non-traditional methods

Degrees of Emphasis

While Centers are not limited to students from these disciplines, **graduate students working towards degrees** in following areas of study are of particular interest

MS / PhD

- **Applied Math, Mathematics**
- **Applied Physics, Physics**
- **Bioengineering**
- **Computational Neuroscience, Neuroscience**
- **Comp Sci. & Comp. Eng.**
- **Electrical / Electronics Engineering or Electrical and Computer Engineering**
- **Material Science or Engineering**
- **Systems Engineering**

JUMP

Joint University Microelectronics Program

@srcJUMP, #JUMPpdw