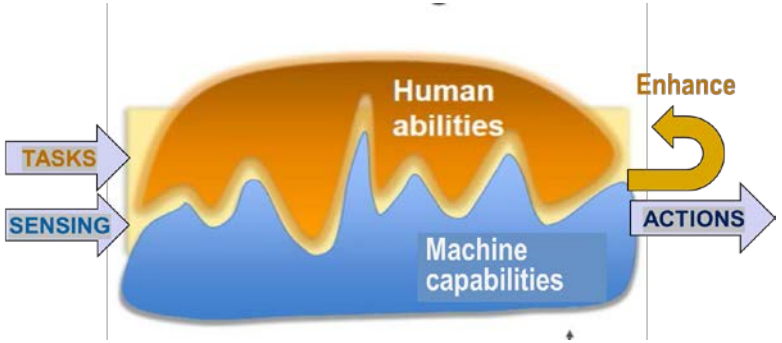


Modified after Report Workshop ICA-1, 2016

Introduction to

Intelligent Cognitive Assistants (ICA)

Mihail C. Roco, NSF

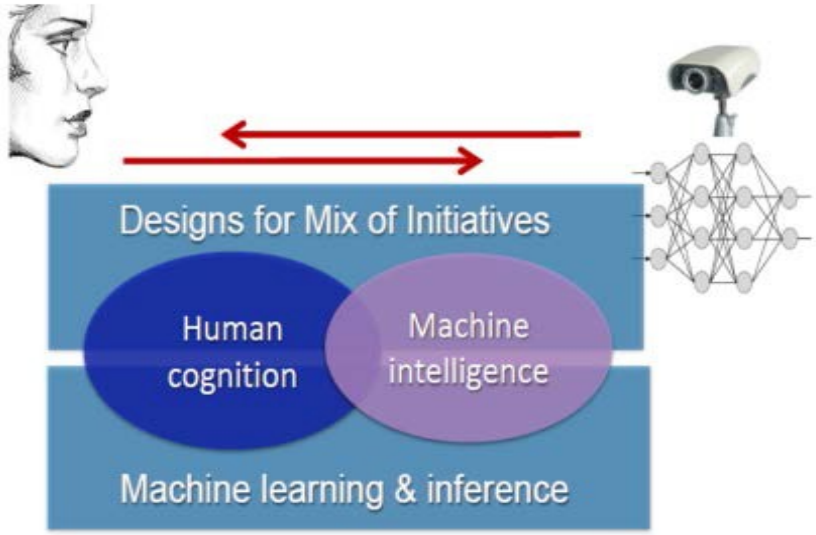
Systems harnessing new machine intelligence and problem-solving capabilities to work collaboratively and enhance human cognitive and physical abilities - by assisting in working, learning, interacting with new cyber-physical systems, transport, healthcare, and other daily activities.

Research needs: *explore scenarios for developing the novel system architectures, concepts and algorithms required for "assistants" to interpret and learn from data, solve unfamiliar problems, have sensorial, decision and action capabilities, and provide informed advice to their human users. Modular systems, functions and architectures are envisioned for a diversity of tasks.*

NSF-wide challenge: Role of engineering

Engineering research needs include:

- neuromorphic engineering
- energy efficiency
- sensors
- system architecture and modular system design
- human–ICA interfaces
- modeling and simulation
- engineering the system to respond to new software and algorithms
- others



Report Workshop ICA-1, 2016

Examples of applications:

- individual and team work in production,
- personalized learning and workforce development using new technology,
- assisting elderly and people with disabilities

Several origins

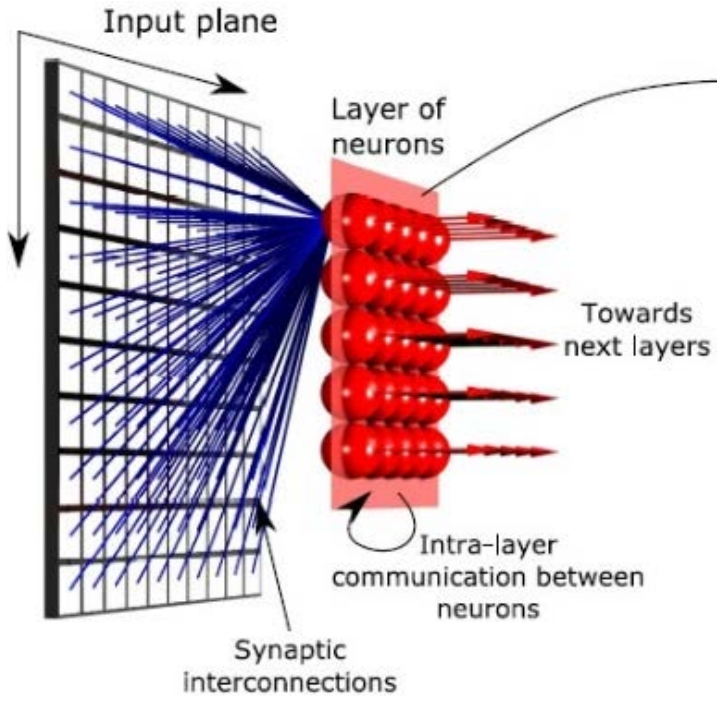
Human–technology frontier: Converging Technologies for Improving Human Performance: one of the visionary projects for 20-30 years ahead – "personal assistant, broker" (NSF-DOC Report, 2002, Springer 2003)

Brain-like computing: "Create a new type of computer that can proactively interpret and learn from data, solve unfamiliar problems using what it has learned, and operate with the energy efficiency of the human brain." (OSTP / NNI Grand Challenge, http://www.nano.gov/futurecomputing, 2015; NSF proposed ICA)

Artificial intelligence and harnessing data: Computing Community Consortium: "Accelerating Science: a grand challenge for AI" (NITRD / CCC Report, 2016) (SIRI, Alexa)

Accelerate outcomes through convergence: "Science and technology convergence", Case study: Intelligent Cognitive Assistants" (JNR, Springer-Nature, 18:211, 2016)

Exploring the opportunities: 2016–2018



Report Workshop ICA-2 preparation, 2017

- *2016 – Workshops on ICA requirements (Workshop ICA-1) and hardware (Workshop NICE)*
  ICA-1 Workshop report is available on NSF and SRC websites
- *2017 – Workshop for identifying research needs and opportunities, envisioning the future, and coordinating NSF–industry partnership*
  ICA-2 Workshop, November 14-15, 2017, at IBM-Almaden
  - Academia
  - Industry – diverse experts across hardware, computational, social, and cognitive sciences: *Amazon, Apple, Applied Minds, Facebook, Google, HP, IBM, Intel, Microsoft, nVidia, NXP, Oracle, Qualcomm, Rethink Robotics, Toyota Research Institute, Viv Labs*
  - Government: *NSF, DARPA, NIH*
- *2018 – Pursue collaborations*

ICA at the confluence of key priority areas

Part of National Initiative: NNI's Grand Challenge on Future Computing

Part of National Initiative: NITRD's Artificial intelligence & Human–cyber interactions

Part of WH/OSTP: BRAIN Initiative (brain- machine interfaces, inspired solutions)

Part of WH/OSTP: National Robotics Initiative

NSF Big Idea: Work at the Human–Technology Frontier

NSF Big Idea: Harnessing Data

NSF Big Idea: Growing Convergent Research

NAE Grand Challenge: Reverse-engineer the Brain

ICA at the forefront of several fields of research

Human-centered intelligent **engineered systems** with cognitive capabilities

Artificial intelligence and deep learning

Semiconductors/IT&C Beyond Moore's Law; Non-von Neumann computing architectures

- Complex **cyber-physical-social modular systems**
- **Smart engineering**: materials, devices and systems
- Large **nanosensor systems**

Smart and autonomous machines

Wireless technologies

Cognitive psychology, **Cognitive prosthetics**

- **Human–technology co-evolution**
- Large data for **decision-making and problem-solving** methods
- Autonomous chemistry and **biosystems**, others

Intelligent Cognitive Assistants

- NSF interest group -

ENG Mike Roco (chair; general-purpose platform)

Shubhra Gangopadhyay (ECCS, devices, brain-machine)

Tony Kuh (ECCS, engineering machine learning)

Jenshan Lin (ECCS, sensors, complex systems)

Jordan Berg (CMMI, smart architectures)

Robert Scheidt (CMMI, intelligent systems)

Julie Martin (EEC, personal learning)

CISE Erwin Gianchandani (OAD, information systems)

Howard Wactlar (IIS, cognitive prosthetics)

Reid Simmons (IIS, smart and autonomous systems)

Tatiana Korelsky (IIS, natural languages)

BIO James Deshler (BRAIN Initiative and bio-interfaces)

EHR Anthony Kelly (new learning approaches, workforce development)

MPS Mohan Srinivasarao (MPS - intelligent devices; CHE - autonomous chemistry)

SBE Betty Tuller (action and cognition)

Intelligent Cognitive Assistants

Input from AdCom after the presentation

- suggestions on the vision
- are other partners needed?
- general comments on engineering priorities in this area

RESERVES

What is ICA (Intelligent Cognitive Assistant)?

With input from the May 2016 SRC-NSF ICA1 Workshop

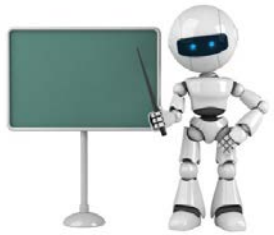
As cyber-physical systems evolve to incorporate more cognitive intelligence capabilities, the interface between them and their human users will also have to evolve to enable them to enhance their benefits to society.

- **Enhance human capabilities and work collaboratively**
  - Complement human qualities – not supplant or disrupt human skilled labor
- **Adapt with flexibility to dynamic, real-world environments**
  - Uncertain environments, social context, or user needs
  - Incrementally learn from experience
- **Cultivate trust among humans and machines**
  - Intuitive interfaces and "common sense" reasoning is required
- **Facilitate "natural" interactions**
  - Understand natural language, gestures, sketching, emotions, moods, etcs
- **Intelligent Agents that interact with you**
  - Social and behavioral sciences required
  - ICAs must facilitate, complement, and augment human abilities

From CMU: one example is SARA, "Socially-Aware Robot Assistant"

Suggested ICA Applications

- **Personal Adaptive Tutor**
  - Adapts to each individual students/employees
  - Awareness to things such as mood, surroundings, situation, etc
  - Leverage traits such as response time to assess knowledge absorption



- **Cognitive Assistants in Smarter Communities**
  - Address social and ethical aspects of cities and communities
  - Team Assistant to support collaborative work environments

- **Context-aware Assistant (E.g. Nail gun training)**
  - Seeing it would make basic information available in AR/HUD - where is the handle, safety, etc.
  - Pointing at others would display warnings
  - Automatic counting of nails, time, etc.

- **Elder Care**
  - Personal/Healthcare assistant to support specific needs
  - Knowledge of medicine habits and connections to doctors

- **Behavioral Models for Autonomous Vehicles**
  - Model the behavior of drivers and pedestrians in the context of “Intention and Negotiation”

- **Other Applications for consideration**
  - Global Instability
  - Environmental sustainability
  - Climate Change
  - Augment factory workforce to reduce repetitive tasks

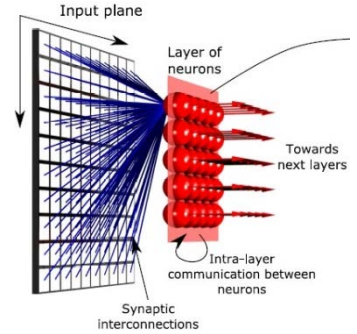
Working Group Proposed ICA Topics of Research (also session topics for workshop)

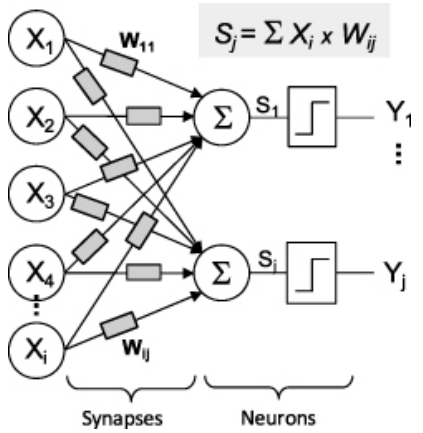
- **Cognitive Psychology**
  - Perception vs Cognition
  - Case Studies of Existing Digital Assistants

- **Natural Interfacing**
  - Natural Language Processing
  - Gestures, Perception, Vision, Sound, etc.
  - Mixed-initiative Interaction

- **Approaches to Artificial Intelligence**
  - Beyond Five Tribes of Machine Learning
  - Cognitive AI
    - Complementary Learning and Real-World Systems
    - Better Understanding of Common Sense Reasoning (Essence of Things)
  - Data Selection for Reinforcement Learning

- **System Architectures**
  - Beyond von Neumann Computing Architecture
    - Energy Efficiency, High Performance
  - Algorithms and Architectures
    - Local Preprocessing for Speed, Security, Context, and Personal History
  - Adaptable, Scalable, and Flexible
    - Modular System Designs
    - Neuromorphic Engineering Approaches





- **Data and Modeling**
  - Data Capture and Privacy
  - Accurate, non-biased
    - Or Sources of Biases are Modeled and Encoded
  - APIs and Toolkits
    - Different Data Types and Usages