ECE 693 – Special Topics: AI for Radar System Design

Dr. Sevgi Zubeyde Gurbuz
szgurbuz@ua.edu

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Course Description

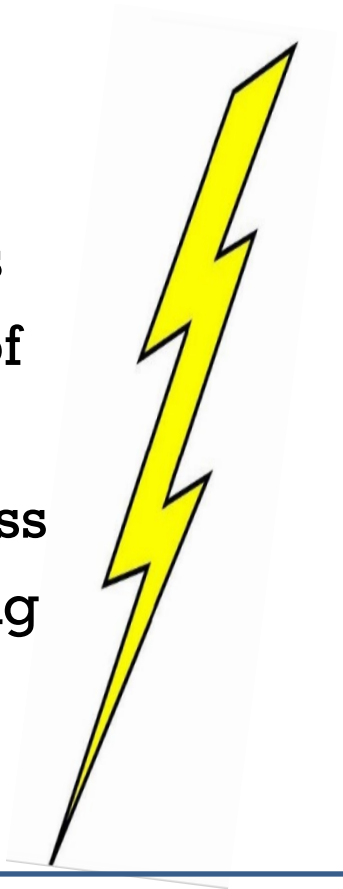
- **Objectives**
  - Recent advances and applications of AI and deep learning as applied to radar system design, especially next generation cognitive radar systems, will be discussed.

- **Required Background and Pre-Requisites**
  - B.S. in ECE, CS, or related field
  - Curiosity and interest in creative design
  - Prior coursework in radar or machine learning NOT required

A Novel Sensing Paradigm

Current Approach

- Unchanging data acquisition process
- Sensors oblivious of each other: no shared awareness
- Adaptive processing and sensor fusion after data acquired



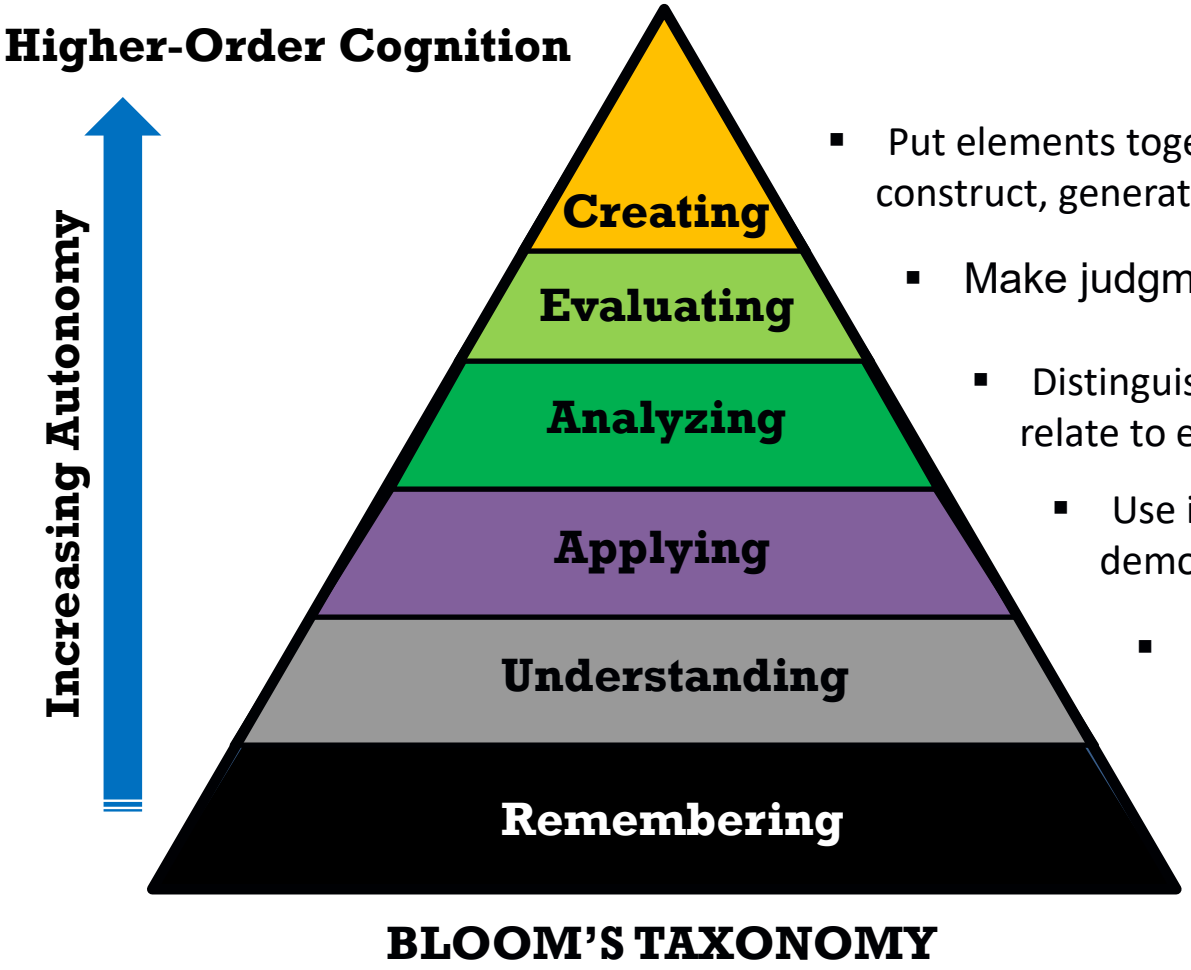
Cognitive Sensing

- a way to make machines and sensors imitate human perception and cognitive processes

BIG DATA → **REDUCED DATA** → **RELEVANT DATA**

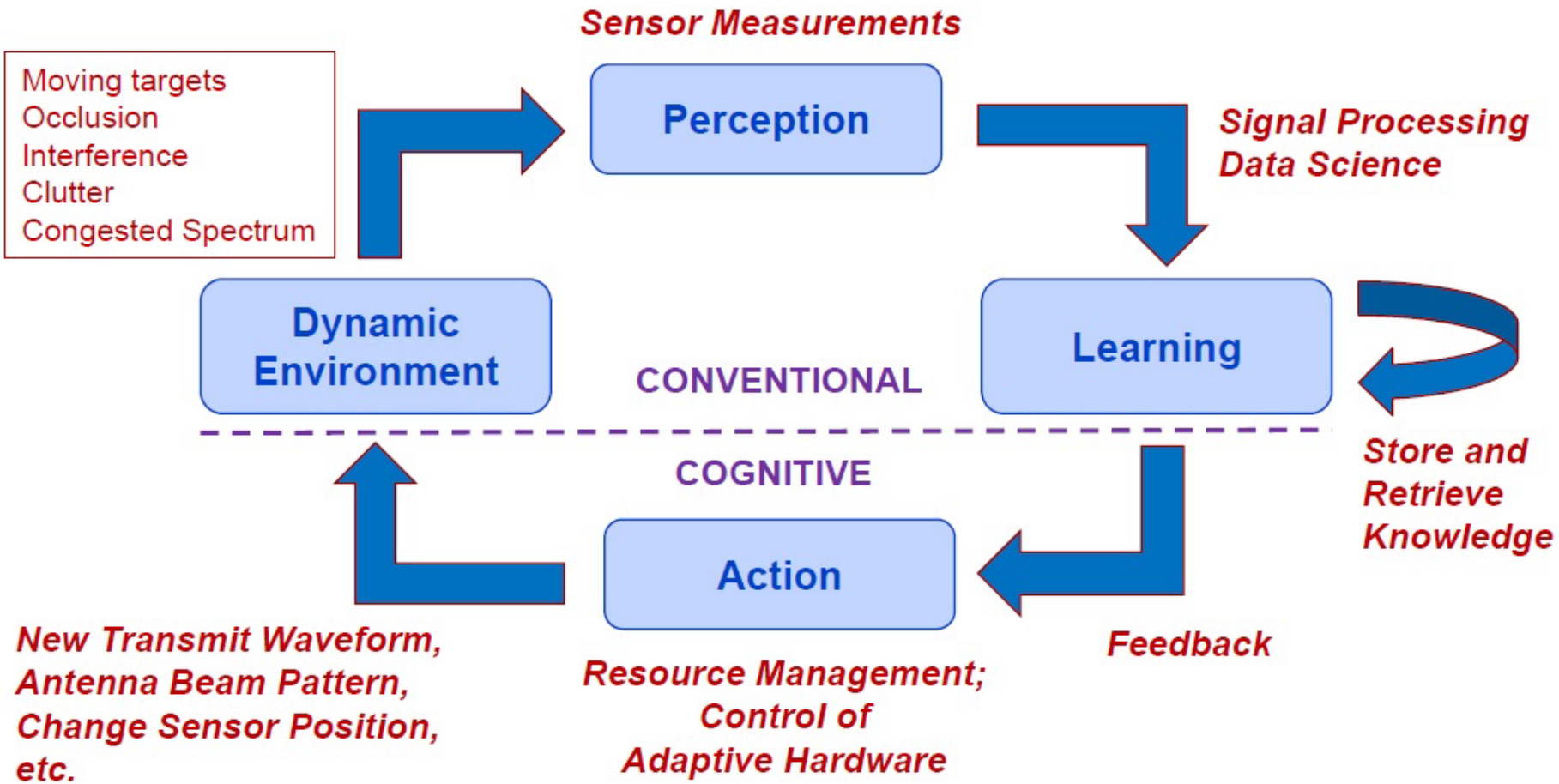
Sevgi Z. Gurbuz (szgurbuz@ua.edu)

Levels of Human Cognition



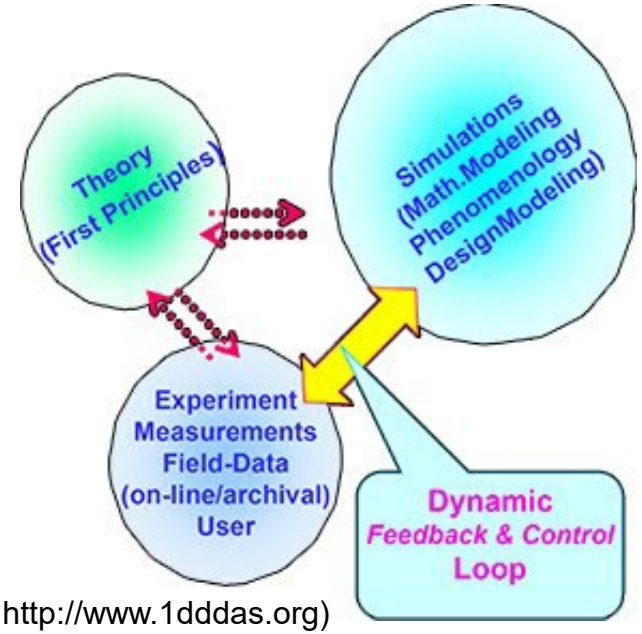
- Put elements together to form a functional whole; construct, generate, design
- Make judgments and justify decisions
- Distinguish between parts and how they relate to each other, and overall structure
- Use information in a new way; demonstrate, convert, solve
- Construct meaning from data; interpret, infer, explain
- Recall relevant knowledge from long-term memory

Modeling Human Cognition: The Perception-Action Cycle

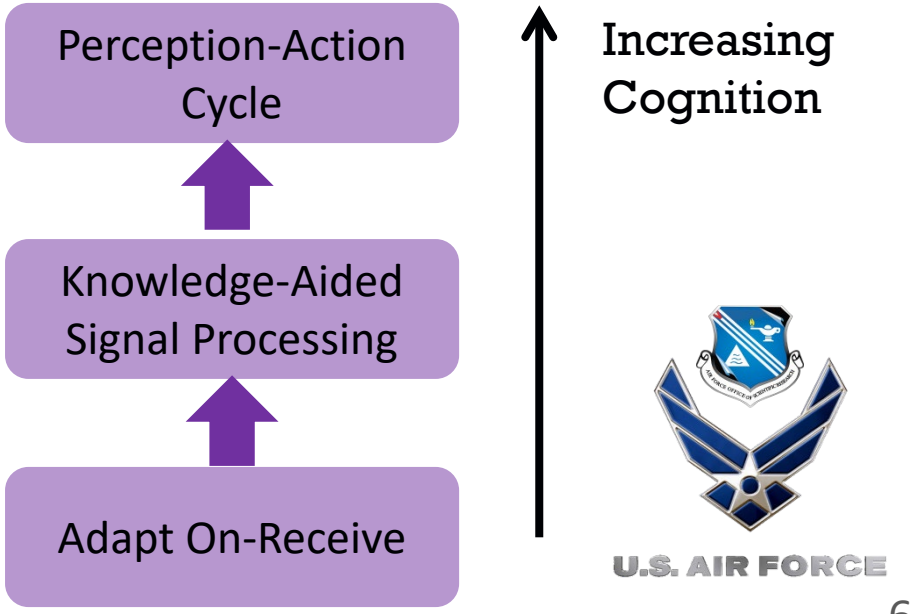


Cognitive Framework Related to Data-Driven System Design

- DDDAS: Dynamic Data-Drive Application Systems
  - ability to dynamically incorporate additional data into an executing application, and in reverse, ability of an application to dynamically steer the measurement process.



(Source: http://www.1dddas.org)



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Outline of Topics

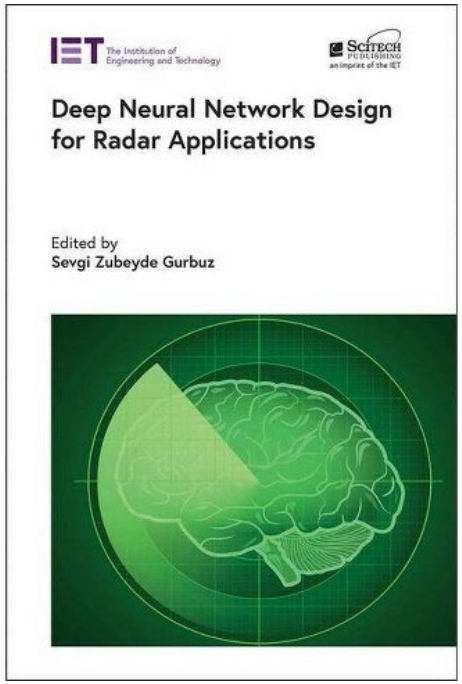
1. Basic principles of radar systems; radar range equation, link budget, FMCW and MIMO radar. Radar data representations (2D,3D,4D)
2. Basic principles of machine learning and deep learning
3. Applications in radar (SAR imaging, micro-Doppler, biomedical, human-computer interaction, autonomous vehicles)
4. Sensing specific challenges - training under low sample support, synthetic data generation and transfer learning
5. Physics-aware machine learning and application to radar-based and multi-modal sensing
6. Sequential modeling, online and iterative learning methods
7. Cognitive radar, adaptive hardware and antenna design, and cognitive process modeling
8. Markov decision processes, reinforcement learning and implementation of a perception-action cycle in radar

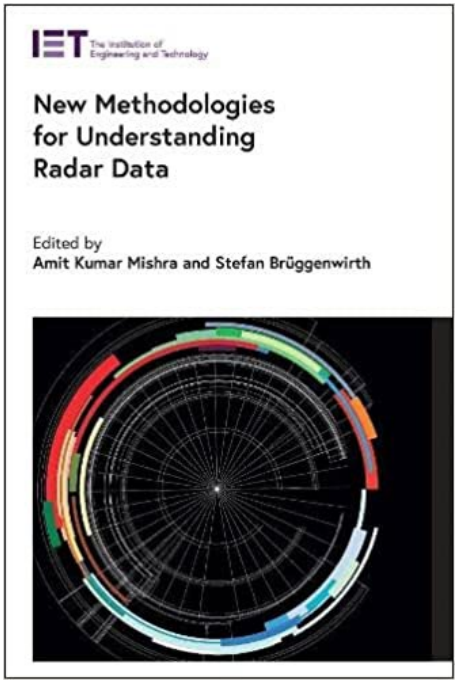
Assignments and Grading

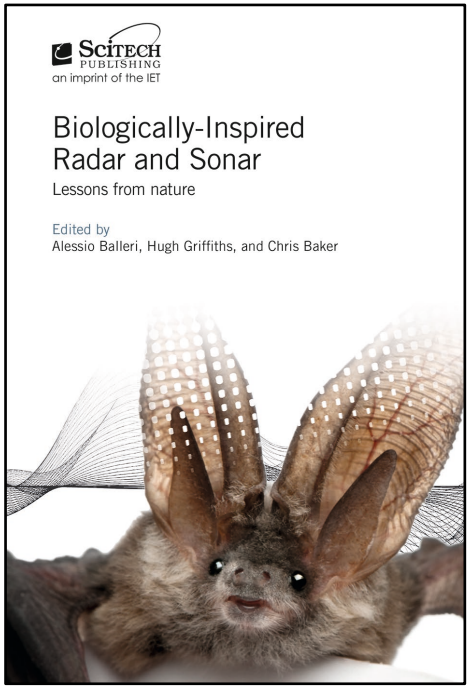
- **Assignments**
  - Presentations - oral, focused on a specific paper or group of papers
  - Paper Summary Reports - short answers to questions around targeted readings

- **Grading**
  - Presentations: 40%
  - Paper Summaries: 40%
  - Attendance: 20%

Sources for Course Content







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Information Request

- Email me the following information:
  - **Thesis research area and application:** if you could summarize your thesis and contribution in ONE SENTENCE, what would it be?
  - **Background statement:** how well do you know the following topics (Low, Some, High)?

Radar Hardware	Detection Theory
Radar Signal Processing	Estimation Theory
Radar Applications	Optimization
Signal Processing (general)	Control
Statistics	Machine Learning

  - **Answer:** What do you hope to gain from this class?

1st Reading Assignment

- S. Z. Gurbuz, H. D. Griffiths, A. Charlish, M. Rangaswamy, M. S. Greco and K. Bell, "An Overview of Cognitive Radar: Past, Present, and Future," in IEEE Aerospace and Electronic Systems Magazine, vol. 34, no. 12, pp. 6-18, 1 Dec. 2019.

- Prologue, Chapter 1, 2, and 3 in Deep Neural Network Design for Radar Applications (Ed. Gurbuz)

- These readings will be provided to you electronically with the understanding that they will not be shared or disseminated in any way

- NEXT CLASS: FRIDAY, Jan. 21st, 2022