Mahmut Semih Akkoç

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College Park, MD, USA

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Research Focus

Ph.D. student in Electrical and Computer Engineering at the University of Maryland, advised by Prof. Sennur Ulukus, working at the intersection of **information theory**, **data compression**, and the **interpretability of large language models**. My research establishes the fundamental limits of what can be discarded: deriving rate–distortion characterizations that govern task-aware compression, and analyzing transformers as tractable dynamical systems to locate where representational work actually happens. Seeking a **Summer 2027 research internship** in efficient AI, compression, or LLM interpretability.

Research Interests: Information Theory | Rate–Distortion Theory | Model & Data Compression | Large Language Models | Mechanistic & Interpretable AI | Transformer Dynamics

Education

- **University of Maryland, College Park** — College Park, Maryland
  Ph.D., Electrical and Computer Engineering — **GPA: 3.93/4.00** — *Sep. 2025 – Aug. 2030 (Expected)*
  Advisor: Prof. Sennur Ulukus | *Focus:* Information Theory, Interpretability of Large Language Models
- **Bilkent University** — Ankara, Türkiye
  B.Sc., Electrical and Electronics Engineering — **GPA: 3.92/4.00** — *May 2025*
- **National University of Singapore** — Singapore
  Exchange Student, Electrical and Computer Engineering — *May 2024*
  Relevant Coursework: Quantum Communication and Cryptography, Quantum Mechanics I, Probability

Publications

Full record: Google Scholar. † denotes equal contribution.

Accepted / Published

- [C1] **S. Akkoc**, S. Liyanaarachchi, S. Ulukus, and A. Yener, "The Rate–Distortion–Deception Tradeoff," in *Proc. 62nd Annual Allerton Conference on Communication, Control, and Computing*, Urbana, IL, USA, Sep. 2026. **(Accepted)**
  - Introduced *deception* as a third axis of the classical rate–distortion–perception framework, characterizing as first author the regimes in which a compressed reconstruction stays within a target fidelity of the source while provably resembling a sample from a different distribution.
  - Derived the achievable tradeoff region, bounding how far a lossy codec can steer output statistics — directly applicable to generative-model watermarking, output auditing, and privacy-preserving compression.
- [J1] **S. Akkoc**†, A. Çınar†, B. Ercan†, M. Kalfa, and O. Arıkan, "Practical Hardware Demonstration of a Multi-Sensor Goal-Oriented Semantic Signal Processing and Communications Network," *Journal of the Franklin Institute*, vol. 362, no. 1, 2024.
  - Led the hardware realization of a goal-oriented semantic communication network as co-first author, demonstrating that low-power commodity edge devices sustain real-time semantic extraction previously assumed to require CPU/GPU-class compute. Designed and validated the multi-sensor fusion pipeline end to end.

Under Review

- [U1] S. Li, T. J. Maranzatto, J. Peszek, T. Teolis, **S. Akkoc**, K. Riedl, S. Ulukus, and N. García Trillos, "On the Diverse Dynamical Behaviors Arising in Deep Linear Transformers," submitted to *Foundations of Computational Mathematics* (FoCM), 2026. arXiv:2607.18584.
  - Recast inference-time transformer computation as an interacting-particle system, proving that in embedding dimension two the depth-wise dynamics reduce exactly to a generalized Kuramoto model with pure second-harmonic coupling — an interpretable, closed-form surrogate for stacked linear self-attention.
  - Characterized the phenomenology induced by the key/query/value matrices — token clustering, oscillation, and bifurcation — and uncovered a hidden Hamiltonian structure explaining the non-collapsing regimes, giving mechanistic criteria for when depth compresses representations versus destabilizes them.
- [U2] T. J. Maranzatto, **S. Akkoc**, and S. Ulukus, "The Role of Feed-Forward Layers in Transformer Dynamics," submitted to *The 30th International Conference on Artificial Intelligence and Statistics* (AISTATS 2027), arXiv:2609.36230.
  - Extends the interacting-particle analysis beyond attention to the feed-forward block, isolating how pointwise nonlinearities reshape token trajectories and which layers carry the compressive work of the network.
- [U3] S. Liyanaarachchi, **S. Akkoc**, S. Ulukus, and A. Yener, "Task-aware Compression with Distribution Matching," submitted to *The Fifteenth International Conference on Learning Representations*(ICLR 2027), arXiv:2609.35684.
  - Derives the optimal compression rate when the reconstruction is consumed by a *mismatched* downstream classifier — one trained on a different distribution than the source — under joint distortion and error-probability constraints, and characterizes the resulting achievable rate region.
  - Proves the error floor of any such scheme is that of the optimal test on the uncompressed source, attainable only if the encoder spends an extra $H_b(p)$ bits conveying its own hypothesis estimate; recasts the design as a rate–distortion–perception problem with a KL constraint matching the classifier's training distribution.

Research Experience

University of Maryland, College Park College Park, MD, USA
Graduate Research Assistant — Information Theory & Machine Learning *Sep. 2025 – Present*

- Develop information-theoretic and dynamical-systems tools for compressing and interpreting transformer architectures, spanning task-aware rate allocation and mechanistic analysis of attention and feed-forward blocks; **one conference paper accepted, one journal submission under review, and two manuscripts in preparation within the first year** of the program.
- Collaborate across four institutions (UMD, UW–Madison, Oxford, Ohio State) on the mathematical foundations of deep learning, translating abstract dynamical characterizations into empirically testable claims about model behavior.

Bilkent University Ankara, Türkiye
Undergraduate Researcher *Feb. 2023 – May 2025*

- **Semantic Signal Processing — Prof. Orhan Arıkan**:
  - Built the embedded hardware demonstrator that turned the group's theoretical semantic signal processing framework into a working multi-sensor system, establishing the experimental basis for a journal publication.
  - Profiled semantic extraction under strict power and memory budgets on Raspberry Pi, quantifying the compute floor required for real-time goal-oriented inference at the edge.
- **Computational Electromagnetics — Prof. Vakur B. Ertürk**:
  - Implemented a method-of-moments solver from first principles to model plane-wave scattering by a perfectly conducting strip, validating numerical results against analytical limits.

Industry Experience

ASELSAN Ankara, Türkiye
Summer Intern — RF & Microwave Systems *Aug. 2024 – Sep. 2024*

- Designed a suspended ring resonator model in MATLAB and CST Studio that estimates dielectric constant and loss tangent, delivering a low-cost alternative to commercial material characterization for antenna development.
- Cross-validated MATLAB against full-wave CST simulations to bound estimation error, then generalized the method into a lookup table and polynomial fits so the tool transfers across materials without re-derivation.

Huawei Ankara, Türkiye
R&D Intern — Semantic Communications *Jun. 2023 – Aug. 2023*

- Prototyped a two-node semantic communication network on Raspberry Pi devices that performs visual semantic extraction entirely on-device, collapsing the transmission requirement from a 10 Mbps raw video stream to roughly 10 bps of task-relevant semantic tokens a five-order-of-magnitude ($\sim 10^5\times$) reduction in bandwidth achieved by transmitting meaning rather than pixels.
- Engineered the TCP-based transport layer and a stream fusion algorithm that merged asynchronous multi-sensor inputs, improving integration accuracy by 67.2% over unfused processing while operating within the power and memory envelope of embedded hardware.

BİTES — Defence & Aerospace Technologies Ankara, Türkiye
Summer Intern — Software Engineering *Jun. 2022 – Aug. 2022*

- Built a multithreaded, socket-based file transfer system in C++ supporting arbitrary file types via binary-mode I/O, applying factory and observer patterns to keep socket creation and worker notification decoupled and extensible.

Technical Skills

- **Theory & Methods:** Information Theory, Rate–Distortion(–Perception) Theory, Source Coding & Lossy Compression, Task-Aware / Semantic Compression, Mechanistic Interpretability, Dynamical Systems & Interacting-Particle Models, Probability & Stochastic Processes, Statistical Signal Processing, Optimization
- **Programming:** Python, C++, MATLAB, LaTeX
- **ML & Scientific Computing:** PyTorch, NumPy/SciPy, Matplotlib, Git
- **Languages:** Turkish (native), English (fluent)

Honors and Awards

Academic Excellence Award Bilkent University, Dept. of Electrical and Electronics Engineering — *2025*
Awarded to top-ranked students for sustained academic distinction across the degree program.

Research Excellence Award Bilkent University, Dept. of Electrical and Electronics Engineering — *2025*
Recognized for research contributions culminating in a first-authored journal publication as an undergraduate.

Best Project Award Bilkent University, Dept. of Physics — *2022*
Selected department-wide for excellence and originality in project design and execution.

Selected Projects

Li-Fi Protocol Implementation on BASYS3 (Xilinx Artix-7)

- Implemented a complete Li-Fi communication stack in **VHDL**, with modular encoding/decoding of audio and text for LED transmission and LDR reception; encoded payloads stored in on-chip ROM and decoded output rendered on a seven-segment display.