New Frontiers in Associative Memories
- ICLR 2026 Workshop Proposal

Abstract

The primary focus of this workshop is to strengthen the analytical foundations of associative memory while exploring its emerging role in the design of agentic AI systems. By bringing together researchers from optimization and deep learning, statistical physics, neuroscience and machine learning systems, the workshop aims to catalyze cross-disciplinary exchange, identify open problems, and foster collaboration toward advancing the theoretical and practical frontiers of associative memory. A central goal is to build a cohesive community at the intersection of these fields, one that unites rigorous mathematical foundations with scalable architectures and applications where associative memories serve as the core drivers of reasoning, adaptation, and intelligent behavior.

Introduction. Associative Memory (AM) has re-emerged as a unifying framework in modern artificial intelligence, connecting classical energy-based models with contemporary architectures such as transformers and diffusion model. Originating from early mathematical formulations in the 1960s–1980s [Willshaw et al., 1969, Amari, 1972, Hopfield, 1982], AM models, most notably the Hopfield networks [Hopfield, 1982, 1984], provided a principled view of collective computation and attractor dynamics in neural systems. Recent theoretical and algorithmic advances have substantially extended these ideas [Krotov and Hopfield, 2016, Demircigil et al., 2017, Ramsauer et al., 2020], offering new insights into the role of associative retrieval as a form of attention or inference in deep architectures [Widrich et al., 2020, Fürst et al., 2022, Hoover et al., 2024, Ota and Taki, 2023].

This modern wave of research has revealed deep connections between AMs and energy-based learning [Niu et al., 2024], optimization dynamics [Santos et al., 2024] and memorization-generalization tradeoffs [Hoover et al., 2025]. Beyond retrieval, AM principles provide a natural framework for test-time regression and adaptation [Behrouz et al., 2025], where networks dynamically update predictions based on incoming observations, effectively performing continual associative inference [Bai et al., 2023]. Recent work has also extended AM to non-Euclidean and distributional domains, such as graphs, manifolds, and probability distributions [Tankala and Balasubramanian, 2025], allowing associative recall over structured and relational data for multi-modal reasoning. Importantly, these capabilities underpin agentic AI systems, where memory-augmented architectures [Xu et al., 2025, Wang et al., 2025, Zhou et al., 2025] support persistent reasoning, tool use, and adaptive decision-making in dynamic environments. Collectively, these advances position associative memory not merely as a mechanism for retrieval but as a unifying computational principle for generation, reasoning, and adaptive intelligence in modern AI systems. Finally, from a physics perspective, the study of transient dynamics [Clark, 2025] and higher-order oscillatory networks [Nagerl and Berloff, 2025] further illuminates how neural systems navigate energy landscapes to converge on memory states, enabling rapid, flexible responses while avoiding spurious attractors, and providing a strong theoretical foundation.

Need for the workshop: Given the flurry of recent work in this area, a main focus of this workshop is on *community building*. The urgency for this workshop arises from the growing fragmentation of research on memory, reasoning, and adaptation across disparate areas of AI, from generative modeling and test-time optimization to agentic and continual learning. While associative memory provides a unifying mathematical and conceptual framework linking these domains, the communities exploring them often operate in isolation, using different terminologies and evaluation paradigms. This workshop seeks to build an integrated community that connects researchers in energy-based modeling, optimization theory, neuroscience-inspired computation, and large-scale Agentic AI systems around a shared goal: understanding memory as the foundation of intelligent behavior. By fostering dialogue between theorists, experimentalists, and practitioners across academia and industry, the workshop aims to catalyze a new phase of collaborative progress, shaping a coherent research agenda for next-generation memory-augmented and agentic AI.

Novel Question To be Addressed. The central open problems and research directions we aim to address in this year's workshop include (but are not limited to):

- Generative modeling and associative memory in non-Euclidean spaces: How can associative recall and generation be defined on manifolds, graphs, distributions, and other geometric domains? Advancing this question is key to developing multi-modal memory-based generative models that reason over structured and relational data.
- Augmenting memory in agentic AI systems: How can associative memory enable persistent reasoning, goal adaptation, and tool use in autonomous agents? Progress here will clarify the role of associative memory in building controllable, self-improving AI systems.
- Optimization and test-time training as associative processes: Can we interpret adaptation, inference, and learning at test time as forms of associative retrieval? This perspective could unify optimization dynamics and memory mechanisms, leading to more data-efficient and generalizable learning systems.
- Energy-based and attractor models for generative modeling: What principles govern the formation and stability of attractor states in generative models such as diffusion networks and modern Hopfield systems? Addressing this problem will deepen our understanding of how generative AI encodes and retrieves structured knowledge.
- Theory of high-dimensional associative dynamics: How do stability, capacity, and convergence scale in stochastic or continuous associative networks? Advances in this area are crucial for developing mathematically grounded and scalable memory-augmented architectures.
- Applications to lifelong learning and multimodal reasoning: How can associative memory mechanisms support continual adaptation and integration across language, vision, and embodied tasks? Solving this problem is essential for building agents that learn and reason over time without catastrophic forgetting.

Schedule. The workshop will include invited talks, contributed talks, a poster session, and a panel discussion. See Table 1 for a preliminary schedule. Each invited talk will take 30 minutes including questions; each contributed talk will take 15 minutes. Although many of the invited speakers have extensively published on Associative Memory in major AI conferences, we have requested that their invited presentations focus on novel ideas and unifying perspectives, rather than reiteration of the already published work.

Invited Speakers. Our (confirmed) invited speakers represent a broad and intellectually diverse set of perspectives that together capture the evolving landscape of Associative Memory (AM) research, from its neurocomputational roots to modern energy-based and agentic AI formulations. **Jay McClelland** (Stanford), a foundational figure in the field whose recent work revisits parallel distributed processing through the lens of modern neural architectures, bridges classical cognitive models of memory with current deep learning frameworks. **Meisam Razaviyayn** (USC) brings a theoretical optimization perspective, with recent advances in convergence analysis and equilibrium learning directly relevant to energy minimization and attractor dynamics in modern AM systems. **Natalia Berloff** (Cambridge) brings a unique physics-driven perspective to associative memory through her recent work demonstrating that networks of phase oscillators with higher-order coupling can function as dense analog associative memories. On the emerging end of the spectrum, **Paul Liang** (MIT) explores agentic and multimodal AI systems that extend the boundaries of associative inference in adaptive and embodied environments, connecting AM principles to reasoning and world modeling. **David Clark** (Harvard) advances the theory of neural memory retrieval and gradient-based energy landscapes, offering analytical insights into generalization and stability in deep associative networks. **Xueyan Niu** (Huawei) complements this lineup by connecting Transformers models with continuous Hopfield networks, revealing how attention emerges from an underlying energy-based associative memory and establishing theoretical links between model size, memorization, and performance scaling.

This lineup ensures diversity not only in seniority, spanning early-career to senior leaders, but also across disciplines (neuroscience, optimization, physics, machine learning systems), genders, and institutions (academia and industry). Collectively, their work embodies the multidimensional nature of modern Associative Memory research, linking foundational theory, physical computation, and the next generation of adaptive AI architectures. No speakers were involved as invited presenters in the previous versions of this workshop series.

Additional Speakers. Although all the invited speakers have already confirmed their in-person participation, if the workshop is accepted, we have composed a list of additional speakers whom we could invite in case of unexpected emergencies: Leo Kozachkov (Brown), Luca Ambrogioni (Donders Institute), and Jason Weston (META AI).

Panel on *AM and Multi-modal, Agentic AI.* Generative and agentic AI systems, ranging from large language models (LLMs) to multimodal and embodied agents, are rapidly evolving, yet they continue to face fundamental limitations in reasoning, adaptation, and memory. Despite scaling and architectural innovations, such models often struggle with contextual forgetting, unstable test-time adaptation, and lack of persistent memory mechanisms. Recent developments in associative memory, energy-based modeling, and optimization-inspired test-time learning offer promising frameworks to address these challenges by reintroducing structured retrieval and attractor dynamics into modern architectures. We plan to have a panel discussion spanning researchers with diverse backgrounds in optimization, physics-inspired computation, theoretical machine learning, and large-scale systems. The discussion will explore how ideas from Hopfield networks, dynamical systems, and energy-based inference can inform the design of next-generation agentic and generative models, models that not only recall information but reason and adapt through associative mechanisms. Furthermore, the discuss will involve focusing on associative memories on more general non-Euclidean spaces to develop multi-model agentic AI systems.

Key topics will include:

- Memory mechanisms in agentic AI and their role in long-term reasoning and tool use.

Table 1: Preliminary schedule. **C**: Participation confirmed. **W**: Invitation sent, waiting for response.

Time	Event	Participants
09:00-09:10	Opening Remarks	R. S. Feris, J. Kempe, Z. Shi
09:10-09:40 09:40-10:10	Invited Talk 1 Invited Talk 2	Jay McClelland (Stanford) [C] Xueyan Niu (Huawei) [C]
10:10-10:40	Coffee Break & Poster Session	🍩🍩🍩
10:40-11:40	4 Contributed Talks	–
11:40-13:30	Lunch Break & Poster Session	🍱🍔🍕
13:30-14:00 14:00-14:30	Invited Talk 3 Invited Talk 4	Paul Liang (MIT) [C] Meisam Razaviyayn (USC) [C]
14:30-15:00	2 Contributed Talks	–
15:0-15:30	Coffee Break & Poster Session	🍩🍩🍩
15:30-16:00 16:00-16:30	Invited Talk 5 Invited Talk 6	Natalia Berloff (Cambridge) [C] David Clark (Harvard) [C]
16:30-17:30	Panel: AM & Multi-modal, Agentic AI	Jay McClelland (Stanford) [C], Dmitry Krotov (MIT-IBM) [C], Parikshit Ram (IBM Research) [C], Ying Wei (Zhejiang University) [W], Moderated by (a subset of) Organizers.
17:30-17:40	Conclusions & Outlook	K. Balasubramanian, B. Hoover and H. Kuehne.
17:40-19:00	Poster Session	

- Generative modeling in non-Euclidean spaces and its connection to geometric associative memory.
- Optimization and test-time training viewed as dynamic retrieval processes.
- Theoretical and empirical insights into the capacity and stability of large-scale memory systems.

All invited panelists will be given 5 minutes for opening remarks, followed by a 45-minute interactive discussion with the audience. We will use RocketChat (or a similar platform) to facilitate participation from both in-person and remote attendees, ensuring an inclusive and collaborative exchange of ideas. The goal of this panel is to articulate emerging challenges, unify diverse approaches, and identify key research directions that can advance the theory and practice of memory-augmented generative and agentic AI

Attendance. Given the recent developments, exciting results, and revived interest in Associative Memory, Hopfield Networks, (including the Nobel Prize in 2024), their connection to test-time inference, memorization-generalization tradeoffs, and agentic AI, we expect to have around 300-500 participants. If accepted, we will publicize this workshop by reaching out to speaker/organizer professional networks and attendees of the previous version of this workshop, as well as, various ML and statistical physics mailing lists (such as ML-News, WikiCfP), social media (such as X/Twitter, LinkedIn, r/MachineLearning, Facebook), and various affinity group mailing lists.

Diversity Statement. Diversity among organizers, invited speakers, panelists, and program committee members was one of the key objectives in organizing our workshop. While the AI

community traditionally suffers from under-representation of certain groups of researchers and more work certainly needs to be done on this front, we are happy to report that we have achieved a good combination of men and women in all the participating groups (invited speakers, panelists, organizers). There are East Asian, South Asian, White, Latino and Middle-eastern researchers among the invited speakers, additional speakers, panelists, and organizers. Geographically, the participants are located in various parts of the USA, UK, and Asia. The invited speakers, panelists, and organizers represent both academic institutions, and industrial labs. Our confirmed invited speakers and panelists span a wide range of career stages, from esteemed renowned researchers (e.g., J. McClelland), to early career researchers (e.g., P. Liang). Julia Kempe and Hilde Kuehne have a long history of involvement in the mentoring of women and other underrepresented minorities. They will oversee the diversity efforts for this workshop and will collaborate on this with other organizers.

Contributed Papers, Talks and Posters. We plan to have seven slots for oral contributed talks of 15 minutes each, thus giving almost as much time to the contributed talks as the invited talks (not including the already interactive panel discussion). The remaining accepted contributed talks will be presented as posters at an 80-minute poster session. We will use OpenReview to manage the contributed submissions. Each contributed submission will receive three reviews, and we expect each reviewer to evaluate no more than three submissions. We will assess submitted contributions using the rules for conflict of interest used for the main track ICLR conference, e.g., reviewers cannot be from the same organization as authors, recent coauthors cannot review each other's submissions. We expect to have approximately 40 to 50 contributed submissions. We will maintain two tracks for submission – the general track, and a track for tiny papers that will align with ICLR's Tiny Papers initiative for papers that contain late breaking developments but can be significantly limited in scope. The accepted tiny papers will also be invited for a poster presentation. We have already secured a sufficient pool of qualified reviewers: members of the program committee, the organizers, and some of the invited speakers. We will appropriately notify the members of the program committee regarding the review process for the tiny papers track. If necessary, we will identify additional reviewers well qualified to evaluate contributions on the topic of the workshop. The tentative deadline for submission of contributed papers will be February 1, 2026, and the final decisions will be announced no later than March 1, 2026. The workshop will be non-archival.

Previous Related Workshops. Previous versions of this workshop was held at NeurIPS 2023 (https://amhn.vizhub.ai) and ICLR 2025 (https://nfam.vizhub.ai/). In each case, there were over 40 accepted papers, 7 contributed talks, and close to 200 attendees and we hope to build upon this success with new speakers and participants in 2024. H.Kuehne and J.Kempe of the current organizers co-organized the previous workshops. K. Balasubramanian, R. Feris, B. Hoover, and Z. Shi are organizing this workshop for the first time this year. While the focus of the last workshop was on energy-based DAMs on Euclidean spaces, this version of the workshop will be dedicated to (i) DAMs on non-Euclidean spaces, (ii) connections to test-time memorization and training and (ii) interface between memory-based architectures and Agentic AI.

Points of Difference. Our workshop will be unique in terms of its interdisciplinary nature, bringing together participants from optimization and learning theory, Agentic AI systems, statistical physics, and deep learning communities.

Workshop materials and outcomes. Similar to the previous workshop (see https://amhn.vizhub.ai and https://nfam.vizhub.ai/), all the relevant material and outcomes (recorded invited

and contributed talks, panel discussion, and accepted papers) will be made available on the workshop website for offline viewing for participants unable to attend in-person or follow along live.

Organizers

Krishnakumar Balasubramanian [UC Davis/Amazon Research (AWS), kbala@ucdavis.edu]: Krishna is an Associate Professor in the Department of Statistics at the University of California, Davis, affiliated with the Graduate Group in Applied Mathematics, the Center for Data Science and Artificial Intelligence Research (CeDAR), and the TETRAPODS Institute of Data Science. He is also an Amazon Scholar and was a visiting scientist at the Simons Institute for the Theory of Computing at UC Berkeley in Fall 2021 and Fall 2022. Krishna received his Ph.D. in Computer Science from the Georgia Institute of Technology and completed postdoctoral research at Princeton University and the University of Wisconsin–Madison. His research lies at the interface of machine learning and artificial intelligence, statistics and optimization. He is a recipient of several honors, including a Facebook Fellowship (2013), the ICML Best Paper Runner-Up Award (2013), and the INFORMS ICS Prize (2024). He contributes actively to the academic community as an Associate Editor for the Annals of Statistics, IEEE Transactions on Information Theory and the Journal of Machine Learning Research, and serves regularly as a (senior) area chair for leading conferences such as ICML, ICLR, NeurIPS, and COLT. Krishna has organized workshops and conferences at places including most recently at the Banff International Research Station (Canada) and Oberwolfach Research Institute for Mathematics (Germany).

Rogerio Schmidt Feris [MIT-IBM Watson AI Lab, rsferis@us.ibm.com]: Rogerio is a principal scientist and manager at the MIT-IBM Watson AI lab. He joined IBM in 2006 after receiving a Ph.D. from the University of California, Santa Barbara. He has also worked as an Affiliate Associate Professor at the University of Washington and as an Adjunct Associate Professor at Columbia University. He has authored over 200 technical papers and has over 50 issued patents in the areas of computer vision, multimedia, and machine learning. Rogerio's work has been covered by the New York Times, ABC News, and CBS 60 minutes, among other media outlets. He served as an Associate Editor of TPAMI, a Program Chair of WACV 2017, and frequently serves as an Area Chair of top premiere computer vision and AI conferences, such as NeurIPS, CVPR, ICLR, ICML, ECCV, and ICCV. Among other honors, Rogerio received a prestigious Technology and Engineering Emmy Award, which recognizes breakthroughs in technology that have a significant effect on television engineering.

Benjamin Hoover [Georgia Tech / IBM Research, bhoov@gatech.edu]: Benjamin is a final-year PhD candidate at the Georgia Institute of Technology and an AI Research Engineer at IBM Research. His work focuses on developing a unified framework for associative memory, integrating ideas from Transformers, diffusion models, and kernel methods. His research has received oral, spotlight, and best demo awards at NeurIPS and ICML, as well as a Best Paper Honorable Mention at ACL 2023. His work has been featured in both Nature Reviews and Quanta Magazine. Benjamin has served as a reviewer for leading machine learning conferences including NeurIPS, ICML, and ICLR, and he has managed the website for both previous iterations of this workshop.

Julia Kempe [NYU, kempe@nyu.edu]: Julia is a Silver Professor of Computer Science, Mathematics and Data Science at the Center for Data Science and the Courant Institute of Mathematical Sciences at New York University, and a Visiting Senior Researcher at Meta FAIR. From 2018-2023

she was the Director of NYU's Center for Data Science and a member of the NYU President's Senior Leadership. From 2011-18 she worked as a quantitative researcher in finance. Before that she was a Research Director at the CNRS in Computer Science in Paris, and Associate Professor of Computer Science at Tel Aviv University. Her interests range from earlier work in quantum computing and quantum complexity, to machine learning theory and applications. Her awards include the CNRS Bronze Medal, Knighthood in the French Order of Merit, and Membership in the Academia Europea. Julia has organised a multitude of workshops, conferences and seminars; most recently at NYU and the Flatiron Institute, and is on the organising committee of the proposed NeurIPS workshop "AI in the Synthetic Data Age: Unintended Consequences and Potential Mitigation".

Hilde Kuehne [University of Bonn, `kuehne@cs.uni-bonn.de`]: Prof. Dr. Hilde Kuehne is the head of the Computer Vision for Multimodal Learning Group at the University of Bonn. Her research focuses on learning without labels and multimodal video understanding. She is an Associate Editor of TPAMI, serves as area chair for various conferences, including CVPR, ICCV, and NeurIPS, and served as program chair for WACV 2024. Beyond her work, she is committed to bringing more diversity to STEM, and she is a board member of the Women in Computer Vision Initiative. She is also involved in the application for the 4th Workshop on Self-Supervised Learning at NeurIPS 2024.

Zhaoyang Shi [Harvard University, `zshi@fas.harvard.edu`]: Zhaoyang is a Postdoctoral Fellow in the Department of Statistics at Harvard University. He received his Ph.D. in Statistics from the University of California, Davis, and his B.S. in Mathematics from Fudan University. Zhaoyang's research lies at the interface of statistical inference, network analysis, and generative models. Zhaoyang has received multiple distinctions for his research, including the UC Davis Statistics Peter Hall graduate student research fellowship and INFORMS Applied Probability Society Conference Travel Awards. Most recently, he is also an invited speaker to the SIAM UQ 2026 and the Joint Statistical Meetings (JSM) 2025. Zhaoyang has served as a reviewer for leading journals and conferences such as the Annals of Statistics, JMLR, NeurIPS, and ICML. He also helped co-chair a session in JSM 2025 "Network Analysis and Causal Inference".

Program Committee A list of Program Committee members, with an indication of which members have already agreed:[1]

Sugandha Sharma (MIT) [C], Hamza Tahir Chaudhry (Harvard)[C], Jacob Zavatone-Veth (Harvard)[C], Tom Burns (Brown U)[C], Bao Pham (RPI)[C], Mikail Khona (MIT), Hidenori Tanaka (Harvard), Bishwajit Saha (RPI) [C], Satyananda Kashyap (IBM Research) [C], Tankut Can (Emory U) [C], Andrey Gromov (META AI), Paolo Glorioso (Stanford U) [C], Tom George (UCL), Andy Keller (University of Amsterdam) [C], David Lipshutz (Flatiron Institute), Arian Khorasani (MILA) [C], Jascha Achterberg (Cambridge U) [C], Binxu Wang (Harvard), Francisco Acosta (UCSB), Leo Kozachkov (MIT)[C], Parikshit Ram (IBM Research) [C], Rogerio Feris (IBM Research) [C], Mikhail Burtsev (London Inst for Math Sci) [C], Eleanor Spens (UCL) [C], Dmitry Krotov (IBM Research) [C], Julia Kempe (NYU) [C], Hilde Kuehne (U of Bonn) [C], Sara Solla (Northwestern U) [C], Daniel Lee (Cornell) [C], Benjamin Hoover (GA Tech) [C], Luca Ambrogioni (Donders Institute), Matteo Negri (Università di Roma Sapienza) [C], Gabriel Raya (Tilburg University) [C], Hongzhi Wang (IBM Research)[C], Carlo Lucibello (Bocconi University) [C], Paul Francois (U of Montreal) [C], Mohammed J. Zaki (RPI)[C], Olawale Onabola (MILA) [C], Danil Tyulmankov (U South CA) [C].

LLM usage disclosure: LLM was used for polising the writing.

[1] C: Confirmed. 31 researchers confirmed till date.

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