Yue Cheng Contributing to Data Science Field Statement

I request consideration for promotion to Associate Professor with tenure in the School of Data Science at the University of Virginia (UVA). This statement describes the way my published work and research products have contributed to the field of Data Science.

1 Overview of My Research in General Data Systems Area

I am a data systems researcher and I build practical systems solutions that better support emerging, large-scale, data-intensive applications such as big data analytics, data science, deep learning (DL), and artificial intelligence (AI). In the past five years as a faculty, I have focused on *serverless computing* and the intersection of large-scale distributed systems and data-intensive applications (e.g., machine learning, data science, data analytics applications), an emerging area that is becoming increasingly important to the next-generation of cloud computing and supercomputing. *My research provides fundamental solutions that next-generation cloud computing demands to fully unleash the great potential of serverless computing. My research also rethinks serverless computing abstractions to enable innovative, domain-specific, data-intensive applications.*

2 Problems that My Research Aims to Solve

Ultimately, my research aims to answer the following research question:

How to make the life easier for data scientists and programmers who work on building data-intensive applications? Or, in other words, how to make data science programming more productive?

Serverless computing *promises* to achieve elastic autoscaling and pay-per-use, therefore, opening doors to easy-to-use and easy-to-program data science and data analytics applications. However, today's serverless computing fails to deliver such promises, at each level, from application frameworks, platform resource management, to OS scheduling. This is due to fundamental mismatches between existing system designs and new application requirements. Existing systems are designed for traditional, serverful applications. For example, existing serverless data analytics frameworks [SoCC'17, SoCC'20] follow a design philosophy that is commonly used by traditional cluster computing frameworks such as MapReduce and Spark; data analytics programs running on such frameworks, unfortunately, will need to pay huge amounts of performance taxes. As another example, today's proportional-share OS schedulers (e.g., Linux' Completely Fair Scheduler, or CFS) are not designed for optimizing turnaround time of short functions, but instead for optimizing CPU task-level fairness among multiple, presumably long-running jobs [SC'22, SFS Project]. Therefore, such mismatches often force (1) application users to settle for inefficiency and (2) application developers to develop their own ad-hoc solutions, which may not take advantage of all of the benefits offered by the underlying serverless computing platforms.

3 My Research Philosophy

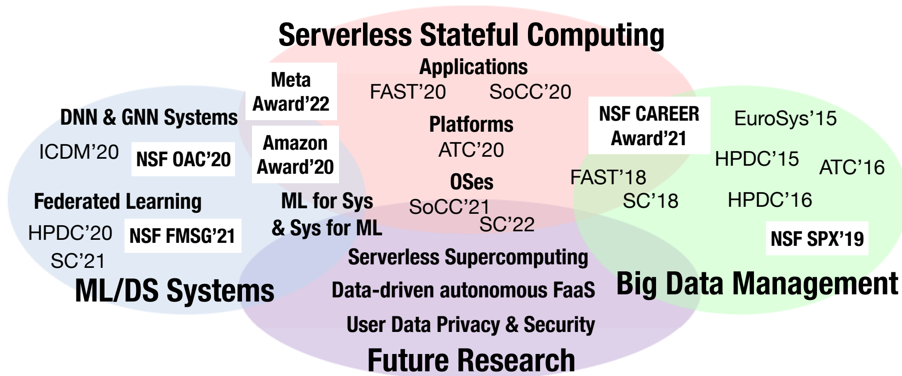
My research gravitate towards simple, elegent solutions to rather messy and complicated distributed systems problems. The main research approach that I have taken is to gain deep understanding of the target systems and applications' needs and to rethink systems' core abstractions based on my understanding; and I iterate between these two activities. Throughout my research I have been motivated by real problems experienced by data scientists, data and app developers, and infrastructure operators in practice. With these first-hand experiences, I perform comprehensive measurements to pinpoint data system bottlenecks, characterize data application behaviors and their needs, and understand practitioners' pain points.

A systems solution often requires designing a new abstraction or adapting an existing abstraction in a novel way (e.g., in a new scenario, under new settings or assumptions). I take different routes when designing new data systems solutions. On the one hand is the freedom of *doing blue sky research, where I openly question the fundamentals underlying distributed systems in face of rapidly-emerging needs and challenges*. For example, I rethink the design of modern cloud data storage and data management systems and build the first, cost-effective cloud data storage system that exploits serverless functions as a novel data storage medium [FAST'20]. In this particular project, we apply a top-down approach to design and build a first-of-its-kind, elastic cloud storage service atop ephemeral serverless functions. By exploiting serverless computing as a novel storage medium, this new cloud storage model can achieve up to two orders of magnitude monetary cost savings for data scientists who work on cloud-native data platforms without sacrificing data storage and data retrieval performance.

On the other hand, I seek *practical and easily-deployable solutions for otherwise sophisticated data systems problems*. Distributed data analytics systems often involve complex cross-component interactions in order to support cross-cutting tasks such as ML kernel scheduling, intermediate data shuffling, data caching, GPU allocation and scheduling, and memory allocation/deallocation. This leads me to gravitate towards simple and general solutions that solve not a specific problem, but which satisfy a general set of applications. For instance, I designed a novel serverless GPU notebook platform called ElasticAI for Adobe Sensei [**?**]. ElasticAI rethinks resource scheduling for emerging interactive data science workloads such as ML model debugging and hyperparameter tuning with new GPU resource scheduling algorithms and mechanisms. This new approach is enabled by a novel take on the serverless computing paradigm: the key insight is that interactive data science workloads (e.g., machine learning debugging and model tuning) exhibits intermittent, and often low, GPU usage patterns, making it suitable for coarse-grained and transparent GPU time sharing that relieves the burden of manual (and often inefficient) server management from the users. **In fact, the new techniques developed for ElasticAI can help save Adobe Sensei on its cloud bills by an average of 2.86 million dollars monthly.**

4 My Contributions to the Data Science Field in General

My current and future research has a strong focus on the intersection of cloud/HPC-scale systems and data-intensive applications. My current and future research can be categorised into three main thrusts as depicted in the chart on the right side: (1) Serverless stateful[1] computing (*the computing substrate*), (2) machine learning and data analytics systems (*the algorithm and policy substrate*), and (3) big data management (*the data substrate*). I next briefly describe



My current, prior, and future research, and their relationships to the field of Data Science.

[1] By "stateful", I mean data-intensive applications that share state, e.g., a big data analytics program that can be decomposed into multiple fine-grained tasks each processing a subset of the input data and sharing and coordinating intermediate data among other peer tasks.

how my published work and research products aside from papers have contributed broadly to the field of Data Science.

4.1 Published Work

As shown in the chart, my research has appeared at top Computer Science conferences (labeled as top by a series of rankings including the commonly used `csrankings.org`). I have regularly published at USENIX File and Storage Technologies Conference (USENIX FAST, $2\times$), USENIX Annual Technical Conference (USENIX ATC, $2\times$), The International Conference for High Performance Computing, Networking, Storage, and Analysis (SC or SuperComputing, $3\times$), ACM High-Performance Parallel and Distributed Computing (ACM HPDC, $3\times$), and ACM Symposium on Cloud Compuint (ACM SoCC, $2\times$). Most of these Computer Science conferences have a competitively low acceptance rate. For example, my USENIX ATC'21 paper [ATC'21] is one of the 64 papers accepted out of 341 submitted, with a very low acceptance rate of 18.8%)[2]; similarly, my USENIX FAST'20 paper [FAST'20] is one of the 23 papers accepted out of 138 submitted, with an acceptance rate of 16.7% only; furthermore, my recent work to appear in SC'22 [SC'22] received a high rank at the peer-review phase and is nominated as one of five **Best Student Paper Award Finalists** among over 500 papers submitted (with a selection rate of less than 1%).

Published Work Contributing to Data Science. Most of my publications propose new methods, new systems, and new policies to make data analytics and ML applications more efficient and more scalable. These publications include: FAST'20 [FAST'20], SoCC'20 [SoCC'20], ATC'21 [ATC'21] (which propose new serverless stateful computing methods for more performant and more cost-effective data analytics and data storage); HPDC'20 [HPDC'20], SC'21 [SC'21], ICDM'20 [ICDM'20] (which propose new, distributed/decentralized machine learning systems for emerging federated learning and ADMM deep learning); EuroSys'15 [EuroSys'15], HPDC'15 [HPDC'15], ATC'16 [ATC'16], HPDC'16 [HPDC'16], SC'18 [SC'18], and FAST'18 [FAST'18] (which propose new ways of data management and data storage for various use cases including but not limited to cloud big data analytics, internet-scale web applications such as Twitter, enterprise data processing systems, and enterprise container registries).

4.2 Research Products and Commitment to Open (Data) Science

I am committed to open science. I make my research and its dissemination, including publications, datasets, and software artifacts, accessible to support use and development both in academia and industry. I have a track record of open-sourcing my research artifacts. For example, the artifacts of the INFINICACHE project, the WUKONG project, and the FAASNET project are publicly available at [InfiniCache Project], [Wukong Project], and [FaaSNet Project], respectively.

Impact of Open-Source Software and Datasets. The software artifacts and datasets released by my research group have been widely disseminated and widely used by both the industry and academic communities. For example, the INFINICACHE project [InfiniCache Project] has been starred by more than 220 times and has been featured at [IEEE Spectrum Article]; the FAASNET datasets [FaaSNet Project] and the IBM Docker registry workload datasets [Docker Registry Traces] were collected for a total duration of 75 days spanning five geo-graphically distributed datacenters [FAST'18]; these datasets have been downloaded and used by thousands of research groups from the world wide and have been extensively studied and compared against by a series of research works.

[2]Note that an acceptance rate of less than 20% is deemed very competitive for major Computer Science venues.

5 Concluding Remarks

This statement summarizes the way my scholarly work has contributed to the field of Data Science for the last five years. My research has made significant contributions to the field of big data processing systems, cloud computing, and data management systems. My research products have generated real-world impact and have been used by researchers from all over the world for data analysis and computer workload characterization. I am committed to continued excellence in data science research and open science for years to come.

References

[SoCC'17] Eric Jonas, Qifan Pu, Shivaram Venkataraman, Ion Stoica, Benjamin Recht. *Occupy the cloud: distributed computing for the 99%*, In ACM SoCC '17.

[SoCC'20] Vaishaal Shankar, Karl Krauth, Kailas Vodrahalli, Qifan Pu, Benjamin Recht, Ion Stoica, Jonathan Ragan-Kelley, Eric Jonas, Shivaram Venkataraman. *Serverless linear algebra*, In ACM SoCC '20.

[FAST'20] Ao Wang, Jingyuan Zhang, Xiaolong Ma, Ali Anwar, Lukas Rupprecht, Dimitrios Skourtis, Vasily Tarasov, Feng Yan, **Yue Cheng**. INFINICACHE*: Exploiting Ephemeral Serverless Functions to Build a Cost-Effective Memory Cache*, In USENIX FAST '20.

[NSF CAREER] *CNS-2045680: CAREER: Harnessing Serverless Functions to Build Highly Elastic Cloud Storage Infrastructure*, https://www.nsf.gov/awardsearch/showAward?AWD_ID=2045680, 2021.

[SoCC'20] Benjamin Carver, Jingyuan Zhang, Ao Wang, Ali Anwar, Panruo Wu, **Yue Cheng**. WUKONG*: A Scalable and Locality-Enhanced Framework for Serverless Parallel Computing*, In ACM SoCC '20.

[ATC'21] Ao Wang, Shuai Chang, Huangshi Tian, Hongqi Wang, Haoran Yang, Huiba Li, Rui Du, **Yue Cheng**. FAASNET*: Scalable and Fast Provisioning of Custom Serverless Container Runtimes at Alibaba Cloud Function Compute*, In USENIX ATC '21.

[SoCC'21] Li Liu, Haoliang Wang, An Wang, Mengbai Xiao, **Yue Cheng**, Songqing Chen. *Mind the Gap: Broken Promises of CPU Reservations in Containerized Multi-tenant Clouds*, In ACM SoCC '21.

[SC'22] Yuqi Fu, Li Liu, Haoliang Wang, **Yue Cheng**, Songqing Chen. *SFS: Smart OS Scheduling for Serverless Functions*, In SC '22.

[HPDC'20] Zheng Chai, Ahsan Ali, Syed Zawad, Stacey Truex, Ali Anwar, Nathalie Baracaldo, Yi Zhou, Heiko Ludwig, Feng Yan, **Yue Cheng**. TIFL*: A Tier-based Federated Learning System*, In ACM HPDC '20.

[SC'21] Zheng Chai, Yujing Chen, Ali Anwar, Liang Zhao, **Yue Cheng**, Huzefa Rangwala. *FedAT: A High-Performance and Communication-Efficient Federated Learning System with Asynchronous Tiers*, In SC '21.

[NSF FMSG] *CMMI-2134689: FMSG: Cyber: Federated Deep Learning for Future Ubiquitous Distributed Additive Manufacturing*, https://www.nsf.gov/awardsearch/showAward?AWD_ID=2134689, 2021.

[ICDM'20] Junxiang Wang, Zheng Chai, **Yue Cheng**, Liang Zhao. *Toward Model Parallelism for Deep Neural Network based on Gradient-free ADMM Framework*, In IEEE ICDM '20.

[NSF OAC] *OAC-2007976: OAC Core: SMALL: DeepJIMU: Model-Parallelism Infrastructure for Large-scale Deep Learning by Gradient-Free Optimization*, https://www.nsf.gov/awardsearch/showAward?AWD_ID=2007976, 2020.

[Amazon Research Award] *Amazon Research Award: Distributed Large-scale Graph Deep Learning by Gradient-free Optimization*, 2020.

[Meta Research Award] *Serverless and Scalable GNN Training with Disaggregated Compute and Storage*, https://research.facebook.com/research-awards/2022-request-for-research-proposals-for-ai-system-hardware-software-codesign/, 2022.

[NSF SPX] *CCF-1919075: SPX: Collaborative Research: Cross-stack Memory Optimizations for Boosting I/O Performance of Deep Learning HPC Applications*, https://www.nsf.gov/awardsearch/showAward?AWD_ID=1919075, 2019.

[FAST'18] Ali Anwar, Mohamed Mohamed, Vasily Tarasov, Michael Littley, Lukas Rupprecht, **Yue Cheng**, Nannan Zhao, Dimitrios Skourtis, Amit S. Warke, Heiko Ludwig, Dean Hildebrand, Ali R. Butt. *Improving Docker Registry Design based on Production Workload Analysis*, In USENIX FAST '18.

[SC'18] Ali Anwar, **Yue Cheng**, Hai Huang, Jingoo Han, Hyogi Sim, Dongyoon Lee, Fred Douglis, Ali R. Butt. *BESPOKV: Application Tailored Scale-Out Key-Value Stores*, In SC '18.

[ATC'16] **Yue Cheng**, Fred Douglis, Philip Shilane, Michael Trachtman, Grant Wallace, Peter Desnoyers, Kai Li. *Erasing Belady's Limitations: In Search of Flash Cache Offline Optimality*, In USENIX ATC '16.

[HPDC'16] Ali Anwar, **Yue Cheng**, Aayush Gupta, Ali R. Butt. *MOS: Workload-aware Elasticity for Cloud Object Stores*, In ACM HPDC '16.

[EuroSys'15] **Yue Cheng**, Aayush Gupta, Ali R. Butt. *An In-Memory Object Caching Framework with Adaptive Load Balancing*, In ACM EuroSys '15.

[HPDC'15] **Yue Cheng**, M. Safdar Iqbal, Aayush Gupta, Ali R. Butt. *CAST: Tiering Storage for Data Analytics in the Cloud*, In ACM HPDC '15.

[OSDI'22] Xingda Wei, Fangming Lu, Tianxia Wang, Jinyu Gu, Yuhan Yang, Rong Chen, Haibo Chen. *No Provisioned Concurrency: Fast RDMA-codesigned Remote Fork for Serverless Computing*, In USENIX OSDI '22.

[IEEE Spectrum Article] `https://spectrum.ieee.org/pay-cloud-services-data-tool-news`.

[InfiniCache Project] `https://ds2-lab.github.io/infinicache/`.

[Wukong Project] `https://ds2-lab.github.io/Wukong/`.

[FaaSNet Project] `https://github.com/ds2-lab/FaaSNet`.

[SFS Project] `https://github.com/ds2-lab/SFS`.

[Docker Registry Traces] `http://iotta.snia.org/traces/static`.