Additional Priority Idea

Computer Science

How can Yale help define and shape our increasingly computational world?

Over the past 40 years, computers have become essential tools in almost every form of human endeavor. Our lives are shaped by sophisticated computation in countless, almost invisible, ways - in fields ranging from engineering, medicine, and science to mass communication and journalism, to law, international relations, and finance. Recently, a more profound change has taken place. Sophisticated computational techniques, including artificial intelligence, machine learning, formal verification and cryptography are transforming the world and, critically, reshaping the ways in which we generate new knowledge and carry out research.

Three emerging trends are fundamentally transforming the field of computer science:

- The success of artificial intelligence: In the last decade, the fields of artificial intelligence (AI) and Machine Learning have made significant advances that have enabled amazing technologies such as speech recognition, computer translation, and self-driving automobiles. We anticipate that further advances in these fields will greatly increase the fraction of our world controlled by information systems and augment human interaction with technology. Decisions and discoveries will be made by humans collaborating with computers.

- New “vertical” research themes: Computer Science is increasingly becoming organized around “vertical” research themes that cut across the largely historical distinctions between theory, AI, systems, and applications. These new vertical themes include robotics, the Internet of Things (IoT -- the growing network of internet-equipped devices in homes, businesses, laboratories and industries), smart cities, cyber-physical systems, connected health, and blockchains (decentralized, encrypted transaction records) with smart contracts.

- New cyber entities and emerging challenges: The vertical themes spawn many novel cyber entities (e.g., computer programs, systems, devices, data sets, etc.) that present both challenges and opportunities. The application, safety, and social implications of these new entities will require research breakthroughs in key CS research areas, including cyber security, resilience, fairness, and privacy. Computer science must help address the ramifications of computing advances on society, the law, and the economy.

Computer Science is a critically important academic discipline. However, meeting the emerging opportunities and challenges in the field (which involve human, physical, biological, and social entities, as well as a large variety of computing components) will require close coordination among diverse academic research communities, industries, the government, and policy makers. There is a severe shortage of qualified computer scientists at all levels (from bachelor’s to Ph.D.), and the competition from industry and within academia for qualified people is fierce. Success in computer science—both in its application to the pursuit of knowledge and in training the next generation of leaders—requires investment in new types of interdisciplinary researchers who can work across multiple traditional fields. Because CS is now at an inflection point, it will be critical for Yale to take advantage of today’s emerging opportunities to shape and lead a robust computer science program.

Many new opportunities are arising at the intersections of computer science and other fields – referred to broadly as “CS+X,” where X can range from Law, Medicine, or Business to Economics, Biology, Engineering, Music or Quantum Computing. Majoring in CS+X typically entails a program of study that combines a strong grounding in Computer Science, a strong grounding in another discipline, and advanced
coursework or independent project work that combines the two disciplines. Establishing programmatic expertise in specific CS+X areas is a natural fit for a liberal arts university such as Yale, with unparalleled breadth of scholarship in the social sciences, humanities, law, and medicine. By investing in computer science and leveraging these strengths, Yale is uniquely positioned to lead in select targeted fields, including:

- **CS+Social Sciences** (e.g., CS+Psychology, CS+Economics, CS+Political Science or CS+Law)
  As robots and computational devices proliferate, it becomes increasingly crucial that we understand how they should interact with humans. This is studied in the field of Human-Computer Interaction, which lies at the interface of Computer Science with Psychology. As we ask computers to assist in activities such as driving and to make decisions that impact human lives, we must decide how Artificial Intelligence and other computational decision systems should function and be regulated. As our lives become increasingly digital - and attacks on computer systems become increasingly sophisticated - establishing trust in information and identities also becomes a technological challenge. Blockchains, cryptocurrencies, cryptography and cyber security, involving research in Computer Science, Economics, and Law, address these challenges. By investing in faculty, research, and teaching at these critical junctions, Yale and its Department of Computer science will be uniquely positioned to help shape these fields and establish domains of eminence.

- **CS+Biological Sciences and Medicine**
  Computation is permeating every field of biology and medicine. The increasing power and scale of biomedical data has necessitated large-scale computational analysis, spawning the field of bioinformatics that aims to design analytical methods and software tools to aid in interpreting and understanding massive collections of biological data - and more recently the field of computational biology, which seeks to develop predictive models of the dynamics of biological systems across a wide range of scales from molecules to cells to organs and organisms. In addition, computation is essential for modern imaging techniques and underpins emerging techniques in molecular and developmental biology, where it is now possible to analyze RNA, DNA or proteins from millions of individual cells across thousands of dimensions.

- **Artificial intelligence and machine learning** (see Data Science above)
  The fruits of artificial intelligence and machine learning research play a vital role in all these efforts. They include: the computer vision and image processing techniques that allow robots to sense the world or help clinicians to diagnose disease and plan treatments, the algorithms that allow robots to accomplish desired motions, the speech recognition tools that allow us to talk with computational devices, the language processing tools that allow computers to gain knowledge from text, and the data mining algorithms that permit discovery from biomedical data.

**Computer Science at Yale**

The USSC emphasizes the important role of CS in a Yale education. Over the past decade, CS has become one of the most popular subjects of study in the Ivy League, drawing large numbers of students and majors. Yale College’s class of 2019 boasts 116 computer science majors, making computer science the fifth largest undergraduate major. In addition to the expansion of CS majors, the number of students seeking training in CS is also expanding. The number of enrollments in CS courses has increased more than three-fold over the past decade. Additional student and faculty engagement in CS learning has taken place in the form of student-organized Hackathons, coding camps for undergraduates, graduate students, postdocs and faculty, and other forms of peer-to-peer learning. The CS environment has also provided a fruitful environment for innovation and experimentation, including the introduction of Undergraduate Learning Assistants (ULAs) to the Yale ecosystem.
In recognition of these trends, Yale has made a commitment to an expansion of the Computer Science faculty. This expansion is still in its earliest stages. In 2015, the University announced a plan to increase the department from its historical size of 20 primary and fully joint ladder faculty (plus 6 non-ladder FTEs) to an intermediate size of 25 ladder faculty (plus an increased number of non-ladder FTEs), with possible further growth to 30 ladder faculty as strength in the department is established.

USSC endorses Computer Science’s plan to expand its faculty by seizing the intersectional opportunities represented by a “CS+X” approach. In conjunction with this commitment to increase the number of primary faculty, faculty with secondary appointments have been added to the CS community through hiring in adjacent departments, most notably in Electrical Engineering and Statistics and Data Science. We also see interesting opportunities for hiring in the area of Quantum Computing that are worth exploring (see Quantum above). Efforts to strategically invest in computer science research and education will allow Yale to gain strength in this important area of 21st century knowledge. They will also boost science and other pursuits across campus, and help educate the next generation of leaders in fields ranging from the social sciences, to medicine, to law.