The Computer Scientist as Polymath

The Evergrowing Need for Well-Balanced Computer Science

Devin Gonier
Department of computer science
Lewis University
Romeoville, IL
DevinCGonier@lewisu.edu

***Abstract*—Computer scientists need to be actively engaged in many sub-disciplines of computer science and familiar with relevant outside research to be successful. This white paper argues for the importance of this fact by exploring three fields: Intelligent Systems, Net-Centric Computing, and Human-Computer Interaction. After a brief overview of these topics, a prognostication on how technology of the future will increasingly require overlapping expertise in these fields and with outside disciplines will be explored.**

Keywords—Intelligent Systems, Net-Centric Computing, Human-Computer Interaction, Interdisciplinary computer science

I. Introduction

The appellation 'renaissance man' is perhaps best epitomized by Leonardo Da Vinci, who was able to successfully pursue a wide variety of disciplines such as architecture, science, painting, inventing, mathematics and many others. Similarly, computer scientists today must become acquainted with a multiplicity of sub-fields and related outside disciplines. It is easy for a young computer scientist to be myopically attracted to having a depth of knowledge in one research area and neglect to properly study others. Unfortunately, to do so would come at the cost of inhibiting the innovation so typical of 'renaissance men' of the past who were able to see interconnections between disciplines that peers ignored as irrelevant. For example, if it weren't for Darwin's interest in Charles Lyell's slow-moving geology, it is unlikely that Darwin would have observed the similar slow changes associated with natural selection. What breakthroughs in computer science similarly depend on seeing interdisciplinary connections? In what follows, the importance of finding interconnections between subfields will be argued by comparing the sub disciplines: *Intelligent Systems*, *Net-Centric Computing*, and *Human-Computer Interaction*. After a brief overview of these topics, a prognostication on how technology of the future will increasingly require overlapping expertise in these fields and with outside disciplines will be explored.

II. Overview of Sub-Disciplines

A. Intelligent Systems

The field of *Intelligent Systems* typically involves the development of computer systems which perceive their environment, learn from it, and act based upon what has been learned [8]. It diverges from typical user-interface models of computing (i.e. applications that depend entirely on human input where execution is done via predetermined programmed computational steps) in that machine learning algorithms model and respond to data based on revisable learned heuristics from training sets. Research within the field of Intelligent Systems requires strong foundations in machine learning, artificial intelligence, algorithms, programming, mathematics, and other disciplines.

One problem researchers face in this field is the trouble with dynamic environments. Typical computer systems are designed to operate in relatively static software architectures where assumptions remain mostly the same. Alternatively, Intelligent Systems must act in response to environments that frequently change. Intelligent Systems must distinguish between important and unimportant changes and have a good understanding of the kinds of things that tend to change. While this may seem simple, it proves to be a gargantuan task.

Cognitive scientists like Daniel Dennett refer to this complicated cognitive phenomenon as the *Frame Problem*. Dennett explores how simple acts like making a snack involve thousands of assumptions (the knife is where you left it last, milk exits a carton when tilted, objects on plates stay on plates when moved etc.) that are easily taken for granted by humans but challenge computers. The human brain fluidly calculates the changes worth giving attention and the assumptions which are safe to make when going about simple processes. Intelligent Systems must be programmed to interact with dynamic environments to prioritize changes that are most relevant and likely to influence the behavior in question [1].

Similarly, Intelligent Systems need to successfully deal with uncertainty by employing reasoning principles like non-monotonic logic. Intelligent system's reasoning should be able to retract previously held conclusions and determine the acceptable amount of information to suffice a conclusion. Absolute certainty involves variables that most humans completely ignore, but knowing which variables to ignore and which to fixate on is a difficult balancing act. Furthermore, when one draws the wrong conclusion it is essential to be able to revise beliefs appropriately [6], [3].

Finally, both the ability to fixate on relevant changes and determine what is sufficient to draw a conclusion (and revise it) are all a part of the overall goal of acting as correctly as possible within a limited amount of time. Most decisions made within a dynamic environment are constrained by time. If a computer takes too long to process something, then the appropriate behavior may no longer be relevant when that behavior is deemed actionable. These and other problems are what researchers in the field of Intelligent Systems address.

B. *Net-Centric Computing*

The primary objective of researchers studying Net-Centric Computing is to build better "distributed environments where applications and data are downloaded from servers and exchanged with peers across a network on as-needed basis" [5]. In other words, researchers ask the question, how can a system of computers networked together outperform isolated ones? The internet is perhaps the most important example of how advancements in Net-Centric Computing have influenced modern society. One popular model for companies today are systems that balance private information management with outside open user input interfaces, so that private information remains private but is useful in the public sphere.

Net-Centric Computing depends as much upon algorithms as it does on well-designed communication infrastructures. When Net-Centric computing is well networked and incorporates efficient distributed algorithms, it can have several key advantages. First, the processing power of a Net-Centric system is more scalable than a single isolated computer because it is typically easier (and more cost-effective) to add nodes than processing power to a single machine. Second, Net-Centric Computing allows for dispersed access-points of information. Whether access points involve instruments that measure weather conditions across a geographically wide area or many different user-inputs from around the world, the ability to take information into the system is superior to isolated systems that have only a single input medium. One last advantage worth mentioning here is that because distributed systems are not reliant on a single processor they are better able to handle malfunctions than their isolated counterparts.

Net-Centric researchers focus on algorithmic developments that efficiently channel messages, balance message complexity with processing time, and effectively use resources (such as message mediums: i.e. radio vs. wired etc.) Therefore, researching methods for determining when messages are sent (synchronous vs. asynchronous) and to whom (broadcast methods) is crucial [4]. Furthermore, one must factor in how (or if) networks are centralized and how peers connect to one another (i.e. peer to peer, grid computing, flow computing etc.) [5]. Ultimately, much of the development in Net-Centric Computing comes from balancing the amount of time it takes to send and receive messages with the amount of time it takes to process messages within a node.

C. *Human-Computer Interaction*

Since around the early 1970's researchers have been trying to make computers more useable for novice users. Companies which have been successful in this endeavor reap great rewards, as consumers easily see the advantages and usefulness of computing. The transition from command-based computing to desktop-based computing came from careful thinking about how people feel comfortable doing work. Desktop computers were modeled off real filing systems with folders and applications spatially located on screens as icons. The result was a massive transformation in how people do work. Were it not for Human-Computer Interaction (HCI) developments, the computer would have likely been a niche tool isolated to specific groups instead of the ubiquitous use it enjoys today.

The success of HCI depends upon a deep understanding of the "dynamic co-evolution of the activities people engage in and experience, and the artifacts – such as interactive tools and environments – that mediate those activities" [7]. In other words, it's important to see how technology changes and the changes in behavior people have towards technology as a kind of feedback loop. Successful researchers use a variety of different approaches, such as design thinking, to analyze how users engage with technology, then hypothesize other novel possibilities for engaging with it. They innovate new technology to accommodate their hypothesized new process of engagement and transform society as a result [7].

Much of HCI history can be grouped into "three eras: theories that view human-computer interaction as information processing" (as is typical of activities like document creation on a desktop computer), "theories that view interaction as the initiative of agents pursuing objects" (as would be typical of a user searching for something on the internet), or interactions as "socially and materially embedded in rich contexts" (as users of social media would behave) [7]. As a result of these different HCI theories, people communicate and work in modern society in much more sophisticated ways than they did previously.

HCI development is likely to bring many more innovations as technologies like the internet of things become more well-developed and as communities communicate more frequently through social media. Researchers that can foresee these changes and the behaviors that maximize the human utility of computer engagement will not only reap financial benefit, but could change how society functions.

III. INTERCONNECTIONS

Researchers in *Intelligent Systems, Net-Centric Computing,* and *HCI* all have things to say to one another. In fact, a successful computer scientist should be doing research in all three fields. It is likely (and indeed already the case) that Intelligent Systems will engage users in novel ways via networked methodologies. Net-Centric Computing of the future may involve human-computer interactions where computers are able to predict or interpret human needs and wishes, not as they are dictated directly, but as they are modeled through the interpretation of a dynamic environment. In other words, such computers would be able to predict what is trying to be achieved and act appropriately.

Such interactions will not occur on isolated machines, but across vast networks, where people are better able to communicate not only with one another but also with intelligent machines who can reciprocate in the creation of ideas. This new frontier in computing will require novel approaches in HCI where the fluidity with which people engage computers becomes more intuitive (and perhaps more based in natural language processing) than traditional desktop interfaces.

Intelligent Systems' researchers can leverage the advantages of Net-Centric Computing to provide a more data rich environment via access to multiple input nodes. Machine learning algorithms depend on the quality of training data. So, one would expect that more data will help these algorithms run more smoothly and learn more quickly.

Advancements in HCI will be essential in framing how people relate information to an Intelligent System. Moreover, part of the advancements in interpreting the intentionality of certain behaviors depend upon theories for how people in the past have interacted with computers, which comes straight from HCI theories and research.

However, computer scientists must not only look to their own discipline when developing theories. Techniques from psychology, cognitive science, behavioral economics and even business management are necessary for HCI theories to be relevant and powerful. Neuroscientists will continue to assist mapping brain responses to different interfaces to determine how effective they are. This will help to avoid the pitfalls of making assumptions that are untrue about the mind and will navigate researchers towards more effective ideas.

Neuroscience also could have much to offer Net-Centric computing in that as we understand the complex networked algorithms of the brain, we may be able to mimic them in distributed algorithms. How can the nervous systems be used as an analogue for a company's network architecture? Engineers who manage traffic congestion or physicists who understand the physical consequences of message congestion via wireless communication are also extremely important in finding efficiencies in distributed systems. Furthermore, quantum physicists studying quantum entanglement may completely revolutionize the process of messaging and altogether eliminate messaging time. This achievement could exponentially increase the efficiency of networked machines over isolated ones.

Finally, other disciplines also have much to offer researchers of Intelligent Systems. Neuroscientists that study how the brain learns or processes language and vision will grant important insights in developing the architecture of Intelligent Systems. Logicians and epistemologists that study belief revision semantics could prove invaluable in influencing how heuristics are stored and amended over time [3]. Alternative logics like quantum logic or paraconsistent reasoning may help researchers devise more sophisticated algorithms for solving problems or dealing with inconsistencies. Political philosophers may even help frame some discussions about the lasting impacts of technological advancements going forward. Finally, anyone familiar with machine learning algorithms will become quickly aware of the importance of mathematics in maximizing efficiencies. How can cost functions become better structured to efficiently determine the validity of a certain model? Altogether, there are many outside disciplines that can contribute to the development of intelligent systems in the years to come.

IV. Conclusion

It is absolutely essential that computer scientists remain aware of (and ideally are actively engaged in) a variety of sub-disciplines and outside disciplines. The Darwin's, Einstein's, and Da Vinci's of the future will likely be involved with some kind of computer science as it is becoming increasingly a medium for all kinds of development in modern society. Therefore, academics and companies alike should seek out 'renaissance men' that holistically value a variety of subjects in computer science and outside of it. The Kuhnian revolutions of computer science will depend upon these creative associations between disciplines and fields. The polymaths of tomorrow will use computer science to change the world.

References

[1] Dennett, Daniel. "Cognitive Wheels: The Frame Problem of AI." The Philosophy of Artificial Intelligence. Oxford: Oxford UP, 1990. 147-70. Print.

[2] Dodig-Cmkovic, Gordana. "Scientific Methods in computer science." Malardalen University (n.d.): n. pag. Web. 1 Apr. 2017. <http://www.mrtc.mdh.se/publications/0446.pdf>.

[3] Hansson, Sven Ove. "Logic of Belief Revision." Stanford Encyclopedia of Philosophy. Stanford University, 21 Apr. 2006. Web. 08 Apr. 2017.

[4] Muhammad, Rashid Bin, PhD. "Lecture Notes: Distributed Algorithms." Personal.kent.edu (2008): n. pag. Web. 25 Mar. 2017.

[5] Somani, Arun K., and Shubhalaxmi Kher. "Net-Centric Computing: The Future of Computers and Networking." Distributed Computing and Internet Technology Lecture Notes in computer science (2006): 14-26. Web.

[6] Strasser, Christian, and G. Aldo Antonelli. "Non-monotonic Logic." Stanford Encyclopedia of Philosophy. Stanford University, 11 Dec. 2001. Web. 08 Apr. 2017.

[7] "Human-Computer Interaction - Brief Intro: The Encyclopedia of Human-Computer Interaction, 2nd Ed." The Interaction Design Foundation. N.p., n.d. Web. 05 Apr. 2017.

[8] "What Are Intelligent Systems?" University of Nevada Reno. N.p., n.d. Web. 08 Apr. 2017.