Robotics and AI as a Motivator for the Attraction and Retention of Computer Science Undergraduates in Canada

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Abstract

Since the burst of the dot-com bubble in 2000, computer science has seen a significant decrease in enrollment in universities across North America. While this has been well-publicized in the media in the United States, Canada's numbers in this regard have been significantly worse. Within Canada, however, the Department of Computer Science at the University of Manitoba has been relatively fortunate: while a noticeable decrease has occurred, it is statistically much less than has occurred across Canada and the U.S. There are a number of reasons for this, one of which is the use of artificial intelligence (AI), and robotics in particular, as a tool for student recruitment and retention. In this paper, we examine enrollment trends of our university compared to the rest of the continent, discuss some of the reasons behind these trends, and describe how we use AI, and robotics in particular, as tools to attract and retain computer science students.

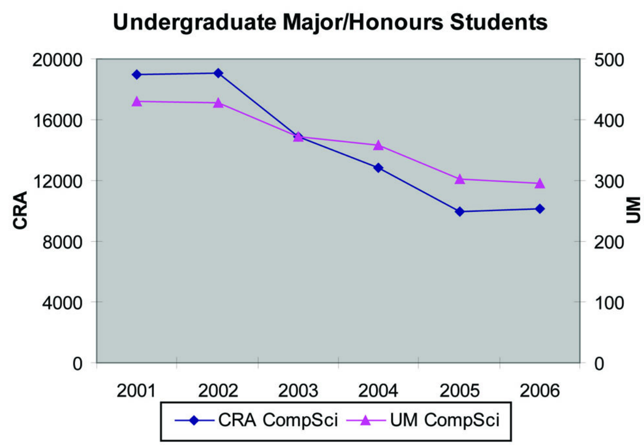

Figure 1: CRA Undergraduate CS Enrollment (North America) vs. University of Manitoba CS Enrollment, 2001-2006.

Introduction: CS Enrollment Decline in Canada

There has been much media emphasis in the past few years on decreased popularity of computer science (CS) among university students in North America. Much of this media emphasis has been on institutions in the US, and has often been sporadic in nature, coinciding with specific results from major universities, or very real concerns from business regarding the future labour force.

Our own university has certainly felt this trend. The University of Manitoba is a major Canadian university, the oldest in Western Canada, and the largest university within 1300 kilometers in Canada (approximately the same size as the University of Calgary, and slightly smaller than the University of Alberta). The Department of Computer Science has approximately 30 tenure-track faculty members, and granted 126 degrees in computer science in 2001 (in two programs, Major and Honours, with a cooperative education option in each), compared to 101 in 2005.

While we are most interested in a direct comparison of universities near us, precise enrollment statistics for CS are generally not widely published by individual universities, and are in fact often difficult to obtain. The most complete dataset from which to draw comparison of our experiences are the annual CRA Taulbee surveys (CRA 2001 2006). These allow separation of Canadian and American statistics, as well as separation of computer science in particular from related fields such as computer engineering. One difficulty in direct comparing these to local statistics is presenting both absolute numbers and relative trends given the difference in scale: Figure 1, for example, illustrates the base numbers of CS undergraduate students in North America compared the University of Manitoba. Our numbers ranged from 431 to 296 students, while North American numbers range from 19072 to 9985.

In order to properly compare trends, we must compare either normalized populations, so that the increases and decreases are examined on identical scales or examine year-over-year percentage increases and decreases. Figure 2 illustrates the former of these, plotting CRA data for North America as a whole, Canada individually, and the University of Manitoba, all for computer science enrollments only, normalizing all groups to an initial population of 10,000 students at the start of the period. The year over year increases and decreases, as a percentage of the previous year's students, are shown for the same three groups in Figure 3. Note

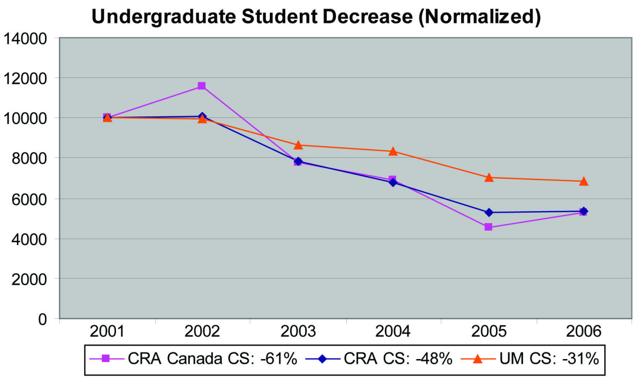

Figure 2: Changes in undergraduate CS enrollment, 2001-2006, with all groups normalized to an initial population of 10,000.

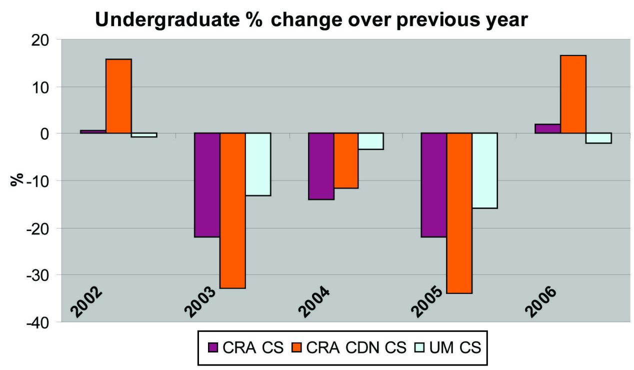

Figure 3: Year-over-year increase/decrease in undergraduate CS enrollment, expressed as percentage of previous year, 2002-2006

that this data tracks only enrolled students, and data for graduands is not compared: this is because locally available data tracks only actual degree recipients, while CRA data tracks only degree candidates for the current year as opposed to those that actually receive degrees. Our local decrease in graduands is noted above, however.

Both of these figures show a particularly difficult situation in Canada relative to North America. Since Canada has only approximately 1/9th the population of the US, and the two countries are one another's largest trading partners, the Canadian Economy tends to follow most of the trends of the US after a given time lag. This is illustrated strongly in the increase in Canadian students in 2001 while the North American whole was already decreasing. Some of this may also be attributable to post-9/11 immigration restrictions in the US (a significant increase in foreign students was certainly apparent at the graduate level locally in 2002, and similar reports can be found across Canada). Following this, however, Canadian CS enrollments declined even more than North America as a whole, resulting in a 61% decrease (maximum-minimum over the entire time period), compared to only a 48% decrease across all of North America. Figure 3 illustrates two particularly difficult years, 2003 and 2005, when a greater than 30% drop occurred each year in Canada. The increase in Canada in the last year of the period also shows that the two Figures must really be examined together, since a 15% annual increase seems more significant than it is in reality, since it is 15% of a much smaller body given the previous years' decreases.

Most interesting to us in this trend is its comparison to our own university. During the 2001-2006 time period, the downward trend in Figure 2 is much less severe, and the entire period resulted in only a 31% decline in enrollment, even though the country as a whole incurred virtually double that rate.

There are a number of reasons for this trend, and one is most definitely economic. The University of Manitoba serves a large area, is the largest university in the province by a wide margin, and gets a large number of local students (e.g. in 2005, 78% of enrollment - 22083 of 28037 students - originated in the Province of Manitoba (ISBook 2006)). Our provincial economy tends to be diverse and stable, and does not undergo the same degree of "boom" and "bust" that are seen in other areas of the country. This alone, however, does not adequately explain a 50% less overall decrease than the country as a whole, in a phenomenon that has swept North America.

Another significant factor, however, is a concerted effort to attract and retain students. While the majority of our faculty do at least some work in attraction and retention (75%, according to an internal survey (Penner 2006)), the authors, who direct the Autonomous Agents Laboratory within the department, tend to participate in almost every potential recruiting event held throughout the year, as well as many external events that serve as opportunities to promote computer science through artificial intelligence and robotics. We began a concerted effort to use our field to attract and retain students starting in 2001, and have increased the degree of our participation in this regard every year.

While we cannot precisely quantify the effect of our own individual work, we believe that direct and indirect methods by which we have used AI, and robotics in particular, as a recruitment and retention tool has had a strong influence on the trends shown in Figures 2 and 3. In this paper, we describe these efforts and discuss some of the ways in which AI and robotics can play a role in student attraction and retention. We begin by pointing out some of the reasons behind the enrollment trend as a whole, and then follow with a description of some of our efforts to deal with these factors and some of the ways in which other areas of AI can also assist in this regard.

Behind the Numbers: Problems to Address

The general reasons behind the trends described in the previous Section are many. Some, such as a perceived lack of jobs, can and will be addressed through the general media over time: for example, that the number of job opportunities in CS/IT are increasing, and that the pay for these jobs is high. Others, however, are more insidious, and will require a significant effort on the part of the field to change.

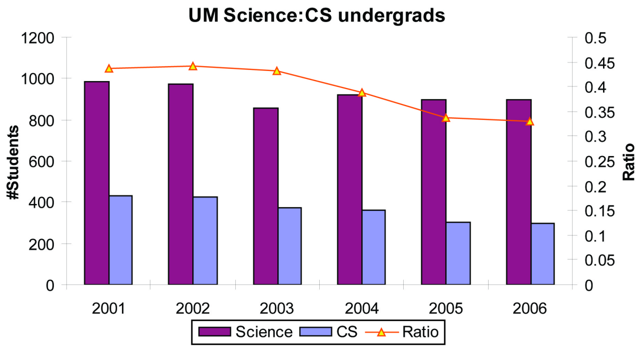

Figure 4: Number of CS major/honours students and their proportion to the rest of the Faculty of Science at the University of Manitoba.

The largest of these is that the type of work involved in CS is not as interesting or exciting as could be found in other fields. A traditional perception of computer scientists as someone who sits in front of a PC writing code in the dark, and never interacting with others, have been reported in many media (and indeed, in lore among many computer scientists). Some of this effect is also from the reverse side of this relationship: that other fields are seen as more interesting or rewarding, and this affects retention and recruitment outside of CS as well. In our university, if we examine the percentage of students in the Department of Computer Science as a proportion of those in its home Faculty of Science (Figure 4), we see a downward trend. This indicates that to some degree, students are being lost to other areas within science, possibly because these are perceived as more interesting fields. The decrease in proportion, roughly 25%, is less than the overall decrease, so clearly some are leaving the sciences all together.

Anecdotally, this seems to be to Engineering, at least locally and in terms of many of what appear to be many of the better potential CS students. From an AI standpoint, good work can of course be accomplished in branches of engineering as well, but this is a serious concern to computer science. This is also partially backed up by statistics as well: while computer engineering students have also decreased throughout the period according to CRA data, for example (38%), this has been less so than computer science students (although CRA data suffers in this respect by a traditional low number of respondents from computer engineering departments). A survey of 51 universities in Canada also found that while some areas had decreased, when considering all areas of engineering as a whole, the field remained stable over the period 2002-2005 (SHRC 2005), indicating that some areas of engineering must be benefitting. Anecdotally, engineering seems to have become what medical professions have been for many years: a place that parents strongly encourage their children to attend, because of perceived future opportunities, and interesting and well-paid career, and possibly other reasons. To increase CS attractiveness and ultimately to attract and retain students, we must emphasize that these features exist just as much in CS, and that it has exciting and fulfilling career options. Given the extent to which CS appears to equate with very mundane tasks to the general public, however, this is a significant challenge.

The second major factor, which interacts with the former, is the degree to which general university populations are changing, and how computer science appears as an option to the currently dominant groups. Almost universally, the most significant way in which changing university populations impacts CS is the increasing number of women attending university (locally, 56% of all students in 2005 were women (ISBook 2006)). Similarly, minorities are increasing in the population as a whole, and this will ultimately impact university populations. Statistics Canada projects, for example, that 31% of children in Manitoba are expected to be aboriginal by 2017, while this ratio was 21% in 2001. Efforts can change some of these balances (by, for example, ensuring that high school graduate males consider a university education as valuable as females), but these numbers indicate that the field must evolve and work to make itself attractive well beyond its traditional core.

Robotics and AI for Recruitment and Retention

In recent years, we have been using artificial intelligence, and robotics in particular, to interest students of all levels in computing and computer science. We believe that part of advancing our field is encouraging good students, so we attempt as much as possible to apply our research work to the improved education of students as well. Our experience ranges from using robots to teach elementary programming to schoolchildren (Baltes & Anderson 2005), to adapting complex robotics problems to be approachable by undergraduates (Baltes, Sklar, & Anderson 2004). We have also done extensive work on tools and techniques for making robotics more accessible by abstracting out some of the peripheral sensing and infrastructure problems that make real robots frustrating for students (Anderson & Baltes 2007b; 2006; Anderson *et al.* 2003) and adapting new technology to make robotics applications more interesting and accessible to students (Anderson & Baltes 2007a). In much of this work, attempting to make hard problems graspable by students of the desired level, while still providing an appreciation of the complexity of the problem is central, and these qualities are very similar to what needs to be achieved for successful recruitment and retention of students.

From this work and our previous experience in recruiting and outreach in our field, we believe that artificial intelligence, and particularly robotics, are both uniquely positioned as a field of computer science to reverse the trends described in Section , and are partly responsible for the lessened impact of those trends on our university.

The major features that AI and robotics can bring to the recruitment process include:

Hands-On Nature There are very few areas in CS where physical demonstrations not simply involving watching a screen are possible, other than interface devices. AI, and robotics in particular, can provide real interactive experiences that more directly involve an audience.

Ability to Relate to Problems The problems faced by AI can be easily explained in terms of problems that people face every day - in robotics, localization, mapping, perception, and agent interaction can easily be cast in an everyday light. This assists in reaching out to parents and students with little current awareness of computational technology. The fact that we can use human behavior as a yardstick for comparison also helps to show the future value of this technology and the current factors holding it back. One of our more telling examples is contrasting video of soccer-playing humanoid robots with that of real humans restricted a similar manner (limited vision).

Exciting Applications With robotics in particular, it is easy for people to see exciting applications themselves (e.g. urban search and rescue, security, etc.). While AI has many exciting applications, one of the difficulties in creating an appreciation of these is AI's ubiquitous behind-the-scenes nature. The fact that a directory assistance program is computerized and uses speech recognition, for example, is not necessarily immediately graspable by the general public in the same way that physical problems they can see themselves are.

Anthropomorphism Anything that gives the appearance of being an intelligent entity serves to engage students and takes on a life of its own in their eyes. While interactive programs (e.g. chat-bots) encourage this phenomenon as well, when using robotics we see this effect increase by several orders of magnitude. Children interacting with robots immediately ask anthropomorphic questions such as "Can he see me?", and the fascination this provokes seems to make people in general more open to seeing the science behind it. Indeed, many of us that work with robots had similar epiphanies provoked by anthropomorphism that led to our own interest in AI.

The efforts we put into applying robotics and AI for recruitment and retention can be divided into two areas: formal, organized events that occur in the university or the community, often specifically designed to interest potential students, and informal opportunities, which can be more pervasive and often have a higher impact because of their breadth.

The former category occur in any university community, but the fundamental thing for both CS and AI is that AI researchers take full advantage of them. Our universities put on special events throughout the year, such as open houses, homecoming, recruitment evenings for exceptional high school students, and high school outreach, and after a number of appearances, AI is always the first area that ends up being approached when a new event is proposed. We ensure that we have an interactive display at each and every one of these. Equally important are community events, where the bias toward recruitment may be less obvious. Local robot games, science museums, and community events can also reasonably easily be handled, since the same displays and examples can be adapted for each. What is important when planning for all of these events is that the general advantages discussed above be strongly focussed upon. The audience should be engaged directly in interaction as much as possible (e.g. teleoperating a robot and seeing how difficult situational awareness is), and wherever possible displays should be live as opposed to video recordings or simple still-life technology. Attempts should be made to ground all of this in everyday examples and the applications the drive the need for this technology, and the people staffing these should be those that can relate to other areas of CS as well (although this is arguably more often the case in an area that crosses boundaries, such as AI). Anthropomorphism will happen on its own, but there are ways of encouraging it: humanoid robots, for example, are less common in laboratories, but we find they encourage anthropomorphism more strongly, and are much more engaging to audiences than other types (Figure 5). We typically use demonstrations such as humanoid walking, kicking a soccer ball, combinations of behaviours such as crawling and getting up, as well as non-humanoid robots performing tasks such as obstacle avoidance and dynamic path planning, and elements of computer vision, such as ball-tracking and stereo vision.

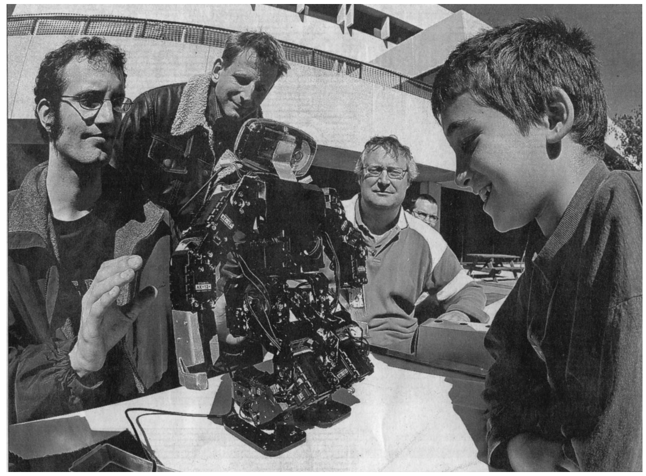

Figure 5: A child's fascination with a humanoid robot at the University of Manitoba's Homecoming (Woods 2007).

There are important weaknesses to physical demonstrations that also must be attended to for these to be a success. Anytime physical robots are involved, for example, things can go wrong. Each of these can be looked on as a teaching opportunity as well, however. If some environmental condition (e.g. a lighting changes) makes a robot less functional, this is an opportunity to discuss how this affects an intelligent system, how we adapt to it a humans, and what must be altered in the system to make this less disabling. If one of the many necessary interactive systems in a robot breaks down, it is an opportunity to emphasize how many separate systems must cooperate for something this complex to function smoothly, and possibly an opportunity to bring in some of the many other areas of computer science (e.g. operating systems) that are not obvious in these demonstrations. Having said this, it is important to have backup beyond live demonstrations (we use video heavily, since these can also be made available for use by other classes when scheduling problems arise). Since hands-on elements are still better than video, simpler demonstrations can also be used as back-up (e.g. a teleoperated interface to a robot, or physically placing a soccer ball for a kick to avoid dependence on video calibration).

Every laboratory is occasionally called upon to do the kinds of public demonstrations described above. Doing as many as possible is an important part of recruiting students, as is attempting to cover a breadth of these (e.g. Homecoming tends to attract parents, while high school outreach attracts the students themselves). Students can also be attracted once in university, and for retaining students, they must continue to see the utility of what we attempt to get across in recruitment settings. Both of these mean reaching students outside of their classes (e.g. setting up a robotics club), but also in their classes, including lower-level classes that students that are not already committed to CS take (e.g. many engineering or mathematics students will take a data structures course, and students from all areas take elective programming). This is an area where it is easy to ignore the fact that small examples, spread broadly, can go a long way. One of the authors (Anderson) traditionally teaches at least one or two courses at the first or second year level, where broad groups of students are reached. It is a small but important matter to attempt to bring in some of the advantages of AI and robotics for examples in these classes. Search in data structures, for example, can easily be brought into a robotics example, abstracted to a high enough level that students do not need an AI course to understand it. Even in first year, recursion and elementary data structures can be characterized using robotics examples, and even areas far removed from the core of AI can allow us to bring a piece of equipment into the classroom and turn the discussion to AI for a few minutes. A classic example is bringing in a small laser scanner from a robot and discussing the speed and efficiency with which data must be moved when 700 integer values are being transmitted serially, many times a second. This provides the same end result of a dry array-copying discussion, while allowing us to show students one small but interesting element from our work.

This is even more easily accomplished in higher-level courses, which is also important to retention. We bring a continual stream of such examples in courses such as non-imperative programming languages, real time systems, and operating systems. Some of this can be thought of as leveraging the breadth that is already involved in robotics: since all of these concepts are especially relevant to robotics, where we are doing both high-level and low-level computation, robotics should be adaptable peripherally to many other courses. This greatly increases the number of opportunities for student contact with our material, emphasizes AI's cross-disciplinary nature, and (because AI is not a required course in our program) allows us to draw some of the very good students to AI from other areas.

One additional element of recruitment and retention in which robotics and AI can be of assistance is in capturing media attention. The same physical nature, ease of understanding common problems, and anthropomorphism that drives student interest also drives the interest of the media. If media are at the types of events outlined above, they tend to gravitate to our demonstrations as well, and the resulting exposure attracts the interest of the general public. Keeping a high profile also means being as public with your AI and robotics work as possible. In robotics, the natural place for doing this is at competitions that offer a research element as well, such as RoboCup or FIRA. Each year our attendance at these events garners attention both within the university and via the media. After a few years this begins to take on a life of its own, to the point where students actively seek out the possibility of joining our group simply via this channel, or indirectly gaining attraction to CS even if they find the commitment level of competition participation too high for them. Our participation in these events is used extensively in promotion of our department and our university as a whole. While the international exposure of such events is part of what drives community and media interest, if funding precludes such participation, similar events can still be organized locally. While the organization of such events takes a great deal of work, so does the fundraising necessary to participate internationally. Even if competitions cannot be attended, keeping a visually engaging website where this work is promoted can be a useful draw, and helps media and students to gather background about your work as well.

Word of mouth generated by students is also important, and while this can be assisted through the class examples described earlier, it can also be assisted by keeping a high profile within the department/unit and keeping an open lab. Many of our students bring their colleagues into the lab to see what is going on, and the attention paid to such activities also helps to keep a critical mass. There are many programs available to help bring undergraduates into the lab (e.g. in Canada, NSERC Undergraduate Research Awards), and a side benefit to this is the word of mouth it spreads about interesting things going on in computer science. We find that even when students do not receive these awards, seeing the lab and being aware through university, media, and word of mouth contacts makes them interested in volunteering to assist in our work. This in turn creates a cycle, assigning in a higher profile and more word of mouth benefits.

Discussion

This paper has discussed trends in enrollment at our home university relative to those across North America, discussed the pros and cons of employing AI and robotics as recruitment tools, and outlined our efforts in this area. We believe that these efforts are one of the reasons why the impact we have seen on the field as a whole has not been felt as badly by our own institution. While we perform the usual types of public demonstrations and promotions that are available at most universities, we believe that attempting to make examples from AI and robotics ubiquitous in other courses is an especially important way that students that have been tempted to take one CS course (or are in a program that requires it) can be further enticed into our field. It is especially important to see the value of many small but insidious examples taken over a long period of time. Doing this at the high school level would be more challenging, in that it requires technological sophistication in teachers across the range of high school subjects, but would be equally valuable.

While we have not yet attempted to specifically direct these efforts to recruit women in particular, as opposed to promote the field in general, we believe the ideas presented here are also useful in this regard. Others have shown that the ability to include storytelling and other imaginative devices have proven especially useful in interesting women in CS, most notably through the use of Alice (Adams 2007). In our experience, there is no reason that these same concepts cannot be included in a robotics demonstration, and harness both the physical nature of robots and increase the effect of anthropomorphism over that already present in virtual characters. The key to doing this, like much of adapting robotics to novices, is abstracting out the most difficult parts, such as vision (Anderson & Baltes 2007b), in order for students to see some results quickly and get exposed to the complexity of the domain gradually. It may also be possible for students to become more interested in virtual worlds through exposure to physical robots.

To make exposure to robots effective for student attraction, the caveats of working with robots must also be understood. The fragility of some types of demonstrations has already been mentioned. Another danger is not having the audience see this as "real computer science" - it is easy to have a student come away from an encounter with a humanoid robot, for example, seeing more of the mechanics of servos and being more impressed with a preprogrammed walking gait than the computer science concepts that underly it. Unintended emphasis on mechanics over computing is an easy way to lead students to engineering instead of CS.

Two things are also needed in terms of human resources to support these efforts. The first is breadth in faculty teaching: we need people with an appreciation for AI and an understanding that such examples can be useful in our first and second year classes where students can be engaged by these. Alternatively, the ability to entice one's colleagues into using AI-based examples, or to allow one into their classes to perform these, is a useful substitute. This brings up the second resource, which is a critical mass of bodies to do these kinds of demonstrations. One individual bringing up examples in a class they would be doing anyway is a minimal additional load, but appearing in the classes of others can be a significant hit to one's schedule. Similarly, a critical mass of faculty and students is necessary to avoid burnout from having the same people attend the same events every time. Having good graduate students is crucial to this, since such demonstrations are both useful in professional training for graduate students, and motivating for them as well.

Much of what has been emphasized as advantages for robotics also serves for other areas of AI - simply to a lesser degree, especially in the hands-on nature and greater sense of anthropomorphism. From an AI standpoint, one additional caveat is that there are ultimately many areas of AI beyond robotics, and this needs to be understood by students as well. While robotics can be incredibly interesting, we would do our field a disservice if the fact that much of AI will ultimately be ubiquitous, but invisible or immobile in a robotic sense, is not emphasized to students as well.

Finally, an important point for AI researchers to realize when their recruitment efforts take on a life of their own and they are overwhelmed with requests for demonstrations is that there is a very important benefit personally and professionally to them from these efforts. A greater profile for AI means attracting better graduate students, more funding, more research and teaching opportunities, and greater professional development for ourselves as well.

Acknowledgement

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