The Role of PostDocs in Computer Science:
A Computing Research Association working paper

1/26/2011

There are a growing number of PostDocs in Computer Science. This increase appears to be affecting the makeup of the academic computing research enterprise and is becoming a major influence on individuals' career paths. This document was written to catalyze a discussion in the computing research community to determine the pros and cons of this trend. Below we report data characterizing the situation, raise a number of questions, and highlight what we believe are key issues for the computing community to consider.

What is a PostDoc?

A PostDoc is a person who has recently completed his or her doctoral degree, but has not yet found a permanent position on a faculty, in a research laboratory, or in industry. Different institutions use different names for the position; the term PostDoc is used here to describe all such cases. A PostDoc position is a *training* opportunity whereby a person can deepen his or her expertise and/or research skills for a few years, en route to a permanent position. The PostDoc position is typically funded either by a fellowship awarded directly to the PostDoc or by the institution at which they will spend a limited time. The following list suggests the perspectives that some different constituencies have of PostDoc positions:

- **PostDocs.** A PostDoc – the person – may accept a PostDoc position for a number of rather different reasons. The PostDoc may seek training or the experience of working under the tutelage of a specific expert, the PostDoc supervisor, or the opportunity to work in a more highly regarded institution than his or her PhD granting university. The PostDoc may be taking time out to strengthen his or her research portfolio in anticipation of a competitive job search. A PostDoc position for one of a professional couple may be a "holding position" while the spouse or significant other has a permanent position or completes his or her own studies. The PostDoc position may be taken *after* securing a permanent position, but before starting in it, for various reasons including synchronizing "two-body clocks," gaining exposure in a related area (e.g., interdisciplinary research), or changing fields. Anecdotally, it is increasingly common for PhDs to remain with their research group after completion of the PhD.
- **PostDoc Supervisors.** Supervisors often hire PostDocs as "experienced hands" to support research work. This is particularly true for research projects with short-term deliverables, where a PostDoc may be more capable than a graduate student to meet contract requirements. A PostDoc can also offer expertise outside the supervisor's area of focus, useful for interdisciplinary research. Yet another reason for a faculty

member to attract and fund a PostDoc is because there is no graduate student available to that faculty member due to, for example, admission rates or student preferences.

- **Institutions Employing PostDocs.** PostDocs can be a source of skilled research labor with relatively low employment costs and no permanent commitment by the institution.
- **Computer Science as a Field.** The academic research enterprise involves (at least) four categories of people: tenure-track faculty, research faculty dedicated to specific research efforts, PostDocs, and students. There is a significant overlap in expertise with respect to the skills of individuals in the different categories. Individuals from different categories are increasingly being asked to do jobs that were formerly restricted to one category.
- **Funders.** Federal agencies that fund research and development as well as industry provide support for PostDocs, using many independent programs. The motivation for such funding includes a commitment to training of personnel, as well as a desire to efficiently execute research and development. It is important that the size of the PostDoc population is appropriate to the size of the other categories of research positions.

Why raise the issue of PostDocs now? First, there has been an increase in the in number of new PostDoc appointments in compuer science and a decrease in the number of tenure-track faculty hires (see Figures 1 and 2 below). Second, we have seen life sciences get very badly out of balance with respect to the number of PostDocs and the long delay before PostDocs, on average, take permanent positions. Is computer science at risk of having a similar problem? Third, there appears to be an increasing trend in computer science departments toward preferring that a tenure-track faculty candidate have a body of publications that is more consistent with having spent time in a PostDoc position, than with that of a newly graduated PhD (see Table 1 below). Our objective is to stimulate discussion throughout the community of the issues of PostDoc balance, population size and career progression, and the impact of those issues on other aspects of the computing research enterprise.

Balance among types of positions in the research enterprise

Since 1997 both the size and the balance between the various categories of researchers has changed. Absolute numbers (as a three-year rolling average) are shown in Figures 1 and 2 [Taulbee]. Figure 1 shows how many new PhDs accept each type of position in the research enterprise: PostDoc, tenure-track faculty, teaching faculty, research faculty, industry and “other”. The most dramatic change is in the number of PhD graduates directly hired into industry; it has increased from roughly 240 in 2004 to roughly 760 in 2009. Today, roughly 42 percent of all PhD graduates are hired into industry immediately after completing their PhD.

The next most significant change is in the number of new PhD graduates pursuing positions *other* than tenure-track faculty, research faculty, teaching faculty, postdoctoral fellowships and industrial jobs. These positions include other academic positions in computer science or computer engineering departments such as part-time instructor-level positions; academic positions in non-computer science or computer engineering departments; government positions; employment abroad; self-employment; or unknown positions (i.e., in many cases, reporting departments were unaware of their graduates' future career plans). Also included in the "other" pool are those without firm employment commitments following graduation (reported as "unemployed"). The number of new PhDs in the "other" category has surged from 244 in 2003 to 645 in 2009, with the greatest increases among those pursuing employment abroad (up from 31 in 2003 to 140 in 2009) and unknown positions (up from 126 in 2003 to 336 in 2009). (The number of PhD graduates hired into academic positions in non-computer science or in computer engineering departments (which may include tenure-track positions in these departments) has always been fairly small and has declined in recent years, so this pool of individuals is not affecting the trends we see among tenure-track faculty hires shown in Figures 1 and 2.)

The total number of PhDs graduated in 1998 was 918 (three-year rolling average). By 2009 the total PhD production had roughly doubled to be 1800.

Figure 1: Hiring of new computer science PhDs from U.S. and Canadian universities, as a 3-year rolling average 1998-2009

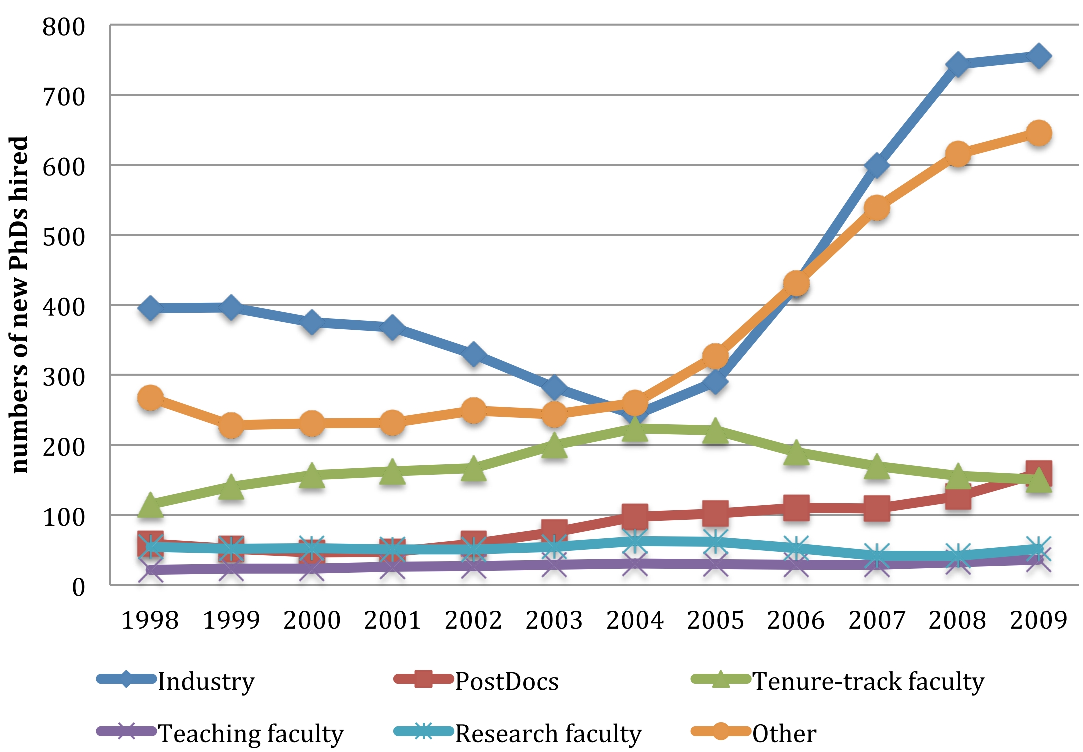
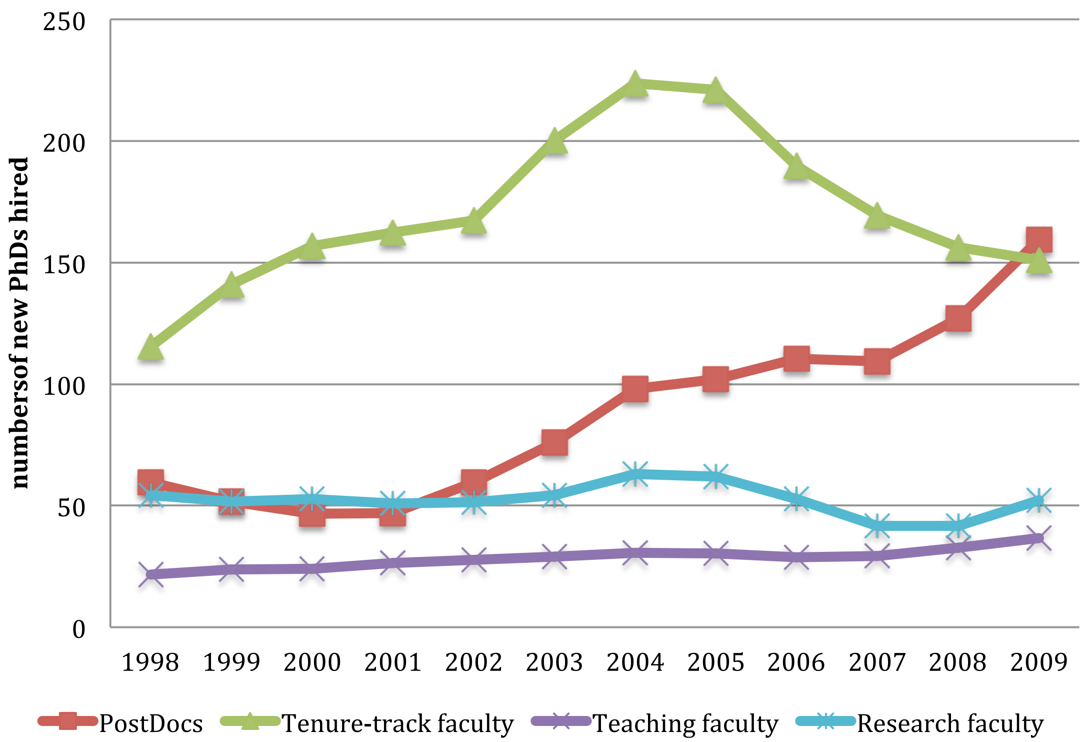


Figure 2 graphs the same data as Figure 1 but excludes the data on industry and "other" so that the remaining data are easier to view. Figure 2 shows that tenure-track faculty positions for new PhDs have declined by one third. There were 224 tenure-track faculty hires in 2004 and 151 in 2009 (note that these numbers correspond to the three-year rolling averages for these years except for the trailing two years). An increase in the number of PostDocs commenced slightly earlier; there were 51 new PostDocs hired in 2001, and that number has increased by more than a factor of three to 159 in 2009 (again, we calculated three-year rolling averages to smooth the data).

Figure 2: Academic hiring of new computer science PhDs from U.S. and Canadian universities, as a 3-year rolling average 1998-2009



The data show that for over a decade teaching faculty and research faculty have roughly stayed constant in number. Today, the combination of teaching faculty and research faculty positions account for roughly 25 percent of the positions in academia, and about 5 percent of all positions.

So, today, for a graduating PhD there are essentially an equal number of PostDoc and tenure-track positions open. Between 2002 and 2004 there were roughly 2.5 times more tenure-track positions open than PostDoc positions. This is a substantial change in a short time.

Recent Taulbee data shown in Table 1 document a gradual increase in the ratio of PhD graduates who pursue a PostDoc prior to being hired into tenure-track positions.

Table 1: Numbers of new tenure-track hires in the U.S. that held a PostDoc in the year prior to being hired

Year	New Hire received PhD previous academic year	New Hire was a PostDoc prior to hiring	Ratio of PostDoc to New PhD
2007	118	38	0.32
2008	109	28	0.26
2009	116	42	0.36
2010*	116	47	0.41

**These data are preliminary as of the latest update to this white paper.*

PostDocs would seem to be more prevalent in areas of research requiring large, interdisciplinary teams. As shown in Figure 3, Taulbee data indicate that the number of PhD graduates in operating systems and networks (an area often requiring large teams to implement prototypes) has surged in the past decade. However, most of these recent PhDs appear to have accepted industry employment (not shown). Artificial intelligence/robotics has consistently been a subfield that attracted more PhD students than most other subfields. There is a surge in the category “other/unknown." This could be the result of a higher number of recent PhDs who are in an interdisciplinary or multi-disciplinary area. It could also be indicative of unemployment, as PhDs without job offers post-graduation may report that to their departments as “other” or “unknown.”

Figure 3: Subfields of new computer science PhDs from U.S. and Canadian universities, as a 3-year rolling average 1998-2009

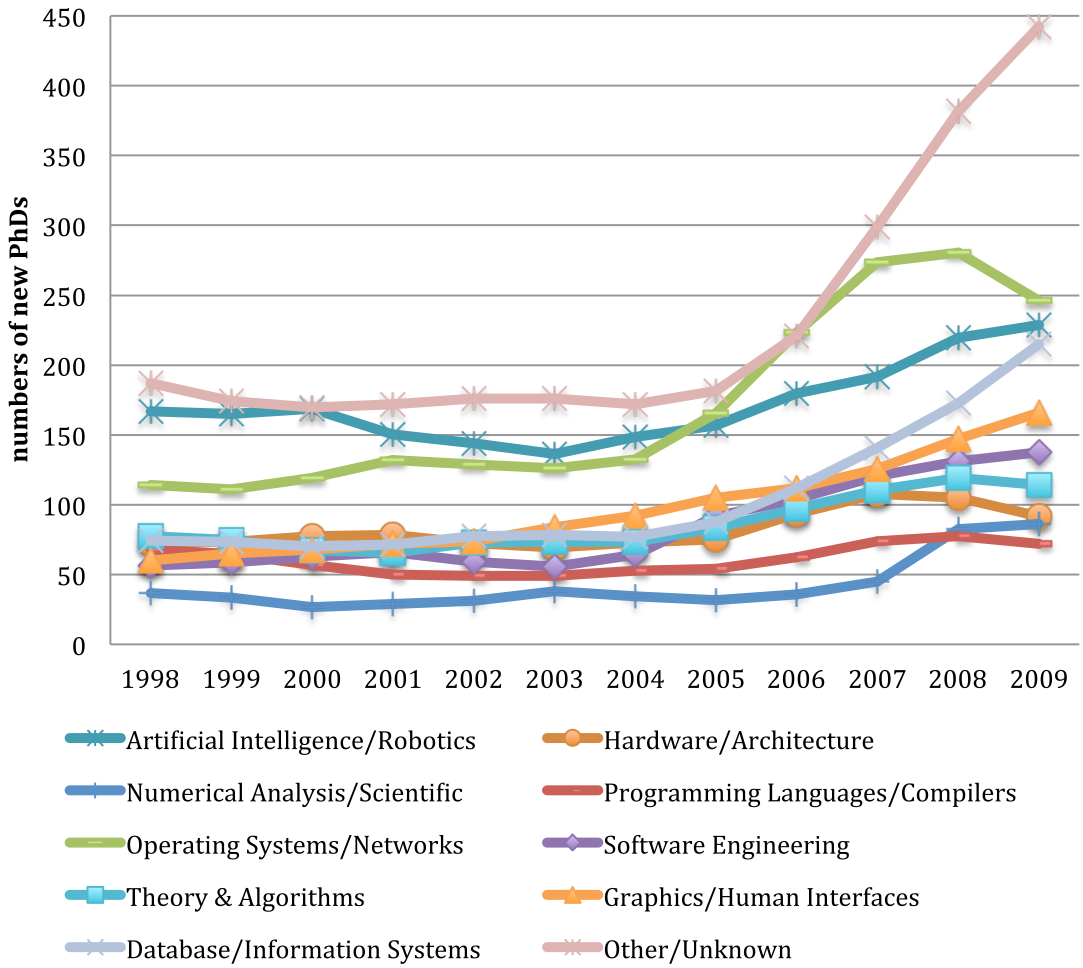


Figure 4 illustrates, for each subfield of computer science, the percentage of new PhDs within that subfield who pursue a PostDoc. The percentages of PostDocs have consistently been highest among artificial intelligence/robotics, theoretical computer science, and numerical/scientific computing.

Figure 4: Percentages of all new PhDs in the U.S. and Canada within each subfield who take PostDocs, as a 3-year rolling average 1998-2009

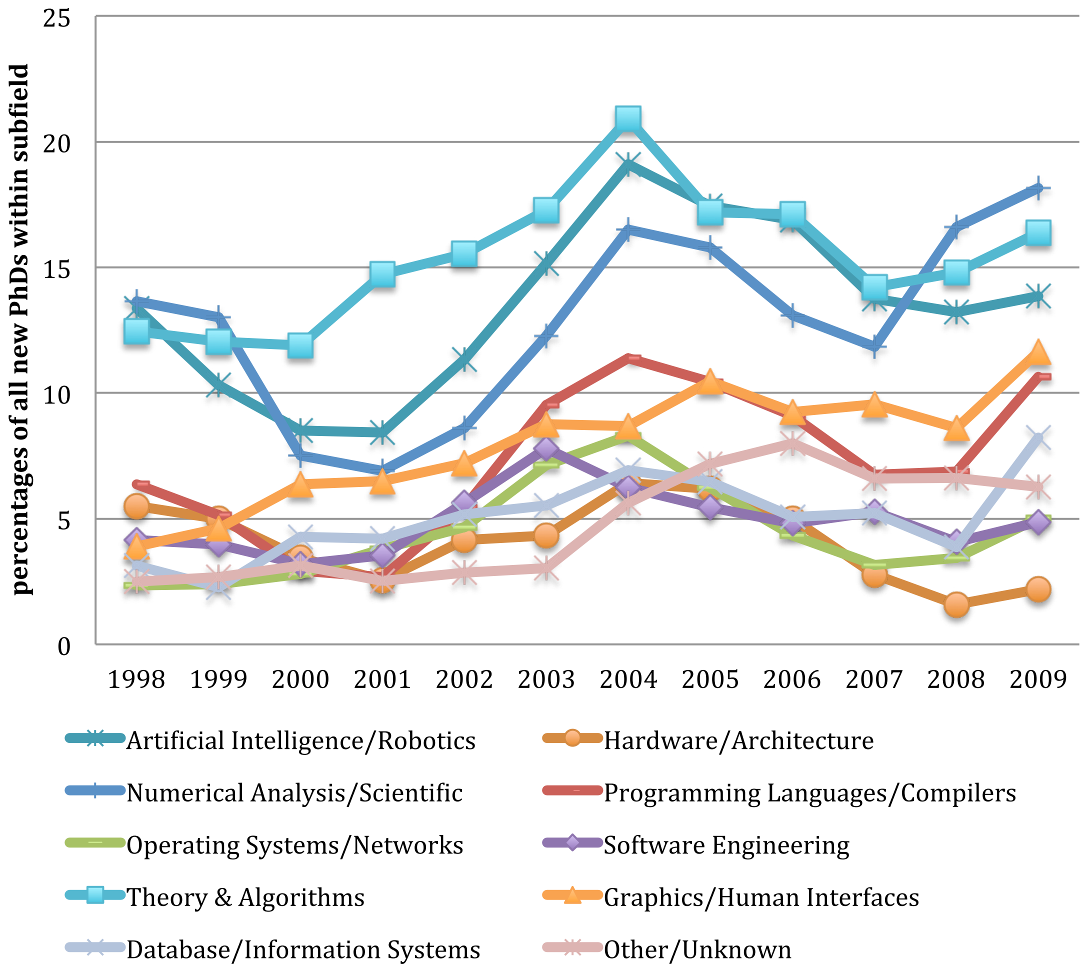
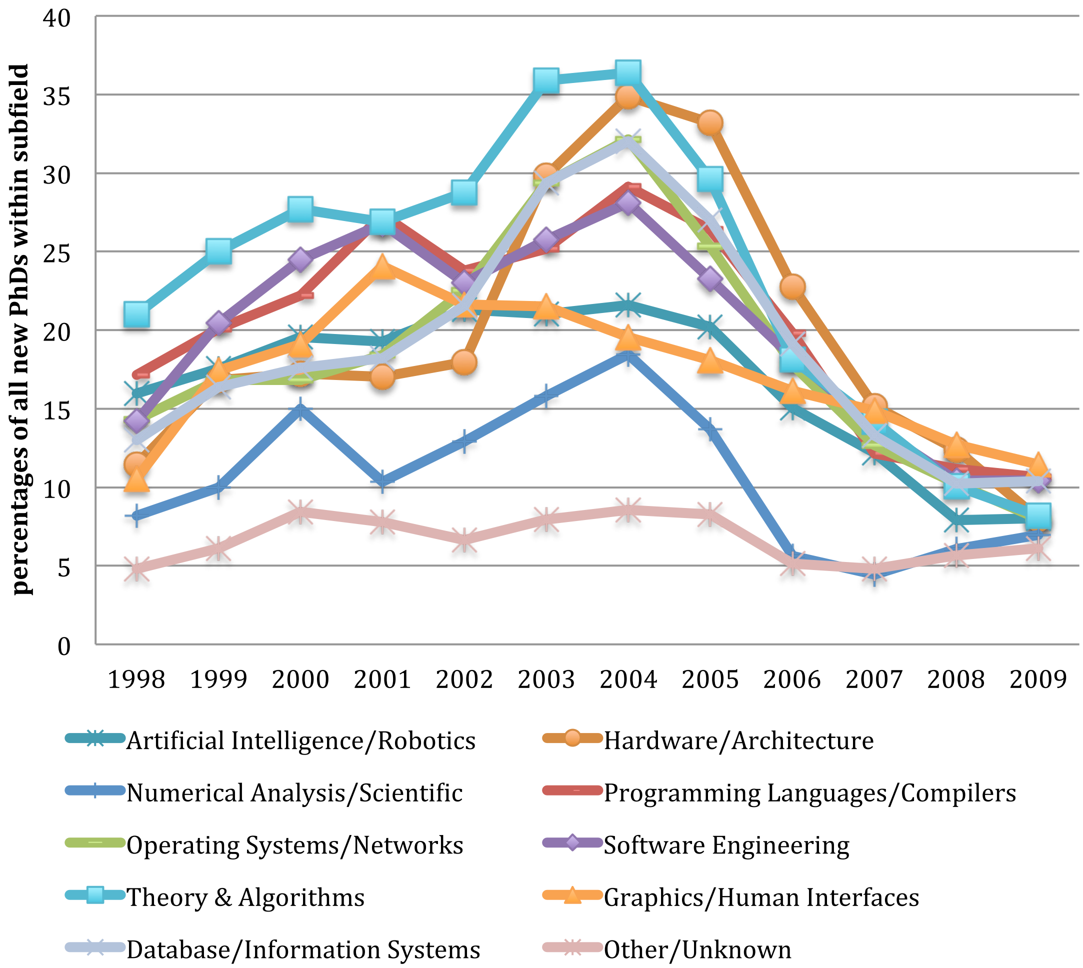


Figure 5 illustrates, for each subfield of computer science, the percentage of new PhDs within that subfield who are hired directly into a tenure-track faculty position. Noteworthy here is the steep decline since 2004 across nearly all subfields. Previous data suggest that many accepted industrial and PostDoc positions. This is a substantial change. Recall that Figure 1 shows that in 2009 760 of 1800 PhD graduates (42 percent) were hired directly into industry.

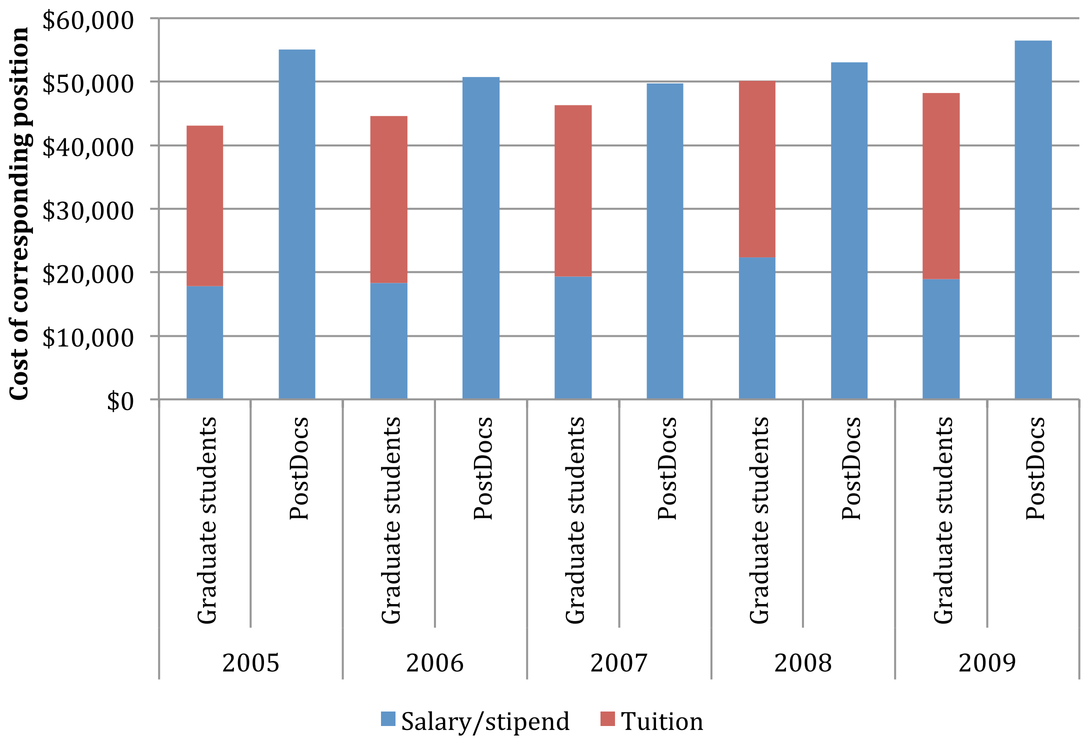
Figure 5: Percentages of all new PhDs in the U.S. and Canada within each subfield who take tenure-track positions, as a 3-year rolling average 1998-2009



Another important consideration is the relative cost for funding different types of trainees in academia. Figure 6 shows Taulbee data on the relative cost of graduate students (stipend plus tuition) and PostDocs (salary only). Essentially the monetary costs are the same while the expertise of the PostDoc will be higher. (Figure 6 charts cost for only U.S. computer science institutions ranked 1-12, as reported in Taulbee. For technical data collection reasons it is not appropriate to combine the data from different tiers. However, trends are comparable for the other tiers.)

Another cost is measured in space. PostDocs are typically allocated more office space than graduate students. The field has increased the number of PostDocs over recent years. In some universities this may have led to strains on space allocation, or lowered standards of space allocation for PostDocs.

Figure 6: Relative costs of graduate students and PostDocs



Next we compare computer science and other fields. Data from the National Science Board (NSB) Science and Engineering Indicators 2010 [NSB2010; Figure 3-46] indicate that the percentage of all computer science and math PhDs who hold a PostDoc position has grown in recent years – from 15-20 percent of those who earned their PhDs between 1972 and 1996 to 31 percent of those who received their degrees between 2002 and 2005. The NSB does not distinguish computer science from math for these data.

For those who accept PostDocs, the average duration of an individual PostDoc position in computer science was most recently reported to be 1.8 years, which is comparable to the average duration of a PostDoc reported for the other physical sciences (1.9 years) but less than the average duration of a PostDoc reported within the life sciences (2.2 years) [NSF-SDR-2006]. In the biological sciences the median length of PostDoc experience for pre-1965 PhD graduates was 2 years. The median length rose to 46 months for those who graduated between 1989 and 1991 [NSF99-310].

Moreover, the average time from graduation to hiring into a tenure-track faculty position (including multiple PostDocs and other experiences) is far less in computer science, suggesting that fewer numbers of PostDocs are deemed to be necessary in computer science as compared to the physical sciences and the life sciences. For example, according to 2006 survey data, 38 percent of computer science PhDs held tenure-track positions within three years of receiving their doctorates. Just 11 percent of other physical scientists (chemists, geoscientists, and physicists/astronomers) and 13 percent of life scientists did so [NSB2010; Figure 3-44 and Table 3-18].

Computer science is notable for the very low level of PostDocs. NSB2010 provides the numbers and relative percentages of PostDocs across different science and engineering disciplines [Appendix 2-32]. We reproduce these data for fall 2006 (*selected* fields only) in Table 2 below. Note that in contrast to earlier Taulbee data, Table 2 reports on the *total* numbers and percentages.

Table 2: Percentages of all U.S. S&E PostDocs by field, fall of 2006

Field	Total Number of PostDocs Within Field	Percentage of All PostDocs Within Field
Medical & life sciences	33,245	67.5%
Engineering	4,626	9.4%
Computer science	458	0.9%
Mathematics	574	1.2%
Physics	2,102	4.3%
Chemistry	4,044	8.2%

During the first decade of this century the economy has fluctuated. "Recipients in a PostDoc position in April 2006 reported that they took their current PostDoc position because 'other employment not available'. This reason was given by 5 percent of PostDocs in the life sciences, 8 percent in computer and mathematical sciences, 10 percent in the physical sciences and 16 percent in engineering" [NSB2010, p. 355]. Again, computer science and mathematics are not separated.

How do PostDocs perceive the value of their experience? NSB2010 [Figure 3-47] reports that between 1972 and 2005 PostDocs who received a PhD in science and engineering felt that the PostDoc experience enhanced career opportunities as follows:

Not at all	10 ± 2 percent
Somewhat	35 ± 2 percent
To a great extent	53 ± 3 percent

There is little fluctuation in responses over time.

Experience of a PostDoc

PostDocs are paid at a rate that is substantially lower than tenure-track faculty and distinctly lower than research faculty. Taulbee data report that the average nine-month salary for an assistant faculty member was $90,000 in 2009. (Note that this is the average for all assistant professors, not the starting salary.) Meanwhile, a research faculty member was paid an average of $81,000, and a teaching faculty member was paid an average of $70,000. At the same time a

PostDoc was paid $52,000. In some universities the benefits of a PostDoc are more like those of a student than those of employees. Benefits to employees may be greater in areas such as health care, retirement, access to childcare, and access to wellness centers.

The PostDoc generally has freedom to focus only on their PostDoc objectives. Typically, there are no other responsibilities, such as the teaching and committee responsibilities of a tenure-track faculty member, course and dissertation obligations of a graduate student, and the proposal writing duties (to sustain funding) of a research faculty member. However, the PostDoc supervisor may direct the PostDoc to assume other responsibilities. At most universities and in industry, PostDocs cannot be Principal Investigators on grant proposals. This may foreclose independence.

PostDocs are evaluated differently than, say, research faculty. PostDocs report to their supervisor, a faculty member, and in some cases, to Offices of Sponsored Research. Research faculty are evaluated by other university entities (e.g., Provosts' offices) using a process that is closer to tenure-track faculty evaluation. Typically, that evaluation is more broadly based, involving more evaluators.

The PostDoc position is taken shortly after the degree. This is most often the time of life when people marry and start families. A PostDoc position is not permanent. The individual must do another job search, and typically must move from one geographic locale to another, with the career disruption, personal disruption and expense that this causes. Relocation is more difficult for women and men who are nurturing a young family. Delaying the bearing of children has health implications for women.

Considering the computer science field, it is desirable for all positions to be attractive to both women and men, and to individuals who are balancing the demands of young families with the demands of their careers. Quality of life in the academic research enterprise is an important consideration.

Some Issues for consideration

Because the purpose of this document is to stimulate discussion we next highlight several key issues:

1. Balance in the categories of participants in the research enterprise
Research in academia is conducted by some combination of tenure-track faculty, graduate students, undergraduate students, research faculty, and PostDocs – with assistance from technical staff. As the data above show, the balance between several of these categories has changed markedly over the past two decades. How should this change be evaluated – from the perspective of quality research production, the constitution of research groups involving different

categories of researchers, student mentoring and training, or faculty development?

PostDoc positions collectively offer a buffer pool of people who remain in the research enterprise, refine their skills and knowledge, and may later attain permanent tenure-track or research/teaching faculty positions. But, if the number of PostDoc positions is too great, then only a small percentage will make this transition to the most desired positions. At some level, as in the life sciences, this is unhealthy for the field, and results in a grim existence for some individuals. At what level is this buffer pool healthy for computer science?

The PostDoc buffer pool of people may swell in numbers during a down economy, as the PostDoc position is the "cheapest" way to keep individuals within the academic research enterprise for a short time. Should funders increase or decrease the number of PostDocs in response to the economy, perhaps in response to academic and industrial hiring trends? Does an increase in funding of PostDocs come at the expense of funding for graduate students? If so, at what point does the growth in PostDoc positions begin to threaten the pipeline of next-generation researchers?

When a recently graduated PhD moves to a new research project, they bring with them new ideas and even different assumptions about dimensions of the research. Does a rapidly flowing pipeline of PostDocs moving through a research organization introduce more vitality, a propensity to challenge assumptions, and new knowledge – in a way that students and the permanent faculty do not? Certainly, PostDoc positions are an inexpensive way to bring in relatively mature researchers from other disciplines to augment interdisciplinary knowledge of a research team. But, is the PostDoc the most effective way to encourage interdisciplinary interactions?

Although in 2009 roughly 42 percent of new PhD graduates were hired directly into industry, historically academic PhD programs have "assumed" that most graduates will eventually accept academic positions. The substantially altered balance between categories (tenure-track faculty, PostDocs and industrial jobs) raises the question of whether the content and the duration of a computer science PhD program should be reevaluated.

Figure 3 shows the variation in the number of PostDocs in different subfields of computer science. Are there reasons to maintain a PostDoc pipeline in one subfield at a higher level than in another? Is the PostDoc experience more valuable in one subfield than another? Does the relative availability of industrial jobs in the subfield influence the answer?

2. Career progression for an individual

Channeling some portion of new PhD graduates into PostDoc positions gives them more time to advance their research credentials before they compete for a permanent position. That raises the question of the quality of the PostDoc experience. Taking a PostDoc position at a highly prestigious department may contribute significantly to the higher likelihood of finding a permanent position in a highly prestigious department [Su2009]. However, Su concludes that there is "mixed evidence for the common assumption that PostDoc training [for science and engineering doctorates] leads to a higher productivity level. PostDoc training does boost the number of research articles within the first 3 years after the receipt of their doctorate degrees; however the effect fades away quickly, and later is superseded by the effect of the prestige of academic departments where scientists obtained positions" [Su2009].

There is a tradeoff in the time spent in completing post-bachelors study to achieve a PhD degree and PostDoc (training) thereafter. The field could consider shortening the time to complete a PhD and more fully institutionalize the PostDoc experience. Closely related is the question of the role for which PhDs are being trained, and therefore the content of the training, as well as how it is packaged.

A PostDoc works under the guidance of a major professor, or industry counterpart. At most universities and corporations, PostDocs cannot be Principal Investigators on grant proposals. This delays the point at which the individual becomes truly independent. To put this in perspective, the average age of first-time (new) principal investigators obtaining R01-equivalent research funding (the major source of support for young investigators, and often considered the "gold standard", in the biomedical sciences) from the National Institutes of Health has risen to 42.6 years as of 2007, up from about 36 years in 1980 [NIH2008]. The average newly minted doctorate does not receive her or his first NSF award until age 39 to 40, with the median age of 37 to 38 [AAAS].

One of the hallmarks of an initial permanent position for a researcher is that they rapidly establish their independent research endeavors. To what degree is a PostDoc experience helpful for a researcher who will take a non-academic, permanent position?

Since the PostDoc is beholden (to a great extent) to his or her supervisor, that person may (even unintentionally) direct the PostDoc to perform tasks that in no way advance the skills, knowledge, or credentials of the PostDoc.

Is there a gender difference in terms of the impact on PostDocs? How adverse is the dislocation and the requirement for transition after the PostDoc to individuals, to couples and especially to families with small children? How should the "quality of life" aspect of the PostDoc experience influence the degree to which the community chooses to utilize PostDocs?

3. Postdoc positions can become a requirement to be hired into a tenure-track position

When PostDocs compete with new PhDs for a tenure-track or industry position, the PostDoc will likely have more substantial research credentials, and thus have a competitive advantage. Over time if there is a robust pipeline of PostDocs, this may lead the computer science discipline to – in effect – “require” a PostDoc experience prior to being hired into the most desirable faculty jobs. Some have observed that this is already true in some institutions in the theory subfield of computer science. Is the increase of the use of PostDoc positions simply a sign of the maturing of the field? Is this a good trend?

4. Balance of financial support

One can make the simplistic assumption that the total computing research budget is fixed and does not increase or decrease with the number of PostDocs. If so, then if fewer (or more) PostDocs are funded, then more (or fewer) graduate students can be supported. Similarly, there may be a trade-off between PostDocs and research faculty (on soft money). If the level of funding is essentially fixed, it is within the power of the community to determine what portion of the salary funds should go to the various categories, e.g., research faculty, students, and PostDocs – and to a lesser degree to tenure-track faculty. Principal investigators certainly make a choice among the categories as they craft proposals. To what extent should the computer science community be engaged in setting guidelines for the balance between PostDocs and students, if the total amount of funding is roughly constant?

In addition, there are “portable” PostDocs. Funding agencies have entire programs dedicated to funding PostDoc awardees directly and not through a research project or institution. If the community were to come to a consensus on the desired level of PostDocs that was deemed healthy for the field and then express that opinion, would the funding agencies and foundations respond as the community indicates?

5. The ecology of supply and demand

The PostDoc issue is part of a larger question about how long-term investment in education is made so that sufficient supply of educated talent is available to meet economic demands. Many other countries fund higher education through the government, linking long-range planning for demand with long-range provision of supply. For example, the Ministry of Education in a country might decide that *N* computer scientists will be needed at various levels of education by the future year *X*, and so the ministry may elect to fund *K* “slots” at various levels now in order to prepare the necessary workforce (modulo attrition and other factors) for the year *X*. In contrast, in the United States a heterogeneous set of higher education institutions, many of them private, provide whatever programs they wish and compete for students in those programs. Students, in turn, choose what they want to study. At the same time, various agencies in the government, mindful that they need experts in various technologies, fund research – and PostDocs – often in targeted areas to encourage the education of talent in the science and engineering areas that the agencies deem important for their future missions.

The U.S. “policy” (by default) has been to provide extraordinary opportunity for students and let the best students excel. Moreover, federal agencies fund science and technology in many areas in an uncoordinated way, largely based on their individual missions and choices. In general, no policy actions ensure that there are “enough” people – or too many – to meet the demand when the demand materializes. In other words, the U.S. approach is a market-based approach rather than one based on a national plan.

Many fields of science and (less so) engineering in the U.S. have shifted modestly or dramatically toward investing in PostDocs. The result has been that in some cases a PostDoc experience is a required, intermediate step between completion of a PhD and finding a tenure-track faculty position. It is instructive to consider the evolution of other fields. It is interesting to speculate whether the dramatic increase in federal science and technology research funding in the life sciences disturbed a pre-existing equilibrium. Certainly, it helped produce a larger number of PostDocs in the life sciences and the time that an individual in those disciplines spend in PostDoc positions has increased, as documented earlier. It is not clear that these fields *wanted* or *expected* to shift in this direction; it is likely that they had little choice because over-production of PhDs relative to tenure-track faculty positions required the introduction of an intermediate step wherein post-PhD graduates would continue to compete.

In computer science industry demand for PhDs has increased dramatically over the past few years. There are good reasons to prefer the market-oriented model that we now have over a planning-oriented model many other countries follow, but the relationship between supply and demand must be addressed in some way, regardless of what model the nation follow. Ultimately, the discussion of PostDocs is a discussion that relates to the fundamental question about how we want the academic, scholarly, scientific, and technical research systems to work.

Each of the above issues involves questions. There is good reason for the field to consider them and to make strategic choices to ensure the health of the field and the appropriate production of the educated population that the economy of the country depends upon.

Get involved – discuss the PostDoc issue

This document is intended to catalyze a thoughtful discussion in the computing research community about the role of the PostDoc. It is posted on the Computing Research Association (CRA) Web-based forum site along with a blog: http://www.cra.org/postdocs.

We ask that you get involved. Sponsor discussions in your department, in your company and at conferences. We hope that individuals will post their thoughts.

We also hope that CS departments or any group that holds a discussion that comes to some consensus on some aspect of this issue – or arrives at a deep division – will post that result and attribute it to the group, not just to an individual.

The CRA will produce a revised document early in summer 2011 representing as accurately as we can the consensus – if any – on different aspects of the PostDoc matter as well as the pros and cons on different issues. Historically, the computing research community has rarely come together to express a consensus. While the topic here is PostDocs, this is also an exercise to see if the community can arrive at a thoughtful consensus on any part of this topic. Some describe this research community as responding to a crisis by circling the wagons and shooting inwards. We hope to see a different outcome this time. But only if you act and respond!

If you want to talk to those of us who authored this paper, and who want to be helpful as the community considers the PostDoc issue, contact any one of us:

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