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Article *in* IEEE Robotics & Automation Magazine · December 2011

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Final version, DOI: 10.1109/MRA.2011.943235
Andreas Birk. What Is Robotics? An Interdisciplinary Field Is Getting Even More Diverse. IEEE Robotics & Automation Magazine, 18(4):94-95, 2011

What is Robotics? An interdisciplinary field is getting even more diverse

Andreas Birk

Robotics is a very young field, which is quite interdisciplinary due to its very nature of developing and building systems that – following its science fiction roots that preceded the real technology – combine electrical and mechanical "body" components with computer "brains". Accordingly, mechanical engineering, electrical engineering, and computer science are core disciplines involved in robotics. This already makes robotics education quite challenging. There are some natural differences in the curricula of these three disciplines, especially when it comes to the typical coverage of mathematical topics during undergraduate and graduate studies. But fortunately, the borders between these different disciplines have become much more dispersed in recent years. Robots have become popular tools in CS education at many places; not necessarily to just teach robotics but for the more general goal to educate CS students about a variety of physical system aspects. At the same time, mechanical and electrical engineering programs nowadays include substantial amounts of CS related courses. I even dare to claim that not only robotics but all engineering fields have nowadays become strongly software-driven and hence CS aspects are a significant part of their education activities. But we are now facing a new, more radical paradigm shift, namely an increasing relevance of bio/cognitive disciplines in robotics.

I want to substantiate these claims by two simple statistical analyses shown in Figures 1 and 2. They are based on a naïve frequency count of the occurrence of certain keywords in authors' affiliations in robotics publications. They are by no means a thorough study but they give some interesting indications of how things developed, respectively are developing.

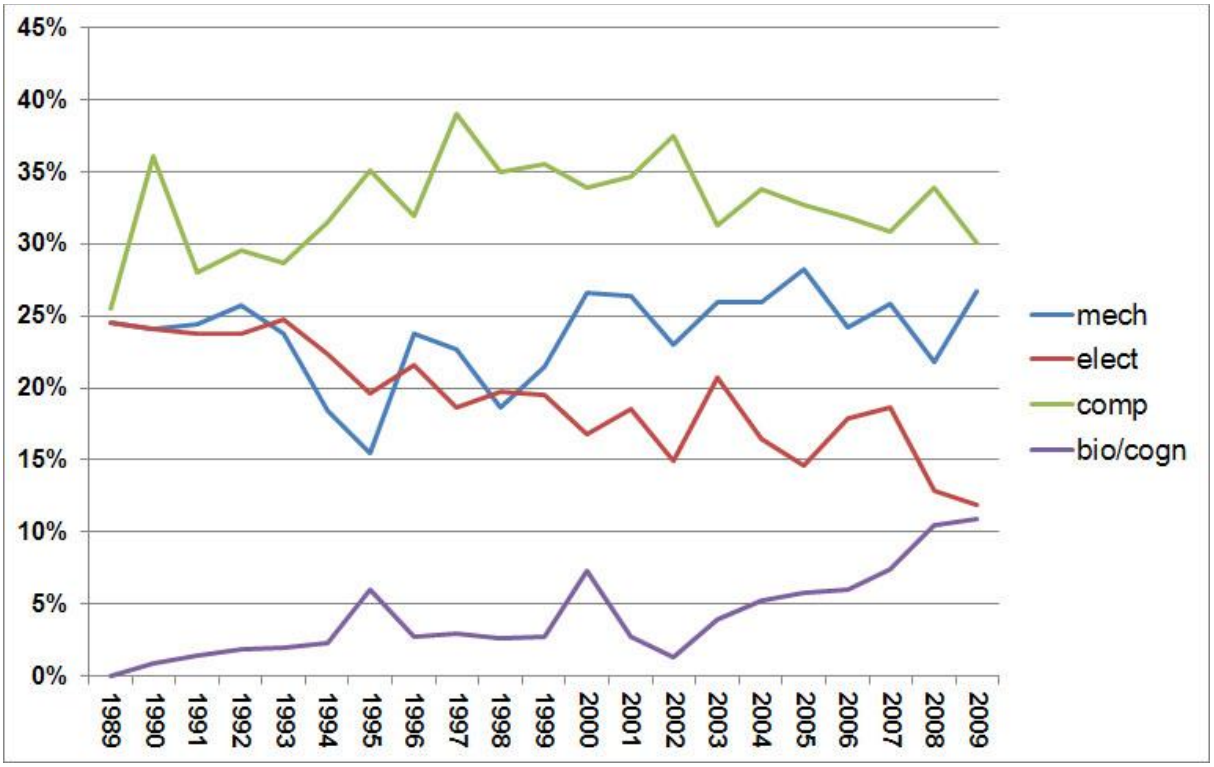

Figure 1: The distribution of robotics related disciplines in authors' affiliations in all articles of the top ten robotics journals from 1989 to 2009. In addition to the so-to-say classical disciplines involved in robotics

in form of Computer Science, Mechanical Engineering, and Electrical Engineering, there is a significant rise of biological/cognitive contributions.

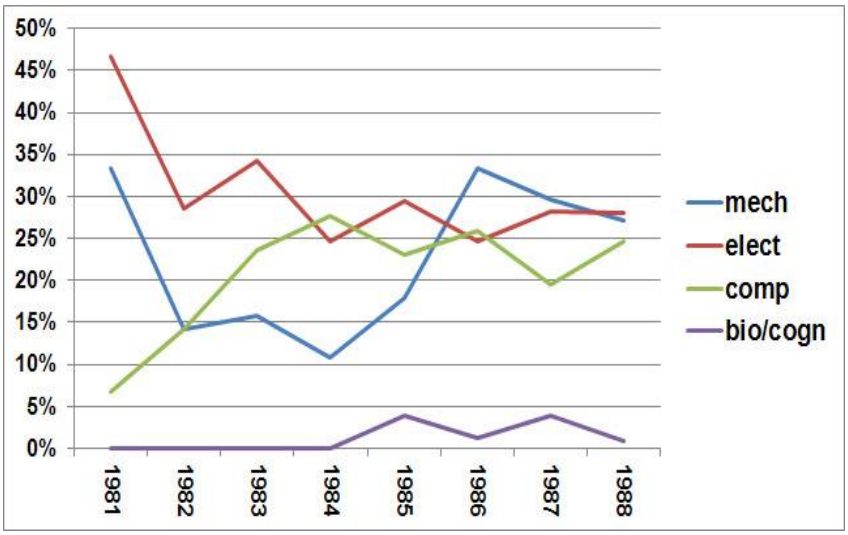

Figure 2: The distribution of disciplines in authors' affiliations in all publications with the keyword "robot" in the Web of Science from 1981 to 1988.

Concretely, the data is taken from the ISI Web of Science. Figure 1 is based on all publications that appeared from 1989 to 2009 in the top ten robotics journals ranked by impact according to the Science Citation Index. Overall, about 5,000 articles were taken into account. The Web of Science uses a standardized scheme for the abbreviation of disciplines, which hence eases a simple search in the authors' affiliations of each article for the according keywords representing the disciplines of interest here, namely Mechanical Engineering, Electrical Engineering, and Computer Science. In addition, the amount of researchers with bio/cognitive affiliations was taken into account, i.e., the according keywords for Biology, Neuroscience, Psychology, and Cognitive Science were also counted. The percentages reflect the amount occurrences of the different disciplines per year. Each article of course may have multiple authors working each in a different discipline and some affiliations may even include multiple keywords, which were all accordingly counted.

Figure 2 shows data for the period of 1981 to 1988. As robotics journals are not that well covered in this time period in the Web of Science, simply all publications that could be retrieved with the keyword "robot" within the Web of Science were used for this analysis. Still, this only leads to about 1,000 publications in total for this time period. The main analysis was done just like for Figure 1, i.e., by a frequency count of the occurrence of the different disciplines in the authors' affiliations.

The first thing that can be noticed is that CS related work indeed seems to be dominating robotics in the last two decades though mechanical and electrical engineering clearly also have their fair shares. The data from the 80's suggests that a rise in the importance of CS in robotics has started in the early years of that decade. This is pretty much in line with the general trend of the increasing significance of software-oriented aspects in all engineering disciplines. As mentioned before, I think that current engineering curricula in general and robotics education in particular already reflect this. There is of course always room for improvement, but students of electrical and mechanical engineering can nowadays hardly avoid getting also some decent CS knowledge if they want to succeed in their studies. Also vice versa, CS students – especially the ones being interested in a robotics oriented track – do have increasing opportunities for early exposure to electrical and mechanical basics through according courses at many institutions – including programming courses that feature the use of robots.

But there is also a significant rise of contributions to robotics from a completely new direction, namely biological/cognitive research. Whereas the representation of authors from according fields was almost negligible in the years covered in Figure 2, it has significantly increased in the last decade as can be seen in Figure 1. The trend is even indicating that the number of researchers having some

biological/cognitive affiliation may surpass the number of electrical engineers in robotics in the medium term. Of course, one may object that grouping Biology – mainly linked to bio-inspired work – plus Neuroscience, Psychology, and Cognitive Science – obviously mainly linked to cognitive research – into one “discipline” is a bit bold. But from an educational (and possibly even research) perspective, they share sufficient similarities to justify this. This holds especially when looking at them from the perspective of the so-to-say classical robotics disciplines, i.e., Electrical and Mechanical Engineering, and Computer Science. Especially, the bio/cognitive discipline(s) are traditionally purely descriptive studies of natural systems whereas the classical robotics areas are inherently constructively oriented disciplines dealing with artificial systems.

I believe that the trend of increasing bio/cognitive contributions to robotics cannot be ignored for education and that it poses tremendous challenges but that it also offers great opportunities. There is of course first of all the challenge to incorporate elements of the basic canon of knowledge of this/these discipline(s) into robotics curricula. This will hopefully happen to some extent just by itself: it can be expected that some of the bio/cognitive researchers who are active as (co-)authors of robotics publications will also engage in robotics teaching activities. In addition to the core knowledge aspects, there is a further element where the bio/cognitive perspective may prove to be tremendously useful for robotics education. As descriptive sciences, these disciplines have developed methodologies and best practices, which are very beneficial for engineering students even if they do not care too much about the bio/cognitive side of natural systems. Boldly speaking, we should try to incorporate bio/cognitive fields into robotics education not only to profit from their insights on the working principles of natural systems; but we should also use this opportunity to learn from their methodologies and best practices to make robotics more scientific.

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