Position Statement: Robotics Science

Ruzena Bajcsy[1]

EECS Department, UC Berkeley, CA bajcsy@eecs.berkeley.edu

1 Introduction

Robotics as a subject of inquiry has had from its beginning an identity problem. Questions such as:

Is Robotics a science or engineering? Is it an application of certain discipline or does it have a core of problems, tools, methodologies which are unique to robotics?

Is robotics a multidiscipline or are there enough unique problems, methodologies, theories to stand as a single discipline on its own right?

Some researchers who are more pragmatic say: does it matter?

My answer is that indeed it matters, especially when one competes for national and international resources of support. It does matter, when one is concerned what training is needed to produce the professionals who could pursue and advance the field of robotics. It does matter, when one needs to clearly define what is robotics as a discipline, what are its objectives, what is the basic knowledge upon which robotics is build on and what are the criteria of success.

2 What is Robotics?

Robotics has both the analytical and synthetic component, hence is both science and engineering, just like Computer Science is.

The difference between biology however is that we first must build artifacts (complex artifacts. Biology analyses the living nature) which then we analyze their behavior, their interaction with other artifacts and the environments including humans.

We use all the observations and data analysis as our counterparts in psychology, and sociology use. Think of robot behavior in any environment, or a swarm of robots interacting with each other.

The synthetic part of robotics brings us closer to the engineering discipline though robots are typically more complex than most of engineering artifacts .During the design process we have to employ all the engineering tools and methodologies in order to achieve the desired performance and behavior. The difficulty here for robotics is the complexity of interaction amongst the components within robots, the uncertainty and unpredictability of the environment in which they live, which leads to at best nondeterministic performance within some bounds.

So why I believe robotics is science?

Because it has to address, develop theoretical foundation of interactive complex physical and dynamic systems.

Just as chemists cannot claim that they understand a complex molecule until the can synthesize it, we cannot rest until we have foundation (tools, theories, methodologies) that will enable us to design (synthesize) complex robots with predictable behavior and guaranteed performance in a given environment within given bounds.

Let us remember that in the living world animals are adjusted (their body, perceptual and mobile capabilities) to their environment. Yet they are adaptive within some bounds. In turn we have to adhere to good and proven analytical methodologies to verify the predicted behavior of the robots.

3 Robotic System Science

It has been established for some times that Robots are made of physical components (sensors, motors, manipulators, hands legs, wheels, and of course computers).

Robotics science is also segmented into sub disciplines that utilizes the intellectual power from:

Perception, control, action and planning, Kinematics, dynamics, mobility, mechanisms of adaptation and learning, knowledge organization, behaviors and decision making: cooperative and competitive, and so on.

It is only natural that researchers feel more comfortable to study each of these sub-disciplines in isolation, especially if one accepts that each of these sub-disciplines is intellectually demanding. Nevertheless, I believe that one cannot make true progress in robotic science if one does not consider the system as the whole.

This is of course extremely demanding both intellectually but also materially, it requires a larger group of people with different skills, a proper infrastructure and it requires long term sustained funding.

The good news is that progress is being made both at the theoretical level as well as at the technological level.

At the technological level, we are benefiting from the miniaturization of computers, sensors, actuators, from new materials which are lighter, sturdier, more flexible and less energy hungry.

At the theoretical level, we have made great advances in control, non-linear control, hybrid control, distributed control, adaptive control, modeling complex systems, understanding multidimensional signals and geometry of space, data reduction without much loss of information, modeling uncertainty and making decision under uncertainty.

Finally, great progress has been in the development of learning mechanisms.

4 Conclusion and What Needs to be Done

There are several implications following from the above analysis:

We need good models of the task that the robotic system is expected to perform.

We need models of the environment and context in which the task must be accomplished.

The robotic systems must be adaptive to unexpected changes though the variations must be bounded Under these conditions we must have theories and methodologies that guarantee performance.

If we take lessons from biology, we do not have universal living organism but rather organism that are adapted to their environments to accomplish task of survival. Different environments provide constraints on design and functionality of the organism.

Hence our aim should be understand these constraints and design robotic systems in a systematic way so that they can exist and perform the given task. I believe this is possible.