DEVELOPMENTS IN VOCABULARY STANDARDIZATION FOR ROBOTS AND ROBOTIC DEVICES

CHRISTOPHER HARPER

Avian Technologies Ltd., 28 Dumaine Avenue, Stoke Gifford
Bristol BS34 8XH, UK
e-mail: cjharper@avian-technologies.co.uk

SANJA DOGRAMADZI

Bristol Robotics Laboratory, University of the West of England, Frenchay Campus, Coldharbour Lane, Bristol BS16 1QY, UK

M. OSMAN TOKHI

Dept. of Automatic Control and Systems Engineering, University of Sheffield, Mappin Street, Sheffield, S1 3JD, UK

With the emergence of mobile robots, including service robots for use in public, domestic and industrial environments, a more comprehensive standard to cover the new robots and associated technologies is needed. New scopes of the robots applications involve almost in every case an autonomous system that can potentially cause harm to the environment, including people or malfunction and fail the mission completely. ISO has developed a set of standards supporting aspects of robot design such as performance measurement, safety assurance, user interfaces and similar for industrial robots manipulators. Evolving robot applications require the standards to be revised to incorporate requirements for new robotic domains. This prompted a group of international robotics experts in 2007 to initiate a development of new terms and regulations and modify the current robotics standard, ISO 8373, to include terms that are applicable to the new generation of robots. This paper provides an outline of the progress of the working group and the associated challenges in updating the international robotics vocabulary standard.

1. Introduction

Robotic technology is at the point where an increasing range of industrial and consumer product applications are becoming practicable. Traditionally, robots have been employed mostly in manufacturing industry; however, recently service robots have begun to appear in a variety of fields, such as medicine, transport, commercial services (such as cleaning), and agriculture. Primitive domestic robots have been produced for applications such as vacuum cleaning and lawn mowing, and even in their original domain of manufacturing, robots are being developed for new types of scenarios and environments such as operation in close cooperation or collaboration with humans, or where new levels of flexibility and mobility are required than was previously the case with the traditional robotic manipulator systems.

Almost all robotic applications inherently involve the operation of autonomous systems in either, (a) environments where the action of the robot has the potential to cause harm, or (b) in remote environments where failure or malfunction of the robot causes mission failure and prevents recovery of the robot; in environments such as space or the deep ocean, the costs of the robot are likely to be extremely high, leading to major financial loss in addition to other losses. In all these applications, robots must be designed to be dependable – safe, reliable, fault tolerant, and exhibiting 'mission-worthy' operational behavior. Robots are no different from other safety critical systems in this respect, and will require similar certification approvals before they can be put into service.

Standards play an important part in the certification of safety critical systems, and typically perform two particular roles. They can contain sets of functional and non-functional requirements that are agreed by the particular standards community to provide operational behavior that is appropriate for the correct achievement of tasks (the 'mission-worthiness' aspect), or for safe operation. Alternatively, they can provide guidance on the correct methods and techniques for designing and implementing system designs so that the appropriate design assurance can be achieved.

2. Why Standards in Robotics?

Almost every envisaged application of robots and robotic devices within the scope of concern of TC-184 SC2 will be either *safety- or mission-critical*. Robots are likely to be used either in environments where their actions could potentially cause harm to people or the environment (in which case they are safety critical) or they are likely to be used in environments that are so remote and inaccessible that the robots will not be retrievable if they should fail or malfunction (in which case they are mission critical). In either case there is a need to ensure that any such robots are *dependable*, i.e. that they are safe and reliable, and can be *assured* of being so before they are put into service.

As with other industries developing dependable or safety critical systems, standards play an important part in their assurance and certification to facilitate trade across international boundaries. Standards are a useful tool in defining how appropriate safety behavior can be achieved by a product (otherwise known as *safety requirements*), especially in respect of its interoperability with other systems or socio-technical infrastructure. Standards can also define the design and development practices that provide sufficient assurance that these requirements are actually satisfied in any particular product system. Many of the standards that have been developed (previously) for industrial robots, and (presently) for service robots, define *safety requirements* for robotic applications. Safety standards capture a consensus as to what constitutes best practice in achieving safety in these applications, and what constitutes best practice in the methodology of the design processes used to produce them.

It is quite possible to develop a safety critical system without reference to any particular standard. A system may be shown to be acceptably safe without recourse to the requirements or practices contained in a standard, and this is often the case for systems with novel technologies or applications. However, it is often the case in such situations that safety assurance and certification is expensive; without the background of an established body of knowledge provided in a safety standard, regulatory agencies issuing certificates of ‘mission-worthiness’ are often highly conservative in their approach to reviewing and accepting safety cases. Without the relative certainty of an established set of product and process requirements, they often insist on an inordinate degree of analysis, testing, and project management procedure in the hope that such constraints minimize the likelihood that any faults or errors affecting the safety of a system might occur in service.

A notable example of just such a problem occurred with the launch of the *da Vinci®* robotic surgical system in 2000 [1]. The manufacturer of this system, Intuitive Surgical Inc., was required to obtain US Food and Drug Administration (FDA) approval for the *da Vinci* system to be used in laparoscopic operations for medical procedures such as prostate surgery and gynecological surgery. The FDA was initially uncertain about how to go about the approval process, and chose to obtain the relevant clearance by multiple methods. If an agreed international standard had been available at the time, they might have agreed to only one particular approach, thereby saving costs and timescales.

The higher costs of certification can affect the commercial viability of application, delay introduction of new robot types into service, and increase costs of robots and their utilization into society (see [2] for a discussion of these issues in the medical robotics field). Without the availability of suitable safety standards, robots are likely to be held back from introduction into commercial service, and remain only in academic research labs.

3. ISO Standardization Activities for Robots and Robotic Devices

ISO has developed a set of standards supporting aspects of robot design such as performance measurement, safety assurance, user interfaces, etc. These standards were originally developed for industrial robots such as industrial manipulators but, as discussed above, the evolving nature of the robotics field requires that the standards be revised to incorporate requirements for new industrial applications and for new robotic domains such as medicine, personal care, and domestic service. ISO Technical Committee 184 (TC-184) Sub-Committee 2 (SC2) has the responsibility for developing these standards, and is currently in the process of developing several new and revised standards for robots and robotic devices.

One of the standards being revised is ISO 8373 [3], a vocabulary of terms and definitions used in the other ISO robotics standards. This paper describes the ongoing efforts of TC-184 SC2 WG1 to define a vocabulary that is consistent, compatible with existing robotic domains, and yet is extensible and able to support the future development of standards for new domains.

The ISO 8373 standard is being revised and updated in conjunction with other ISO robotics standards. In particular the ISO 10218 Parts 1 [4] and 2 [5] that cover industrial robots, and two new standards for service robots in personal care that are being developed by TC-184 SC2 WG7, are adopting terminology that is significantly revised from previous conventions, and therefore it is necessary to update ISO 8373. It is also the case that several other robotics standards have modified the standard vocabulary in their own terms and definitions sections, and an opportunity exists to absorb these changes into the main vocabulary standard.

In the absence (until recently) of international standards for service robots, several countries, most notably Japan and South Korea, have established their own national standards to support industrial collaboration, safety assurance and certification, and the establishment of viable markets in these new domains. This has included the development of vocabulary standards within the respective national standards frameworks, in support of their technical standards. However, given the commercial advantages of establishing global markets for service robots, it has been seen as useful to develop international standards that absorb the content of the respective national standards. This will encourage the international acceptance of robotic products that is essential for viable global markets in these new fields. Therefore, representatives from both Japan and Korea are serving in WG1 to contribute their respective national standards into the revision to ISO 8373.

4. Progress and Challenges in Defining Vocabulary Terms

The update to ISO 8373 faces several distinct technical challenges.

1. The need to incorporate terminology related to robot types that have not hitherto been found in industrial manipulator robots.

   In particular, terminology relating to mobile robots is required, as traditional industrial robots have been mainly static installations in manufacturing assembly lines. Many envisaged service robot applications will be largely mobile in nature, and terminology for the functions, mechanisms, performance and assurance of mobile robots is urgently required.

2. The need to ensure that the terminology is consistent across all relevant technical standards for industrial and service robots.

   The terminology defined I ISO 8373 should be used consistently in all related technical standards. Each standard must be reviewed to ensure that different interpretations are not applied to the same standard. As mentioned in Section 2, some of the existing standards have made changes to the definition of terms, and the update to ISO 8373 must incorporate those changes back into the main vocabulary listing.

   The standard is also absorbing terminology from national standards such as the Korean KS B6937 [6] & B6938 [7] and Japanese JIS B0134 [8], B0185-0187 [9,10,11] standards. The challenge is to integrate all these national standards sources without producing inconsistencies in the international standard.

3. The need to provide an appropriate terminology that is extensible to new robotic domains without requiring radical revision of existing definitions.

Robotics is such a wide field that it will not be possible to provide a standards framework at the present time that can support all conceivable future applications. The standards will evolve continuously, being added to on a continual basis as new applications are developed, and this will include the vocabulary that supports them. In particular, therefore, it is necessary to provide a classification scheme for the different categories of robot (industrial, service, domestic, etc.) that (a) is compatible with existing definitions of industrial robots, (b) defines the new categories needed for the current revisions to the standards, and (c) permits new categories to be added in a consistent manner in the future.

The work in progress in TC-184 SC2 WG1 aims to update ISO 8373 so as to fulfill each of these challenges.

5. The Definition of "Robot"

One of the toughest challenges facing the vocabulary standard has been the problem stated in the third item of Section 4 above, namely the problem of classifying robot types. Despite the fact that robots have been in practical use for decades, there is no universally accepted generic definition at ISO level for the term 'robot', which offers a clear distinction between those machines that are commonly thought of as robots and other machinery that is thought of as 'automatic' but not 'robotic'. Furthermore, in the absence of any such general definition, the existing standards for industrial robots have therefore defined the term robot in such a way as to satisfy the needs of the industrial robotics sector, which is not entirely consistent with the concept of mobile service robots and yet cannot be wholly abandoned because of the objective to ensure that existing industrial robotics standards remain compatible with the revision to ISO 8373.

The original definition of "robot" in ISO8373:2007(E) – the version of the standard from which the current revision is derived [3] – is also the definition for "manipulating industrial robot" (the two terms are listed together), and is defined as follows:

> *"Automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes which may be either fixed in place or mobile for use in industrial automation applications*
>
> *NOTE:*
> *The robot includes*
> *- the manipulator (including actuators);*
> *- the control system (hardware and software)."*

This definition causes problems for mobile service robots, as definition does not include wheelbases or other motion platforms within its scope, and may exclude some classes of service robot that have only two axes of freedom or motion. Therefore, a generic definition of robot must be produced, which permits the above definition as the subclass of "manipulating industrial robots" (thereby maintaining compatibility with - and validity of - existing industrial robotics standards), but which permits other sub-classes to be defined (i.e. mobile service robots) for other purposes.

Work is continuing on the development of a suitable definition of “robot”, but at the time of writing the most comprehensive proposed definition is:

> *“Automatically controlled, reprogrammable actuated mechanism with a degree of autonomy, programmable in more than one axis and moving around its environment, either fixed in place or mobile, to perform an intended task.”*

The previous definition of manipulating industrial robot is therefore a refinement of the above definition, making a more restrictive specification vis-à-vis the number of axes, the range of environments and the type of mechanisms, which are relevant to that particular sub-class of robot. Other sub-classes, for example mobile servant robots or people carrier robots, will have their own particular restrictions. Thus, new standards can be written around new and different refinements of this general definition without compromising earlier work, and hence the standards framework and its supporting vocabulary can be extended incrementally as new application safety requirements are demanded. This is but an example of the type of work in progress in TC-184 SC2 WG1 for the new revision of ISO 8373. Many of the other terms and definitions in the revision are being reorganized in a similar manner.

6. Work in Progress and Future Directions

The new revision to ISO 8373 will be organized into the following chapters:

1. Scope
2. General Terms (including classification and safety)
3. Mechanical Structure*
4. Geometry and Kinematics*
5. Programming and Control*
6. Performance*
7. Autonomy (including perception, sensing, intelligence)

Chapters labeled with an asterisk are those whose scope remains largely the same as previous versions of ISO 8373 (although there may be significant changes to the content). The other chapters are either new, or are substantially revised, with a different scope to previous versions even if the title is the same.

At the time of writing this paper, the schedule for the new revision of ISO 8373 is for a committee draft to be ready by the end of June 2009, with the aim of producing a DIS (draft international standard) version of the new standard by March 2010 and a FDIS (final draft international standard) by end of 2010, and formal publication of the International Standard (IS) early in 2011. However, this schedule is subject to the schedule of TC-184 SC2 meetings at which appropriate decisions to make progress can take place, and may be adjusted a little to fit that schedule.

References

1. S. Kichen, *Forbes Magazine*, Medical Renaissance, (2005), URL: http://www.forbes.com/2005/07/26/surgery-science-medicine-cz_sk_0727surgery.html
2. Y Wang, S Butner and A Darzi, *Proceeding of the IEEE*, The Developing Market for Medical Robotics, **Vol.94**, No.9, 1763 (2006)
3. ISO Standard, *ISO8373:2007(E) Manipulating Industrial Robots-Vocabulary*
4. ISO 10218-1, *Robots for industrial environments — Safety requirements — Part 1:Robot*
5. ISO 10218-2, *Robots for industrial environments — Safety requirements — Part 2:Robot system and integration*
6. Korean Standard, *KS B6937 Classification & Definition*
7. Korean Standard, *KS B6938 Mobility & Intelligence*
8. Japanese Standard, *JIS B0134 Manipulating Industrial Robots-Vocabulary*
9. Japanese Standard, *JIS B0185 Intelligent robots-Vocabulary*
10. Japanese Standard, *JIS B0186 Mobile robots-Vocabulary*
11. Japanese Standard, *JIS B0187 Service robots-Vocabulary*