Some aspects of disambiguation of multi-disciplinary knowledge

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Structured abstract

BACKGROUND
The outburst in the internet-based sharing of knowledge has opened a Pandora's Box of the third millennium (the phrase "to open Pandora's box" means to perform an action that may seem beneficial, but that turns out to have unexpected consequences). Scientific and engineering contents are distributed by means of the high-speed internet; however, this includes dissemination of misaligned and otherwise ambiguous concepts as well. Bearing in mind the increasing trends in knowledge migration between initially disunited disciplines, there is an urgent need to mitigate misunderstandings that block the communication avenues. This work presents a contribution to disambiguation of multi-disciplinary knowledge, by means of exposing selected examples of ambiguity and proposing the disambiguation solutions.

PURPOSE
Ambiguous presentations obstruct knowledge sharing, application and expansion, and hence there is a pressing need to investigate the relevant causes and roots, and to propose appropriate remedies.

DESIGN/METHOD
A review of scientific and engineering databases enabled detecting acute examples. Selected cases of importance in engineering are subjected to systematic scrutiny based on ontology, semantics and epistemology.

RESULTS
The ambiguities are exposed and the causes explained. Engineering educators are prompted to recognise the damaging effects of conceptual misalignments and to consider the proposed improvements.

CONCLUSIONS
There is an urgent need to improve the definitions of key engineering concepts that are currently burdened by ambiguous interpretations. The examples of disciplines where the scientific taxonomy is well established (such as entomology and some branches of geology and medicine) should be followed and a systematic hierarchy of transparent definitions introduced.

KEYWORDS
Disambiguation, definition, multidisciplinary

Introduction

“If a little kid ever asks you just why the sky is blue, you look him or her in the eye and say, ‘it’s because of quantum effects involving Rayleigh scattering combined with a lack of violet photon receptors in our retinae’,” (Plait, 2002).

In the ongoing communication of science and engineering, information is shared in system languages in which each term presumably means one thing to both those who present knowledge and their audience, (Locke et al., 2007).

This, evidently, is not the case, as is shown in the following text. The discrepancies are present in definitions addressing the principal scientific concepts well established over the centuries. It is discussed elsewhere how detrimental these inconsistencies are in applications of knowledge, e.g. in engineering, and even more so in education (Abhary *et al*, 2009,a,b). Typical examples include homonymy and synonymy.

What is harmful about the use of homonyms? Over recent centuries our knowledge about thermodynamics, or about materials, or about other domain, has been expanded continuously, sometimes at an increasing acceleration each year. Every year numerous publications appear presenting new results on research in polymers, a research about applications of statistics in geology, physics, biology... etc. If we undertake a search via the internet about the publications whose titles contain both the words "rolling" and "steel" for the year 2012 we find over 2,400 and for 2011 over 2,300 references. So if this means about 2,000 titles per year over the past 5 years we have approximately 10,000 publications over this short period. Let us assume that 50% of these publications are irrelevant to our professional interests - this still leaves us with reading about a 1,000 publications per year. Do we really need to increase this volume by using identical terms for differing concepts?

Synonyms are counterproductive. Why do we need several differing terms to denote an identical concept?

It is useful to clarify, at least to some extent, what is meant by “knowledge”. Knowledge is a comprehensive aggregation of canons grouped within a variety of disciplines. A discipline is a configuration of theories and hypotheses grouped for convenience that emerges due to the similarity of addressed phenomena and other issues and due to the connectedness of employed definitions and conjectures. A theory is constructed by a set of interrelated definitions, while a hypothesis is a set composed of interrelated conjectures. A definition is a relation that improves the actualisation probability for contemplated phenomena or other issues.

Before exposing several typical and important cases of such conceptual misalignment, a brief point will be made about one of the central nodes in the knowledge structure - the definition. A definition is a probability intensifier for an anticipated or detected (observed) realisation (actualisation, objectivisation); each definition is unalterable, terminable, infinitely (and simultaneously) shareable, and it does not contradict, or otherwise deny, any other definition (more detailed definitions of this concept are given elsewhere, e.g. by Abhary et al 2009 a,b, and Spuzic and Nouwens, 2004).

The rules of clear definition give to knowledge a high order of precision. At the opposite end – a definition that is overshadowed by any ambiguity – slows down or even blocks the knowledge communication arteries. Bearing in mind the recent trends in internationalising the engineering curriculum, and the role of the English language in sciences and engineering it is important to analyse the occurrences of ambiguities and their root causes.

It is important to note that the following examples address principal scientific and engineering concepts that are embedded into the core of our understanding and application of knowledge.

Examples of ambiguous concepts

Precision

The terms *precision*, *reproducibility* and *repeatability* are sometimes used interchangeably. For example, precision is defined as “a measure of test or assay reproducibility” (Segen, 2002). Repeatability is defined as the ability to get similar results at a series of examinations (Blood et al., 2007). Precision is defined in a similar fashion by Taylor (1999). Such abundance is wasteful and confusing.

In our everyday thinking, one could easily associate a concept of repeatability with the efforts needed to repeat something at all. For example imagine there is a hollow right circular cylinder and attached to its opening at the lower end is a target. The inner diameter of this cylinder is defined by a geometrically perfect circle, and its longitudinal axis points at a right angle to the target centre (bullseye).

A perfect disc made of very elastic material fits the cylinder hole, however, it slides irresistibly down, until it hits the centre of the bullseye. Assume that we do have available (at no cost) very large number of these disks, and the operation of removing a disk from the bottom of the cylinder is very easy along with conveniently returning the target to its original position. The operation of lifting the cylinder, however, in order to let it slide down from the upper opening of the cylinder depends on some attributes of the cylinder and the disk.

Now, if we think of a very tall cylinder, a large-diameter hole, and a massive disk, one would think that the whole experiment is not easily repeatable, however precise the outcome might be. On the other hand, a light small disk fitting into a small, short cylinder is repeatable.

Furthermore, the word “reproducible” is derived from the word “produce”, and a layman could, by a sheer reflex, start thinking of the efforts and costs of producing and manufacturing the above mentioned assembly.

Therefore a separate term “precision” is suitable to denote a concept that has nothing to do with repeatability and reproducibility: precision defines merely a measure of whether an exercise results in a more or less equal outcome. This concept can be very conveniently defined in terms of mathematical statistics, as show by Taylor (1999).

Centrality and average

Mathematical terms deserve quite high ranking in a hierarchy of interdisciplinary nomenclature. However, the science of mathematics if not free of artificially generated ambiguities. One example is a consequence of homonymy in the usage of the concept of “centrality”, also termed “measures of central tendency” and “location statistics”. This prolixity can be easily avoided by standardising the criteria used by the editors of scientific and engineering journals, and certainly by improving the coordination in engineering curricula across the academic community.

In addition, the term “average” has its own homonyms as well: the terms “arithmetic mean” or simply “mean” are broadly used by differing authors however with the identical meaning.

Rather than disseminating this homonymy it would be more useful to teach the students that the concept of “centrality” is a hypernym used to denote the whole group of concepts such as average, mode and median, including the concepts of geometric mean and harmonic mean (not to mention “k-times trimmed mean”, “medimean” and similar important measures).

The discussions about the differences in the concepts of “geometric mean” and “average” are educative and inspiring; the difference between the concepts of “centrality” and “location statistics” is: none.

Tolerance

The concept of tolerance in bioengineering, environmental engineering, science of biomaterials, medical sciences and related disciplines is defined as the ability of an organism to endure without reacting under the exposure to various substances and effects such as noise, electromagnetic radiation or heat. In the core of this concept there is an idea that the larger this tolerance the higher is the value showing the presence of foreign agent. However the natural reflex of a person who enters the domain of environmental engineering with a knowledge based on principal engineering education would be that tolerance is an attribute of an object itself, and it is not a response to a foreign agent. A standard definition in engineering is that the tolerance is total difference between the upper and lower limits in measured value.

A biochemical engineer would probably have to read several times a specification suggesting that tolerances of certain compounds in a drug must be radically decreased in order to respond to increasing tolerances of certain vectors. In this sentence “tolerance” is used twice each time with two differing meanings. The first use is based on the meaning that a tolerance is defined as a difference between the permissible extreme values of the measured quantity within the discussed drug. The later meaning is actually an attribute defining the reaction of the vectors exposed to the discussed drug.

Both interpretations include complex considerations about the tolerance effects. In each case, the increasing tolerance can be beneficial or disadvantageous, depending on the observed scenario, and the motives of analysis.

For example, tolerances figure are an important factor in Taguchi methods, used broadly to measure financial loss to society resulting from poor quality. This does not create a conceptual conflict with the statements such as a warning from health institutions about the need to use the antibiotics more carefully to avoid an increase in the tolerance of patients to these antibiotics.

However, if we say that there a need to impose lower tolerances to attributes of an object, and these attributes are related to the increasing tolerances of the receptor of that object, these two uses of “tolerance” are incompatible.

The above situation is further complicated by the fact that, in statistics a concept of tolerance is used in relation to concepts such as multicolinearity and confidence intervals.

The solution to the above misalignments, which creates increasing difficulties in multi-disciplinary communication, is to separate these three concepts, by using mutually differing terms to denote each separate definition.

Ring

In computer science, term “ring” is used to denote a concept of hierarchical protection domains. Inasmuch as the analogy with our ordinary notion of a ring is useful, the situation is complicated by the homonymous usage of this term “ring” in geometry to denote annulus. Moreover, within the same discipline – mathematics – the term ring is used to denote an algebraic structure generalizing the arithmetic operations of addition and multiplication.

Bearing in mind that algebra and topology are used in computer science, it would be certainly inconvenient to communicate results of research where ring theory (which studies the structure of modules and special algebras, as well as an array of concepts, such as homological attributes and polynomial identities) is used to improve protection rings (structures designed to protect data and functionality from faults and malicious behaviour).

The simplicity of possible solutions to the above ambiguities is mind provoking. Instead of ignoring the above synonymy and homonymy, coining a new special term for the use in algebra and topology, and promoting the use of the term “annulus” in geometry, would certainly be an extenuating step and encouraging example.

Conclusions

It is impossible to optimise quality in knowledge sharing unless the underlying theories are defined by means of transparent concepts and unambiguous terms that can be communicated interactively within a multidisciplinary frame of reference.

Isolating the scientific concepts by using specialised discipline-based terms represents an obstacle to interdisciplinary sharing of knowledge. The ambiguities, such as synonymy and homonymy that emerge beyond such artificial boundaries present a serious hindrance in research and education oriented towards globalisation of knowledge.

These ambiguities amplified by the trends of developing portfolios such as environmental sciences, mechatronics and biotechnology must not be simply ignored.

Contemporary communication methods provide feasible platforms that can be employed within the real-time to standardise the principal scientific and engineering concepts for sharing across a broad interdisciplinary framework.

There is an urgent need for improving the definitions of key engineering concepts that are burdened by ambiguous interpretations. The examples of disciplines where the scientific taxonomy is well established (such as entomology and some branches of geology and medicine) should be followed and a systematic hierarchy of transparent definitions introduced.

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