Sensors & Transducers, Vol. 160, Issue 12, December 2013, pp. 457-462

Sensors & Transducers

A New Fusion Method of Table Tennis Sensor Information System

[1] Ji PING, [2] Ding ZHIYI
[1] School of Physical Education, Ning Xia University,
Yinchuan, 750021, China
[2] School of Mathematics and Computer Science, Ning Xia University,
Yinchuan, 750021, China
E-mail: jiping319@163.com

Received: 13 October 2013 /Accepted: 22 November 2013 /Published: 30 December 2013

Abstract: We have collected Table Tennis Training data by sensor System to improve training level. Table Tennis Sensor System analytical methods must be better designed, including definitions, analysis principles, and Information Fusion to avoid inconsistent vocabulary and potentially incorrect interpretation of training data. A continuing problem for Information Fusion of Table Tennis Sensor (TTS) is to develop efficient information unit. Many experts see information fusion as an important solution. The quality of TTS information fusion include establishing and maintaining a database of Table Tennis training information, searching for applicable information to be fused in a design, as well as adapting information toward a proper structure. In this paper, a new Data Vector Model (DVM) method is suggested here for training data classification and fusion of Table Tennis training data. We found that this new method gives a higher accuracy in training data selection and fusion process of TTS compared to the existing formal methods. We can improve the level of Table Tennis training by this method. *Copyright © 2013 IFSA.*

Keywords: Table tennis sensor, Training data, Fusion of information, Data vector model.

1. Introduction

In the International System (SI) of units, there are 7 base quantities (length, mass, temperature, luminous intensity, time, etc.), from which all other quantities in the sciences and in engineering are derived. Of these 7 base quantities, only time (and multiples of its base unit, the second) is used in Table Tennis Sensor System engineering for the analysis of two project parameters: duration and effort. These parameters are then used in derived quantities, such as number of faults and number of tests, to represent some aspects of Table Tennis Sensor System quality, such as availability and modifiability.

In the field of Table Tennis Sensor System engineering, the single term metrics is often used in reference to multiple concepts: for example, the quantity to be measured (measurand1), the analysis procedure, the analysis results or models of relationships across multiple analysis, and analysis of the objects themselves.

In recent decades, hundreds of so-called Table Tennis Sensor System metrics have been proposed by researchers and practitioners alike, in both theoretical and empirical studies, for measuring Table Tennis Sensor System products and Table Tennis Sensor System processes [6-9]: most of these metrics were designed based either on intuition on the part of researchers, or on an empirical basis, or both, and they are often characterized by the ease with which some development process entities can be counted. The inventory of Table Tennis Sensor System metrics is at the present time so diversified and includes so many individual proposals that it is not seen as economically feasible for either the industry or the research community to investigate each of the hundreds of alternatives proposed to date.

With the notable exception of the analysis of the functional size of Table Tennis Sensor System (ISO 19761), no base measure for Table Tennis Sensor System has yet reached an international level of standardization. Initiatives to precisely define and develop international consensus on base analysis for Table Tennis Sensor System and Table Tennis Sensor System quality are few and far between. For instance, there are still some noticeable differences in the vocabulary used for Table Tennis Sensor System analysis process in ISO 15939 and ISO 9126 [3-6], compared with the analysis vocabulary adopted in the sciences and in engineering as a common taxonomy of analysis terms, including metrological terms like meter, lumen, Celsius degree, etc. [1].

Comparing analysis views from these standards will allow researchers to carry out comparative studies of multiple alternative analysis for the same attributes, and then to publish their studies and recommendations, so that industry has the necessary information on which to base their selection of an analytical method appropriate to their needs. We have no intention of proposing a specific Table Tennis Sensor System analysis framework in this paper. even though it would be desirable to do so, but instead we aim to provide a better understanding of two analytical methods, in order to help Table Tennis Sensor System engineers obtain accurate, repeatable, and reproducible analysis results.

2. Related Work on Analysis Concepts and Terminology

2.1. Metrology

The domain of knowledge referred to as metrology forms the foundation for the development and use of analysis instruments and analysis processes in the sciences and in engineering.

While metrology has a long tradition of use in, for example, physics and chemistry, it is rarely referred to in the Table Tennis Sensor System analysis literature. A notable exception in the Table Tennis Sensor System engineering literature is NIST (National Institute of Standards and Technology), which investigated “the underlying question of the nature of IT metrology” in 1996, and identified “opportunities to advance IT metrology.” NIST proposed, for instance, “logical relationships between metrology concepts,” consisting of four steps to follow to obtain measured values: defining quantities/attributes, identifying units and scales, determining the primary references, and settling the secondary references. In addition, in 1999, Gray discussed the applicability of metrology, and the necessity of applying it, from the Table Tennis Sensor System analysis point of view: “We are still perhaps on the eve of giant steps in the new century for information technology. We will still need better analysis and more uniformity, precision, and control to achieve these giant steps.” Since then, metrology has been used for the design of the COSMIC analytical method, and is also addressed in [2].

2.2. Analysis Definitions for the Practical View

While in the Table Tennis Sensor System engineering literature, analysis is often defined as a mapping between two structures, this does not give sufficient information about how to measure in practice. It was pointed out in [2] that it is necessary to move beyond the theoretical definition of the mapping to an operational procedure, as described in the vocabulary of the VIM [1] and modeled with a transition through three levels for a practical view (Fig. 1).

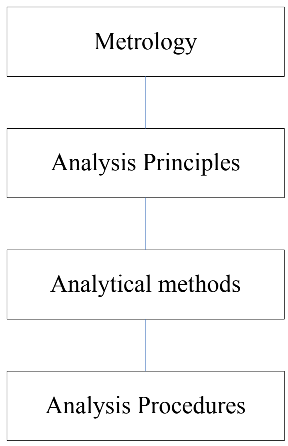

Fig. 1. Analysis foundations.

An analysis principle forms the scientific basis of analysis. For Table Tennis Sensor System entities (products), the analysis principle involves the model(s) used as a basis to describe the concept that is related to a concept to quantify, and which can be quantified by an analytical method. The idea is that modeling, as a central notion in Table Tennis Sensor System product, should be considered at the same level as scientific principles in other sciences and in engineering [2].

2.3. Base Quantity and Analytical Method

To adequately quantify a concept, an analytical method is required, which itself must include a coherent set of definitions and analysis rules, as well as a base unit specific to the analytical method.

A base unit is “an analysis unit that is adopted by convention for a base quantity” [1]. There is only one base unit for each base quantity.

An analytical method is a generic operational description, i.e. a description of a logical sequence of operations for performing an analysis activity, for moving on from the concept to quantify to the value representing the analysis result [5].

An analysis procedure is a set of operations, described specifically and used in the performance of particular analysis according to a given method [6].

An analytical method should be implemented concretely by some concrete operations achieved through measuring instruments and/or practical operations: selection, counting, calculation, comparison, etc. This description of an analysis according to one or more analysis principles and to a given analytical method is called the analysis procedure, which is more specific, more detailed, and more closely related to the environment and to the measuring instruments (e.g. tools) than the method, which is more generic.

Box A: Examples of some analysis terms in Table Tennis Sensor System engineering.

Box A gives examples of a base quantity, a base unit, a concept to quantify, and a measurable concept.

Note that the term metrics is avoided in the definitions above: although it is widely used in Table Tennis Sensor System engineering, its use causes ambiguity, and possibly confusion, by suggesting erroneous analogies; therefore, this term is not used in this text.

3. The Analytical Method

In this section, the four steps recommended for designing an analytical method for a base quantity are described in more detail [2]. In Section 4, we analyze, using these steps, the design of two base quantities related to the quality of the Table Tennis Sensor System.

To obtain a base quantity [1], it is not only necessary to apply an analytical method to the measurable concept, but also to use the base unit in the analytical method, and to identify and define that base unit if this has not already been done. Now, when measuring in practice, an analysis procedure should be documented as a distinct activity. This is because the analysis procedure used to obtain the analysis result (i.e. a base quantity) in a specific environment is required in order to instantiate the analytical method (e.g., a procedure to determine the functional size of a project using the COSMIC analytical method with use cases).

The four steps recommended by Abran in [2] to design an analytical method are:

1) Determine the analysis objectives;

2) Characterize the concept (and the sub-concepts) to be quantified;

The word “process” is used because the references suggest a number of steps.

3) Design the Meta model (of the relationships among the sub-concepts);

4) Define the numerical assignment rules.

These steps can also help to verify the design of the analytical method for a specific base quantity. As well, they can be applied to specify or improve the design of analytical methods for many of the base quantities 3 embedded in the metrics proposed in ISO 9126.

3.1. Determine the Analysis Objectives

The first step is to identify the objectives for measuring the base quantity. In ISO 9126, these objectives are related to the quality characteristics and sub characteristics to be measured. The analysis context determines the type of user of the base quantity, the life cycle phase in which it will be used, and the number of constraints to using it when the information is available. The mapping between analysis-related terms is adduced in Table 1.

Table 1. Mapping between analysis-related terms.

VIM	ISO 15939	ISO 25021
Concept to quantify	Attribute	Property
Analytical method	Analytical	Analytical
Base unit		
Base quantity	Base measure	Quality

3.2. Characterize the Concepts (and Sub-Concepts) to be Quantified

Table Tennis Sensor System is often perceived as an intangible product, but one that can be made visible through multiple representations: a set of screens and reports for a user, a set of lines of code (or executable statements) for a programmer, and a set of Table Tennis Sensor System model representations for a Table Tennis Sensor System designer are some examples.

Characterization can be achieved by first stating explicitly how the concept (e.g., defects in the Table Tennis Sensor System documentation) to be quantified (e.g., defect in the Table Tennis Sensor System documentation) is decomposed into sub-concepts (e.g., how defects in the Table Tennis Sensor System documentation are decomposed into sub-concepts).

Knowledge about the objective should determine what information should be included in the quantification of the concepts to be measured, or excluded from it, in terms of sub-concepts. Moreover, it is important to care-fully define what is included, as failure to do so can result in sub-concepts that are defined differently being included in the design of analytical methods attempting to measure the same concept. For example, Base Functional Units (BFC) is different in the IFPUG standard and the COSMIC Analysis Manual: IFPUG considers an elementary process (such as an IFPUG Input or Output) as a BFC, while COSMIC considers a data movement as a BFC. This makes it challenging to compare the results of these analytical methods.

3.3. Design the Meta Model

Defining concepts and sub concepts is only one part of the method for characterizing them. It is also necessary to apply principles and set rules. Principles link the compliance of a specific concept (or sub-concept) to its definition. For example, an entry data movement in the COS-MIC analytical method “shall not exit data across the boundary, or read or write data.” Rules help to confirm the status of a concept (or sub-concept) in a particular situation. For example, the trigger (a sub-concept) of an entry data movement could be the internal clock of a computer, even though it is generated periodically by hardware. Having defined the sub concepts related to the concept to be quantified, the next step is to construct the Meta-model of the analytical method.

The Meta-model is constructed based on the sub-concepts of the concept to be quantified. The relationships (or roles) between that concept and the sub-concepts that represent the Table Tennis Sensor System, or part of it, constitute the Meta-model. The Meta model describes how to recognize the concept(s) and/or sub concepts in the analytical method. For example, definitions, principles, and rules are de-scribed in detail in the COSMIC Analysis Manual for determining the functional size of requirements in the COSMIC analytical method.

A generic Meta model should not be specific to any particular Table Tennis Sensor System, and must be independent of the specific context of the analysis, i.e. how the Table Tennis Sensor System is implemented (unless it is what we want to measure). For example, in the analysis Meta model of ISO 19761 (COSMIC), the functional user enters and receives data that are read and written by Table Tennis Sensor System. This Meta model, which shows the relation-ships between the sub concepts (i.e. users, type of data movement – entry, exit, read, or write) of the Table Tennis Sensor System that use different physical units (I/O hardware, computation hardware, and storage hardware. It should also identify the measure and (input).

Each type of data movement in the COSMIC analytical method rules is considered as an input (i.e. the measure and) to be taken into account in the analysis process.

3.4. Define the Numerical Assignment Rules

Assigning numerical rules is part of the process of designing an analytical method. A numerical assignment rule can be described from a practitioner’s point of view (generally text) or from a theoretical point of view (generally a mathematical expression).

A quantity should be associated with a scale type [2]. Only certain operations can be performed on certain scales of analysis, and the mathematical algorithm proposed by an analytical method must conform to those operations. For example, differences between two ordinal values cannot be quantified; therefore, adding ordinal numbers is not allowed. When the scale types are not taken into account accurately, the quantities obtained could be wrongly interpreted.

The purpose of the analysis determines the usage of the base quantity and which base unit should be used. This affects the definition of the numerical assignment rules. For example, to obtain the number of COSMIC function points, it is necessary to identify a base unit. In COSMIC, the base unit is defined as a data movement that is related to different types of data movement (Entry, Read, Write, and Exit) within a functional process.

4. Present Method in the Data Fusion Procession

Existing methods to software fusion of information for TTS, process cover a wide spectrum of data encoding methods and search or matching algorithms. The en-coding methods differ with respect to their soundness, completeness, and the extent to which they support an estimate of the effort it takes to modify a data. Text-based encoding and fusion is neither sound nor complete. Its disadvantages have been thoroughly in the information fusion literature [5, 6]. Lexical descriptor-based encoding method also suffers from a number of problems about developing and using classification vocabulary [7]. Software specific problems include the fact that one-word or one-phrase abstractions are hard to come by in the software domain [8]. From the user’s point of view, lack of familiarity with the vocabulary is also pointed out as draw back in using a fusion of information for TTS, system effectively [9]. In this context Data Vector model will be a promising solution for fusion of information for TTS, process [10].

4.1. Methods Used

It is an algebraic model in which documents and queries are represented as data Vectors as follows:

$$dj = (w1, j, w2, j, \dots ,wt, j)$$
$$q = (w1, q, w2, q, \dots ,wt, q)$$

Each dimension corresponds to a separate term. If a term occurs in the document, its value in the data Vector is non-zero. An indexed collection of documents is represented as a term table which has documents as fields and words as primary key for row. The (D)i (Word)j-th entry of this table records how many times the j-th search term appeared in the i-th document. The following Fig. 2 shows a sample data Vector model.

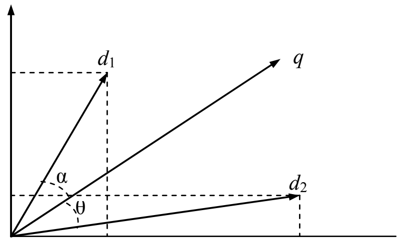

Fig. 2. A sample data vector.

The first major data of a data Vector space search model is the concept of a term space. A term space consists of every unique word that appears in a collection of documents. The second major data of a data Vector space search model is term counts. Term counts are simply records of how many times each term occurs in an individual document. This is represented as a table. By using the term space as a coordinate space, and the term counts as coordinates within that space, we can create a data Vector for each document. As the number of terms increases, the dimensionality of DVM also increases. Table 2 shows the structure of the word database and Table 3 shows the structure of the rank table.

Table 2. Structure of word database.

Words	d_1	d_2	d_3	d_4	**…**	d_n
	1	1	3	1	0	1
	2	0	2	1	0	1
	0	1	3	0	0	2
	0	0	0	0	0	0

Table 3. Structure of rank table.

Dno	**Rank**
d_1	1
d_2	2
…	…
d_n	1

For these words documents and corresponding ranks will be stored in the rank table. Based on the ranking terms are compared as “ranked higher than”, “ranked lower than” or “ranked equal to” the second, making it possible to evaluate complex information according to query criteria. Here search data Vector space search model ranks the documents it finds according to the estimation of their relevance, making it possible for the user quickly to select the information according to their requirements [7].

Relevancy rankings of documents in a keyword search can be calculated, using the assumptions of document similarities theory, by comparing the deviation of angles between each document data Vector and the original query data Vector where the query is represented as same kind of data Vector as the documents.

It is easier to calculate the cosine of the angle between the data Vectors instead of the angle:

$$\cos\theta = \frac{d_2 \cdot q}{\|d_2\|\|q\|} \tag{1}$$

A cosine value of zero means that the query and document data Vector are orthogonal and have no match (i.e. the query term does not exist in the document being considered).

4.2. The Document Classification Algorithm

VOP classifier is an instance-based learning algorithm that is based on a distance function for pairs of observations, such as the Euclidean distance or Cosine. The V-Optimal Path (VOP) classifier algorithm has been studied extensively for text categorization by Yang and Liu [6]. In this classification paradigm, k shortest paths of a management data are computed first. Then the similarities of one sample from testing data to the k shortest paths are aggregated according to the class of the paths, and the testing sample is assigned to the most similar class. The similarity in score of each path document to the test document is used as the weight of the categories of the path document [8]. If there are several management documents in the k shortest path, which share a category, the category gets a higher weight. In this work, we used the Cosine distance to calculate the similarity score for the document representation.

One of advantages of VOP is that it is well suited for multi-modal classes as its classification decision is based on a small path of similar objects (i.e., the major class). So, even if the target class is multi-modal (i.e., consists of objects whose independent variables have different characteristics for different subsets), it can still lead to good accuracy. A major drawback of the similarity measure used in VOP is that it uses all Vectors equally in computing similarities. This can lead to poor similarity measures and classification errors, when only a small subset of the Vectors is useful for classification [5].

Steps for VOP Using Average Cosine:

Step 1: Select k nearest management documents, where the similarity is measured by the cosine between a given testing document and a management document.

Step 2: Using cosine values of k shortest paths and frequency of documents of each class i in k shortest paths, compute average cosine value for each class i, Avg_Cosine (i).

Step 3: Classify the testing document a class label which has largest average cosine.

In order to reduce the dimensionality of DVM and keep useful information, we first compute concept data Vectors for given categories. Then, using the concept data Vectors as projection matrix, projection of both management and testing data is done. Finally, we apply VOP algorithm on the projected DVM model that has reduced dimensionality.

Steps of Combined Method for Data Vector Based Algorithm and V-Optimal Path Algorithm:

Step 1: Compute a concept data Vector for each category using true label information of management documents and then construct concept data Vector matrix C (w-by-c), where c is the number of categories.

Step 2: Do projection of DVM model A (w-by-d) using concept data Vector matrix C (w-by-c) (i.e., C^T * A).

Step 3: Apply VOP with the projected DVM model (i.e., c-by-d matrix).

5. Analysis of the Designs of Two Table Tennis Sensor System

There are hundreds of definitions of Table Tennis Sensor System metrics in the Table Tennis Sensor System engineering literature, but only a few attempts have been made to provide comprehensive definition of a measurable concept for an analytical method. We have chosen two designs of Table Tennis Sensor System analytical methods, because their definitions are documented and are both related to Table Tennis Sensor System quality:

1) The analytical method for code, from Munson and Nikora;

2) The analytical method for the size of "use cases from the documentation"4 in [7].

Using the analysis concepts and criteria in [2], it is possible to determine whether or not the analytical method proposed for the concept to be quantified is complete. This section discusses how each example fulfills the requirements for each step in the design of an analytical method.

6. Discussion and Future Work

In the Table Tennis Sensor System engineering literature, few references focus on the definition and design of Table Tennis Sensor System analytical methods. Among those that do are Munson, et al. and the ISO standards on functional size analysis. To avoid inconsistent vocabulary and potentially incorrect interpretation of data, Table Tennis Sensor System analytical methods must be better designed, including definitions, analysis principles, analysis rules, and base units.

In this paper, we have proposed a novel approach to the information content of data in a database. We gave a set of basic concepts and described an experimental system that makes use of this notion. A number of examples were used to test our system. With information sources outside a database imported into the system, the information content of a random event (data values) within the data-base expanded dramatically. Users could make the most of the information content of data by posing queries. Thus, more information can be discovered than conventional queries. The increase of random events' closures is based on the boost in original DVM and the inference capability using DVM. Identification of original DVM rules could be hard due to wide range of sources outside database. However, once original DVM have been identified and then fused into the computing unit of our system, the system provides a powerful engine for users to query a database.

Acknowledgement

This paper is supported by the national natural fund of China (Grant Number: 61063003).

References

[1]. A. Jansen and J. Bosch, Table tennis sensor system architecture as a set of architecture design decision, in *Proceedings of the 5th Working IEEE/IFIP Conference on Table Tennis Sensor System Architecture*, Pittsburgh, 6-10 November 2005, pp. 109-120.

[2]. J. Lee, Table tennis sensor system engineering with computational intelligence, *Springer Publication*, 2003, pp. 183-191.

[3]. X. Ferre and S. Vegas, An evaluation of domain analysis methods, in *Proceedings of the 4th CASE/IFIP8 International Workshop in Evaluation of Modeling in System Analysis and Design*, 1999, pp. 2-6.

[4]. B. Boehm, Table tennis sensor system engineering economics, *IEEE Information System Engineering*, Vol. 10, No. 1, 1984, pp. 4-21.

[5]. B. Boehm, A spiral model of table tennis sensor system development and enhancement, *IEEE Computer*, Vol. 21, No. 5, 1988, pp. 61-72.

[6]. A. Hamid and S. E. Madnick, Lesson learned from modeling the dynamics of table tennis sensor system development, *Communication ACM*, Vol. 32, No. 12, 1989, pp. 14-26.

[7]. J. Ropponen and K. Lyytinen, Units of table tennis sensor system development risk: how to address them? A Project Manager Survey, *IEEE Transaction on Information System Engineering*, Vol. 26, No. 2, 2000, pp. 98-112.

[8]. N. Medvidovic and R. M. Taylor, "A classification and comparison framework from table tennis sensor system architecture description languages, *IEEE Transactions on Information System Engineering*, Vol. 26, No. 1, 2000, pp. 70-93.

[9]. R. Kaur and J. Sengupta, New approach in table tennis sensor system development-fusion process model, *Journal of Information System Engineering and Applications*, Vol. 3, No. 10, 2010, pp. 998-1004.