

Engineering of Knowledge Structures: Perspectives from Traditional Disciplines and Systems Principles

Doji Samson Lokku, Anuradha Alladi

Tata Consultancy Services, Hyderabad, India
{doji.lokku@tcs.com, alladi.anuradha@tcs.com}

Abstract. A human endeavor can be seen as leveraging certain ‘means’ in order to accomplish a given purpose. The means could be several, but inevitably knowledge underlies all of them. The proposed paper attempts to present various perspectives that can aid in order to arrive at the ‘means’ of a knowledge structure.

As per systems methodology, it is the structure and the associated process that when brought together in a given context, give rise to accomplishing a purpose. Accordingly the means could be seen as both the structure and the associated process. Also the concerns that are needed to be taken into consideration while accomplishing a given purpose can be broadly categorized into two, relative to the purpose, in terms of, whether they are *in favor of* or *not in favor of*.

The representation proposed in the paper serves as a guidance while arriving at knowledge structures.

Keywords: Knowledge, Structure, Systems, Purpose, Process, Function, Context

1 Introduction

The epitome of any human endeavor is accomplishment of a stated or intended purpose. Thus a human endeavor can be seen as leveraging certain ‘means’ in order to accomplish a given purpose. The means could be through technology or knowledge or a human intervention or things such as those, but inevitably knowledge underlies all of them. The proposed paper attempts to present various perspectives that can aid in order to arrive at the ‘means’ of a knowledge structure. The aim of this paper is to discuss these perspectives with active participation from the audience using familiar illustrations, so as to reinforce our understanding of the topic.

Traditionally engineering is a profession which addresses the concerns of sustenance (while accomplishing a purpose). Accordingly engineering offers sustenance to a means, as the means aids in accomplishing a purpose. On a smaller scope, a purpose can be viewed as a set of functions. As per systems methodology, it is the structure and the associated process that when brought together in a given context, give rise to accomplishing a function. Accordingly the means could be seen as both the structure and the associated process. For example, the ‘means’ for crossing a river could be a bridge structure.

Principles of systems lend us a handle to capture the concept behind the representation for accomplishing a given purpose. The representation inherits its basis from the principles namely purposefulness, openness, multidimensionality, **counterintuitiveness** and emergent property. The scope of the proposed paper takes into consideration a majority of these principles.

The very many concerns that are needed to be taken into consideration while accomplishing a given purpose can be broadly categorized into two, in relation to the purpose, in terms of whether they are in favor of or not in favor of. Accordingly addressing these varied concerns is expected to result in either accomplishing the purpose to the fullest extent or be able to just cope with, without in any way contributing to the purpose. The former is a fully favorable scenario and the later is a worst case scenario, while accomplishing a given purpose.

For example, a physical structure is expected to withstand seismic or wind forces that come upon it. Where as the sun light that comes into a living room should be maximally utilized towards a healthy living. In other words, the concerns that are in favor lead to thriving and the concerns that are not in favor expects surviving, while accomplishing the purpose. With this line of thought, engineering should ensure that enough sustenance is built into the respective structure & process, both of which are expected to aid in accomplishing a purpose.

This particular representation will find its use in being able to look for the category of concerns that need to be addressed and also to identify the gaps in arriving at the means with respect to the ideal. The currently existing knowledge structures can be seen in the light of this paper and be analyzed for any gaps that exist in them. This representation will also point to the various bodies of knowledge that are multidimensional, using which the varied concerns while accomplishing a given purpose may be addressed.

The representation proposed here for presentation operates at the level of the knowledge that is required for accomplishing a purpose. What are the knowledge structures for ‘Organizing Knowledge’? Familiar human endeavors such as these are attempted for representation, as part of illustration towards the proposed paper.

For the scope of this paper, a human endeavor is viewed as an attempt by people leveraging a certain means, towards accomplishing a given purpose. The purpose could be stated or intended. Also, for the scope of this paper, the purpose which people attempt to accomplish is merely given and as such there is no debate in this paper about the topic of purpose itself, in terms of what is a purpose and why is it a purpose and the related discussion. This particular basic premise about a human endeavor aimed at a purpose is depicted in figure 1.

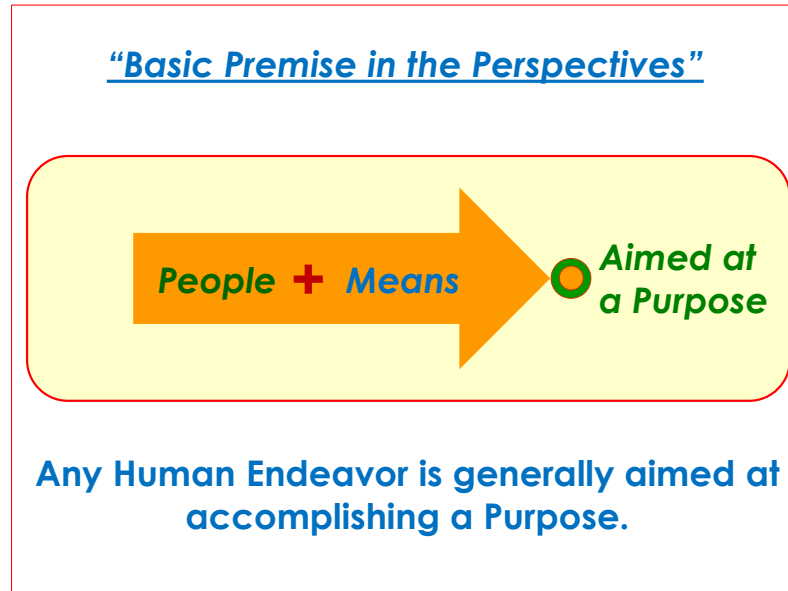


Fig 1 Basic Premise in the Perspectives

Since engineering is about addressing the concerns of sustenance (of a means that would aid), while accomplishing a purpose, the engineering design objective is to come up with such ‘means’ or scheme of things, that supposedly aid in accomplishing a purpose. As per systems methodology by J. Gharajedaghi [1], these means are the structure & process and knowledge is the underlying ingredient.

The various books of knowledge which supposedly describe the concerns a given ‘means’ will be subjected to, are portrayed as the possible solution space. We choose various schemes that aid ‘Organizing Knowledge’ as a case towards knowledge structure and discussed if it reflects the elements that we have described as part of this paper.

2 Systems Principles and Systems Methodology

According to J. Gharajedaghi [1], the following five principles act together as an interactive whole, and define the essential characteristics about systems. The five principles are:

- Openness
- Purposefulness
- Multidimensionality – partially included for discussion in this paper.
- Emergent Property – not included for discussion in this paper.
- Counterintuitiveness – not included for discussion in this paper.

Also as per J. Gharajedaghi [1], function-structure-process-context forms an inevitable whole towards a systems methodology. Accordingly at a smaller scope, function is equated with the purpose and carrying out a function with the aid of corresponding structure & process leads to accomplishing the purpose. This statement also means that in the absence of an associated process, structure alone will not be able to accomplish the purpose. This overall understanding is captured in table 1.

Concerns of Knowledge / Means for accomplishing a Purpose	Concerns of Knowledge that are <i>in favor</i> while accomplishing the Purpose	Concerns of Knowledge that are <i>not in favor</i> while accomplishing the Purpose
Means in the form of a <i>Structure</i>		
Means in the form of a <i>Process</i>		

Table 1. Means & Concerns

This paper is about our attempt to apply these principles and to put together our understanding about systems methodology, in order to arrive at a representation that can aid in engineering of knowledge structures. The systemic principles come into the context of our attempt, leading to the representation that we could arrive at. As an illustration, the various schemes that aid in ‘organizing knowledge’ with their respective structures are viewed through this generic representation.

3 Perspective from the Systems Principle of ‘Purposefulness’

According to J. Gharajedaghi [1], one of the principles of systems is ‘purposefulness’ and he refers to human beings as purposeful systems. According to Russel Ackoff [2], a way to look at human behavior is to view them as systems of purposeful events. Hence a human endeavor ideally is aimed at accomplishing a purpose, whatever the purpose may be. Accordingly ‘purpose’ forms an important element in the representation towards engineering of knowledge structures.

A purposeful system is one that can produce not only the same outcome in different ways in the same environment but different outcomes in both the same and different environments. The ‘scope of a purpose’ can vary based upon the level at which one choose to operate. The discussion on what is a purpose and why is it a purpose is not part of the scope in this paper. In order to accomplish a purpose, people will leverage certain ‘means’ that supposedly adhere with systemic principles. The ‘means’ plus the people who would employ the ‘means’ to accomplish a purpose, is shown in figure 2.

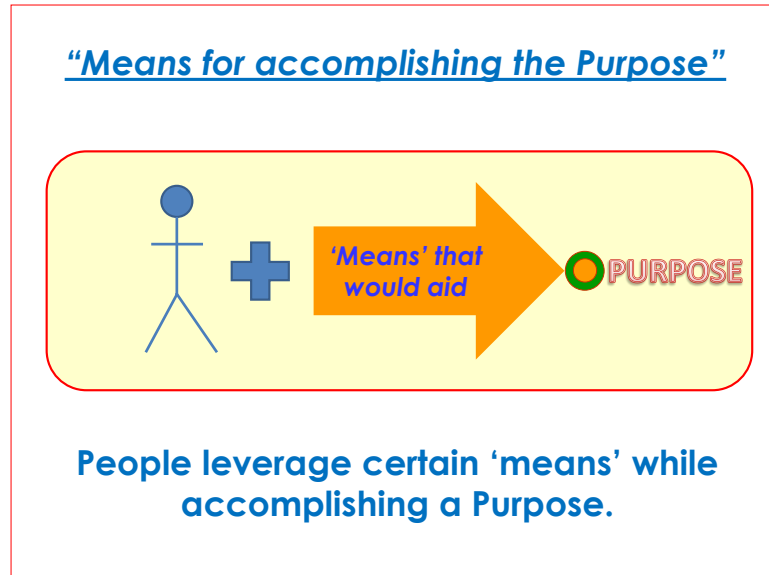


Fig 2 Means for accomplishing the Purpose

4 Perspective from the Systems Methodology

As per systems methodology, structure, function, and process with the context, define the whole or make the understanding of the whole possible. Structure defines components and their relationships; function defines the outcomes; process defines the sequence of activities; context defines the environment in which the system is situated. As per J. Gharajedaghi [1], iteration is the key for understanding the system and iteration on structure, function and process in a given context would establish the validity. Accordingly, the means amounts to the structure & process as depicted in figure 3.

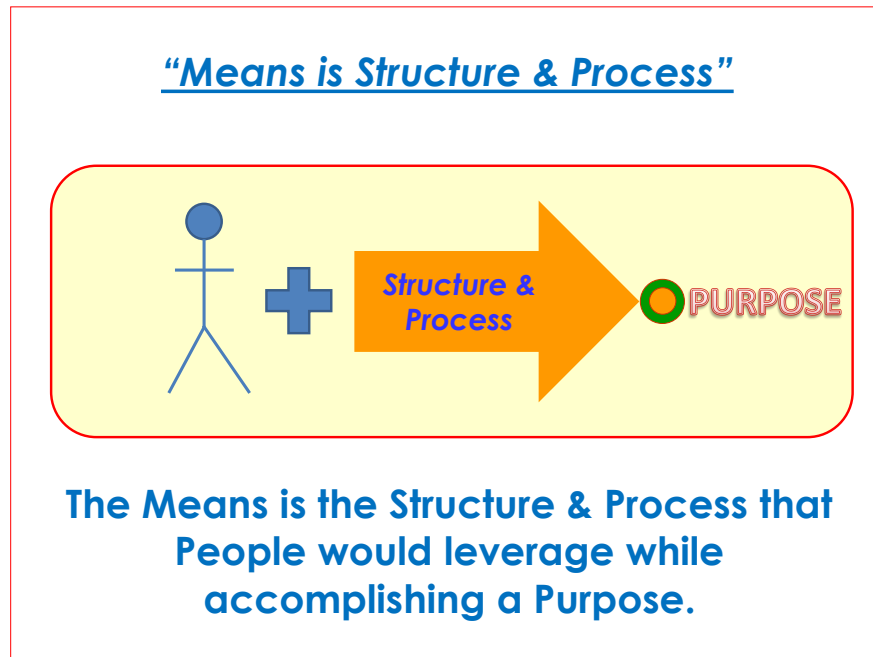


Fig 3 Means is Structure & Process

5 Perspective from the Systems Principle of ‘Openness’

While attempting to accomplish a purpose, the forces or concerns that exist in a context or environment needs to be dealt with. These may be termed as ‘influences’ also. Accordingly, the associated knowledge that becomes relevant to the given purpose can be separated in to two: one is the knowledge that is ‘in favor’ of the purpose and the other is the knowledge that is ‘not in favor’ of the purpose. The same has been depicted in figure 4. The means that is employed to accomplish the purpose should be able to cope with these respective influences. For instance, a combined discipline of knowledge is a concern that ‘means’ aimed at ‘organizing knowledge’ should be able to cope with.

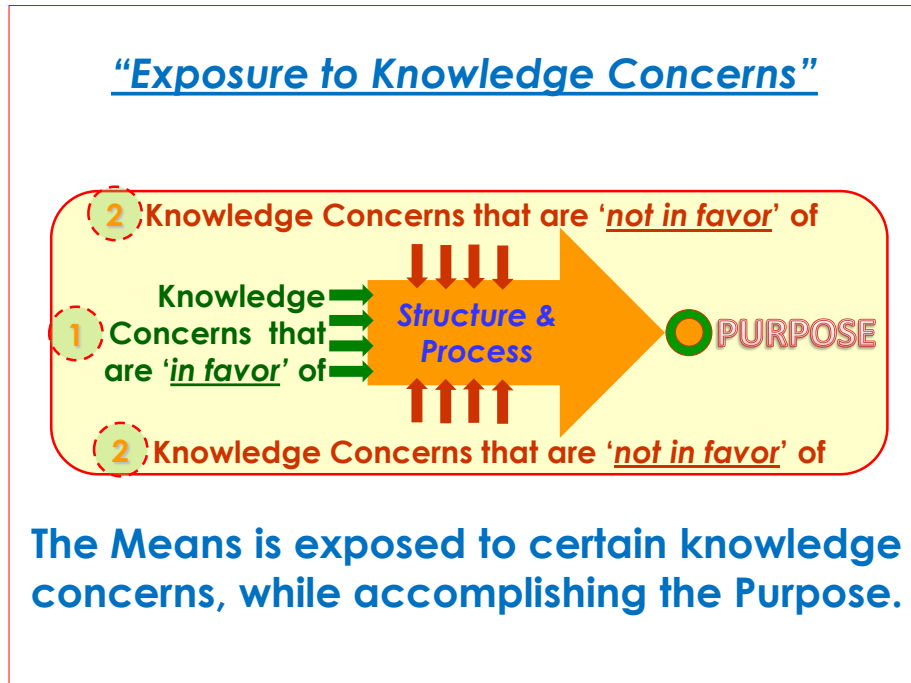


Fig 4 Exposure of Means to Knowledge Concerns

6 Perspective on Solution Space for the ‘Means’

Openness also lends a handle towards access to various bodies of knowledge where one can find not only the knowledge of the problem but also knowledge of the solution too. The BOK (Book of Knowledge) consists of knowledge which refers to both of the concerns that are in favor of and also not in favor of, while accomplishing a purpose. Accordingly, the respective solutions also may be found within this knowledge base. The representation of it is depicted in figure 5.

Though we have separated the knowledge into two, relative to the purpose, the sources for identifying the knowledge are the same. They are the various bodies of knowledge resident in books and other media and also the body of knowledge that is present with people. These sources of knowledge consist of and refer to both those concerns (and influences) that are in favor and also not in favor, as depicted in figure 4. These sources of knowledge should not be confused with the ‘classification of knowledge’ which has been described as part of the illustration on ‘organizing knowledge’.

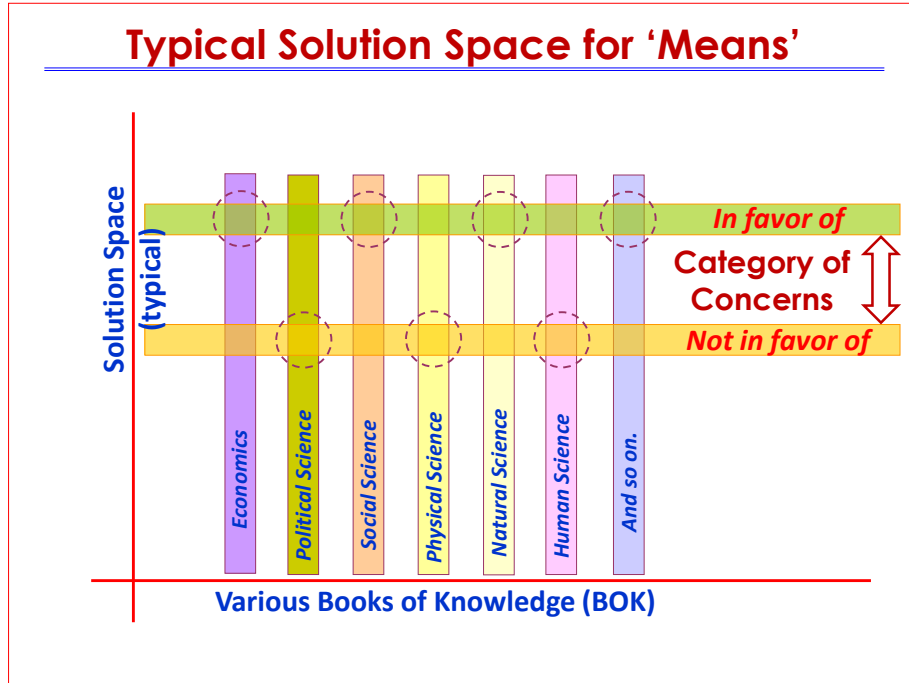


Fig 5 Typical Solution Space

7 Perspective from the Systems Principle of Multidimensionality

Multidimensionality is about the ability to see complementary relations in opposing tendencies. This principle maintains that the opposing tendencies not only coexist and interact, but also form a complementary relationship.

According to J. Gharajedaghi [1], "human beings form varying relations with each other, creating an interactive type of structure. Interactions between purposeful people in a group take many forms. People may cooperate on one kind of tendencies, compete over others and be in conflict over others and all of this at the same time. People learn and mature over time and are subject to change. The result is an interactive network of variable members with multiple relationships, recreating the network on a continuous basis. This is what is meant by plurality of structure".

In the context of knowledge structures, with knowledge being resident with people, accepting the plurality of structure is necessary to appreciate the principle of purposefulness and multidimensionality. Unlike traditional (physical) structures that endure, knowledge structures can continuously change and recreate themselves on a continuous basis.

Plurality of structure is an attribute by which ‘knowledge structures’ can recreate themselves continuously. As the purposes are realigned and the respective concerns change, the structures need to adjust towards renewed missions. Knowledge being non-physical, this manner of recreation is possible to achieve on an ongoing basis.

8 Further work on the Perspectives

Do we engineer the structure (and the process)? Or, do we engineer the knowledge? Perhaps we need to do both. What are the ‘Degrees of Freedom’ of the means employed? What are the limits of tolerance for them? What are the units or dimensions for knowledge structures? How do we take advantage of ‘plurality of structure’ in order to cope with change? How about the other principles namely counterintuitiveness and emergent property? What are the various realization levels [5] of discourse? All these are of interest and going forward we will study them. The proposed paper presentation can offer an opportunity for people to collaborate and carry out further study on these and related topics.

9 Context of ‘Classification of Knowledge’ and Description of various Schemes for ‘Organizing Knowledge’

There are several schemes for organizing knowledge. Those who have come up with these schemes have thought about the various concerns and also they have thought about these concerns differently. What should be the ideal scheme? What are all the concerns that it should address? Why is it that a given scheme has become popular in spite of other schemes having better features?

We choose this illustration for the reason that it is to do with knowledge. The classification of knowledge has several schemes with corresponding structures aimed at ‘organizing knowledge’.

There are various ways knowledge classification has been done by the research scholars in the world, Barbara H. Kwasnik [3] & A N. Raju [4]. These classification schemes are commonly used in the libraries in the world. There are various classification methodologies which are in place. Some of the popular ones are Dewey Decimal Classification (DDC), Universal Decimal Classification (UDC) and Colon Classification (CC). These are briefly described in the following paragraphs.

DDC has been devised by Melvil Dewey in the year 1876. It is the most widely used classification scheme available in about 135 countries in the world. It has been translated in to more than 30 languages in the world. More than 90% of the libraries in the world are using DDC for the classification of books, which includes Public, Academic, and Special libraries in the world. DDC has 7 standard subdivisions, representing areas, individual languages and literature, racial and ethnic groups, languages and persons.

The entire knowledge as per DDC has been classified between 000 to 999. These main classes are divided further into 10 main classes. Each class is subdivided into ten more and so on. Arabic numerals are used in the classification scheme to denote a given subject. The scheme also has the flexibility to assign new emerging areas of knowledge into the scheme. This means there are unassigned numbers throughout the scheme for the emerging subjects to be included into the scheme. 23rd version of the DDC was released in 2011. The DDC scheme has more orientation towards languages and literature.

The classification numbers are readily available to assign. The notations are arranged hierarchically, which will represent a base subject classification number. For example a book on *Indian Economics* is classified as 330.954 in DDC.

300	– Social sciences
330	– Economics
330.954	– 954 is for India taken from standard subdivisions Table 2 of DDC

UDC scheme is devised by Paul Otlet and Henri La Fontain at the end of 19th Century. It is an analytic synthetic classification scheme. This method of classification helps in indexing and retrieving information easily and faster. Though UDC has been devised based on the principles of DDC, it used more connecting symbols to represent a class number. The advantage with the UDC scheme is that it will enable us to go to minute level of detail, which is required for indexing and abstracting services. Approximately 3% of the libraries in the world uses UDC scheme for the classification purposes. It is mainly used for indexing articles in journals.

UDC is hierarchically expressive, which means the longer the number, specific the class. It also has a syntactical representation which means UDC codes are combined with the help of a COLON (:) to represent a two notational elements /subjects. It is the most flexible scheme of classification of knowledge. The scheme has more emphasis laid on social sciences and technological areas. The uniqueness of this scheme is, it has common auxiliary tables which it will represent with the help of various notations to represent places, people, races, medium etc. These auxiliary tables will facilitate to provide a specific classification number to a given area of knowledge. The scheme also has a provision to accommodate new and emerging subjects.

A book on *Indian Economics* is classified as **33 (540)** using UDC scheme. The classification number is arrived as below:

33	Economics broad subject
33.(540)	for India taken from Common Auxiliary Table of UDC

CC is popularly called Colon Classification, devised by SR Ranganathan, in the year 1933. It was the first faceted analytico-synthetic classification scheme. The name Colon comes from the punctuation mark COLON (:), which helps to separate the two facets of a classification number. Colon Classification number used 42 main classes, which includes letters, numbers and punctuation marks.

The entire knowledge structure in CC are classified alphabetically from A to Z, A for generalia to Z for law. In the lines of standard subdivisions in DDC and auxiliary tables in UDC, CC used PMEST to represent various facets. The CC scheme uses 5 facets which are called PMEST, which means Personality, Matter or property, Energy, Space and Time.

The CC is most user friendly scheme of knowledge classification scheme to assign exact class number for a given subject. PMEST is represented as:

Personality	(,) Comma
Matter	(;) Semi Colon
Energy	(:) Colon
Space	(.) Period/full stop
Time	(') Apostrophe

The classification scheme uses PMEST to complement and supplement various knowledge elements to arrive at a more clear class number to a title. Below illustration helps us to understand the construction of classification number using CC. For example a book on *Indian Economics* is classified as – X . 44 using CC.

X	Economics
.	Space for connect Geography India from the title
44	is for India from PMEST

10 Illustration in the context of ‘Organizing Knowledge’

One topic of illustration that we have identified for discussion in the proposed paper is ‘organizing knowledge’. Now if we look at the scheme DDC from the point of accomplishing the purpose of ‘organizing knowledge’, the concerns or influences this particular scheme will be exposed to while accomplishing its purpose could be several. One such concern is creation of new knowledge. DDC scheme addresses this concern by way of having unassigned numbers which can be used by emerging knowledge.

The universe of knowledge is classified into broad 10 areas starting from 000 to 999, as per DDC. Any subject in the world finds its place in the classification scheme. Classification facilitates to store and retrieve information easily. Since the knowledge is classified into 10 main areas, the information we are seeking will help to relate to its broad subject area, that we can look for.

Each scheme is oriented towards a particular area. DDC is more oriented towards language and linguistics, literature and religion etc, where as UDC is more oriented towards social sciences and technology. The CC scheme helps to classify the title to the last level of detail. The CC scheme uses notations and punctuation marks to provide clear and distinct call number. This leads to lengthy *call* numbers.

In DDC, it will be difficult to assign a *call* number for a title which is dealing with more than one subject. This limitation is adequately addressed in UDC and CC while providing the use of colon and punctuation marks. UDC also uses decimals to denote a particular subject, and helps to arrive at complete details of a given title. Two subjects can be easily represented while separating with a colon or circular bracket.

DDC scheme has wider acceptance level, but if a book is dealing with more than one broad subject, the book can be classified under any one broad subject Depending on the priority you would like to assign. We cannot assign two broad subjects for a given title using DDC. The mechanism to connect two subjects is not available, unlike in UDC and CC.

Whereas UDC has overcome the challenge which DDC has, i.e we can classify a book dealing with more than one subject, by using a colon, to distinguish two broad subjects. The colon signifies representation of two subjects in a given title. For example, a book on *Political Jurisprudence* in India is classified as 34:32:934. In this 34 represents Law Jurisprudence, 32 for Political Science and 934 for India geography.

Colon classification scheme also helps to classify a book with more than two subjects by providing equal priority to two subjects, which is based on subject denoted classification scheme. An illustration of the same is shared here. For example, cultivation of Mangoes by applying financial viability is classified as J382:7 (X). The same can also be represented as X382.7 (J) to lay emphasis on economics.

J	Agriculture
382	Mangoes
:	Energy
7	Cultivation
(X)	Economics

In the above example, two main subjects are brought together and represented equally.

The basic purpose of various classification schemes is to organise knowledge present in various forms in a more methodical manner, so that it helps in classifying in a logical way and arranged on the shelves for easy retrieval.

In today's world, knowledge is available in various forms like books, journals, periodicals, magazines etc. Knowledge creates more knowledge. It is challenging if this published knowledge is not arranged meaningfully. Various classification schemes which are devised by Melvil Dewey, and others will help classify knowledge and arrange it on the shelves so that retrieving the knowledge is easier, without chaos.

While devising the classification schemes, the respective *designers* of the schemes have taken additional care to foresee the future demands and the new and emerging subjects that would come up. Accordingly they left the classification numbers to be accommodated into the existing classification scheme meaningfully and logically. These new emerging subjects take their logical position in the classification scheme, without disturbing the existing population of the scheme.

Basically all these schemes have been developed with the intention to arrange the knowledge so that it will be easy to retrieve as and when required. The various schemes that we have described are the ‘Knowledge Structures’ that are aimed at ‘Organizing Knowledge’. If we look at these various schemes through the lens of a generic representation, the elements that ought to be present in each of the schemes are:

- Purpose of the scheme;
- Influences or Concerns the scheme is exposed to;
- Knowledge concerns in favor of and not in favor of the purpose;
- Plurality of structure in the scheme;
- And a few more which we have not yet discovered.

Accordingly the given scheme will either thrive or survive, depending upon the presence of these elements in the respective scheme. The proposed paper offers to discuss with active participation from the audience, so as to reinforce our understanding about engineering of knowledge structures.

11 Extending this work to Apply in the Context of other Knowledge Structures

There are several others contexts of human endeavors, be it managing knowledge, or enforcing a given knowledge or altogether a different connotation such as nurturing an organization culture or building a corporate brand and so on, in which the generic representation may be applied. Knowing ‘knowledge as an entity’ could be the key in all such endeavors [6].

Another example for a knowledge structure as per our understanding is ‘culture’; it could be organizational culture or culture of a society or country. We very well find that technology is playing a key role in shaping up cultures. For instance use of mobile phones and other electronic communication devices have changed the manner in which people are connected and the way they communicate and relate with each other, whether it is younger generation or older generation.

Another example could be the affordability and earning capacity of individuals in shaping up cultures by way of giving rise to expensive living and credit bearing life styles. Phenomenon such as these can be studied and possibly influenced through the ‘means’ that are arrived at by taking into consideration the various influences that shape up these cultures.

Implications of the systems principles namely emergent property and counterintuitiveness have not been looked into, in the current scope of the paper. But these principles as well contribute in arriving at the representation that has been attempted. Technology can play a vital role in these endeavors by way of the enablement it can bring in shaping up the ‘means’.

12 Summary

This paper is about presenting the views or perspectives from traditional engineering disciplines and principles of systems. The views that are proposed for presentation will help in undertaking engineering of knowledge structures. The basic premise in this paper is that people leverage a certain means in order to accomplish a purpose. The means is stated to be the structure & process, both of which will get exposed to concerns that are in favor of and also not in favor of accomplishing the purpose. The engineering design objective is to build enough sustenance into both the structure & process so as to cope with these concerns. The solution space may be found in various books of knowledge where the concerns also are described.

The chosen illustration can be discussed from all possible angles so that our understanding about engineering of knowledge structures is strengthened. It is our sincere hope that these perspectives will be of help to the audience in their efforts to engineer knowledge or knowledge structures.

13 Acknowledgements

The authors are grateful to Jamshid Gharajedaghi for the knowledge and wisdom that he has presented about systems. The views presented in this paper are not possible without his inspirational writings.

Prof. Kesav V Nori, who has shaped our thoughts while leading business systems research, is quite instrumental in our attempt to bring out this particular paper.

References

1. Jamshid Gharajedaghi, Systems Thinking, Managing Chaos and Complexity, Second Edition, Butterworth-Heinemann, 2006, Elsevier Inc.
2. Russel L Ackoff, Fred E Emery, On Purposeful Systems, Transaction Publishers, New Jersey, 2008
3. Barbara H. Kwasnik, The role of Classification in Knowledge Representation and Discovery, School of Information Studies, Centre for Science and Technology, Syracuse University, Syracuse, NY, 1999.
4. AN Raju, Library Classification Theory, Himalaya Publications
5. Doji Samson Lokku, Kesav V Nori, Morphogentic Constraint Satisfaction Based Approach for Organizational Engineering, ACM SAC, Dijon, France, 2006
6. Doji Samson Lokku, Importance of knowing 'knowledge as an entity' in order to contribute towards Service Science Education, People Education Congress, HBCSE, TIFR, Mumbai, 2009