A Knowledge Based System for the Integration of Indigenous and Scientific Knowledge with Sustainability Constraint

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Abstract:- Integration of Indigenous Knowledge (IK) gained out of domain experience which is implicit and Scientific Knowledge (SK) gained out of formal learning which is explicit is important for the efficiency of knowledge storage and organization. Knowledge about a thing can be inadequate or incomplete due to limitations of representing knowledge using a single world view. Finding efficient methods to represent the integrated knowledge is necessary in order to be able to search for it and to retrieve it. Ontology is a good framework for structuring integrated knowledge in a given domain. This paper presents a conceptual ontological framework, an architectural design for knowledge based system (KBS), and a methodology for the integration of heterogeneous ontologies of a particular domain in an industrial environment.

Key-Words: Ontological Integration, Indigenous Knowledge, Scientific Knowledge, Sustainability, Knowledge Based System

1. Introduction

A knowledge based system designed on scientific methods alone or on purely indigenous method have mostly drawbacks of an incomplete system because human expertise is not formed by an intelligence gained from systematic study alone. Most of the real life situations need an expertise that is designed on an integration of intelligence from a systematic scientific study and intelligence from life experience which is called a commonsense knowledge and indigenous knowledge. Sustainability is feasible by the integration of scientific and indigenous intelligence and it is has been found to be a better solution for the efficiency of a knowledge based system. The knowledge integration process needs to be sufficiently flexible [20]. Integration of locally gained knowledge (Indigenous Knowledge) and systematic knowledge gained from a formal study, training and research (Scientific Knowledge) in a Knowledge Based System (KBS) is the focal point of this paper.

2. Indigenous and Scientific Knowledge

2.1. Knowledge

Knowledge is defined by the Oxford English Dictionary as (i) expertise, and skills acquired by a person through experience or education; the theoretical or practical understanding of a subject, (ii) what is known in a particular field or in total; facts and information or (iii) awareness or familiarity gained by experience of a fact or situation. Philosophical debates in general start with Plato's formulation of knowledge as "justified true belief". There is however no single agreed definition of knowledge presently, or any prospect of one, and there remain numerous competing theories. Knowledge acquisition involves complex cognitive processes: perception, learning, communication, association and reasoning.

2.2. Indigenous Knowledge

Flavier presents typical definitions by suggesting: Indigenous Knowledge is (…) the information base for a society, which facilitates communication and decision-making. Indigenous information systems are dynamic, and are continually influenced by internal creativity and experimentation as well as by contact with external systems [12]. The World Bank [4] states that the basic component of any country's knowledge system is its indigenous knowledge. It encompasses the skills, experiences, and insights of people, applied to maintain or improve their livelihood. However, many practices disappear only because of the intrusion of foreign technologies or development concepts that promise short-term gains or solutions to problems without being capable of sustaining them. The tragedy of the impending disappearance of indigenous knowledge is most obvious to those who have developed it and make a living through it. But the implication for others can be detrimental as well, when skills, technologies, artefacts, problem solving strategies and expertise are lost. So indigenousness does not mean a total absence of science. This paper uses the term indigenousness to refer to the locally gained knowledge from experience or practice traditionally handed down from generation to generation through oral tradition in the form of stories, practices, beliefs, sayings, etc.

2.3. Scientific Knowledge

Science (from the Latin *scientia*, meaning "knowledge") is, in its broadest sense, any systematic knowledge-base or prescriptive practice that is capable of resulting in a prediction or predictable type of outcome. In this sense, *science* may refer to a highly skilled technique or practice [2]. Scientific knowledge is the knowledge accumulated by systematic study and organized by general principles [1].

2.4. Difference Between IK and SK

A wide array of terms and definitions attempt to gather within their meaning all that indigenous peoples know. Such terms include indigenous science, traditional knowledge, local knowledge, traditional trade knowledge, traditional work experience, etc [4]. Indigenous knowledge can mean local knowledge gained out of experience and passed on from generation to generation either in a written or in an oral tradition. Scientific knowledge is defined as the knowledge gained out of regular and systematic study of a subject. Scientific knowledge has contributed to the growth of the production and management while the contribution of scientific knowledge to the sustainability of the system in a particular environment has been under doubt in recent years due to the failure of various pure scientifically monitored systems. The limitation of scientific knowledge is that it is not most of the time adapted to suit a particular context in which it is being implemented and more over it also fails to integrate the local wisdom that is available on the particular field.

3. Ontological Heterogeneity

Ontology matching is a complex process that helps in reducing the semantic gap between different overlapping representations of the same domain [21]. Ontology can exist singularly for a domain because there has not been any other ontology developed for that domain (Fig. 1).

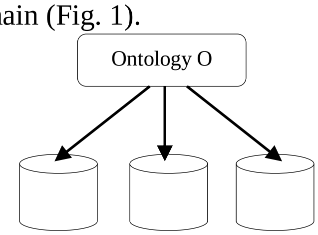

Fig. 1: Single Ontology

There may be several ontologies for a single domain arising from different world views of the ontological engineers resulting in heterogeneity of ontology (Fig. 2).

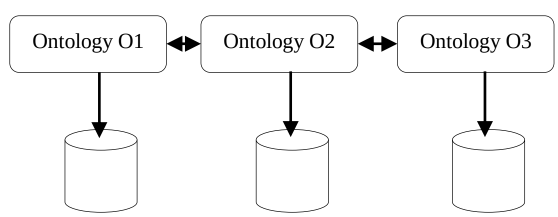

Fig. 2: Multiple Ontologies

In a situation of heterogeneity of ontology there is the issue of integration of ontologies (Fig. 3).

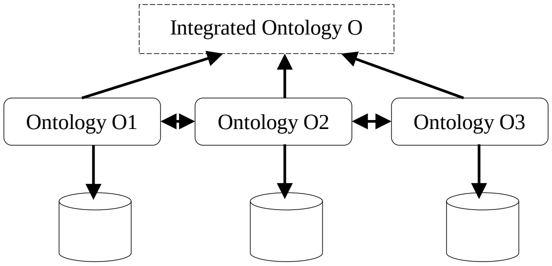

Fig. 3: Multiple Ontologies Integrated

Ontological heterogeneity refers to 'different ontological assumptions' and content heterogeneity when two systems represent different knowledge of a single domain. Heterogeneity in ontology of a domain arises in an environment where an ontology *Os* developed based on a scientific learning of the domain under consideration and an ontology *Oi* developed based on gained experience (local knowledge) of the same domain differ at some level *L*. Various authors and researchers [15] have done works on methods and systems of ontology integration and on a number of amalgamator modules and functions based on matching, unification, merging, mapping, hybridization, generic integration, and coincidental integration [6,7,8]. Authors also propose the following three kinds of matches: inherited, specialized and serendipitous [15]. This paper proposes to consider the following three constraints as the necessary and sufficient condition for the integration of IK and SK in the context of an industrial situation: common minimum, common maximum and best results. The need for integration arises when an integrated system is predicted to produce an efficient result under two constraints: productivity and sustainability.

4. Sustainability as a Condition

The integration becomes a need in a domain where the use of purely scientific knowledge has ignored the significant contribution of locally gained knowledge for a better performance and sustainable growth. The word sustainability is derived from the Latin *sustinere* (*tenere*, to hold; *sus*, up). Dictionaries provide more than ten meanings for *sustain*, the main ones being to "maintain", "support", or "endure" [3]. Sustainability involves a proper and balanced approach to the development and growth of any system that takes into consideration all the components that draw their survival from it. The problems linked with a compartmentalized approach to knowledge are related to the 'superiority –inferiority' view built on the different world views held by people of different cultures, situations, experience, etc. But these different world views have to interact in many situations where performance and efficiency can be achieved through their constant interaction or integration.

The indigenous way of understanding a domain and the scientific way of understanding a domain might differ under various levels and categorization. By the analysis of the differences between indigenous way of representing a domain and scientific way of representing a domain would allow us to amalgamate the two systems into a single integrated system. A careful amalgamation of indigenous and foreign knowledge would be most promising, leaving the choice, the rate and the degree of adoption and adaptation to the clients. To foster such a transfer a sound understanding of indigenous knowledge is needed. This requires means for the capture and validation, as well as for the eventual exchange, transfer, and dissemination of indigenous knowledge.

The paper uses ontological framework as the medium of representing the indigenous and scientific knowledge of a domain. Representing domain knowledge by the indigenous world view and domain knowledge by the scientific world view are taken into consideration for possible integration on the sufficient and necessary conditions: *sustainability and productivity*.

5. Integration of Ontologies

5.1. Equivalence Relation

The heterogeneity of ontology of a particular domain is resolved by matching, overriding, or integrating. Integrating across the differences and underlying constraints is often not easy. Equating properties or classes are not enough for a solution because they may not result in a proper semantic integration. One cannot apply the property of equivalence to the components based on semantic, functions, and expression. The following are the typical properties of an equivalence relation:

Let X be a set and let x, y, and z be elements of X. An equivalence relation, ~, on X is a relation on X such that:

Reflexive Property: x ~ x for all x in X.
Symmetric Property: if x ~ y, then y ~ x.
Transitive Property: if x ~ y and y ~ z, then x ~ z.
where x ~ y means that (x, y) is an element of the equivalence relation ~.

The above mentioned properties of equivalence relation may hold true for expressions but not always for semantics because semantically they might differ in functions. For example, the concept of 'profit' may be different for IK and SK if sustainability components of IK and SK are different. If one considers the sustainability components of a system prescribed by an IK system through its various methods like stories, saying, beliefs, practices, etc, then IK with its holistic meaning to sustainability might have a different and a wider meaning for the term 'profit' than the term 'profit' used by SK.

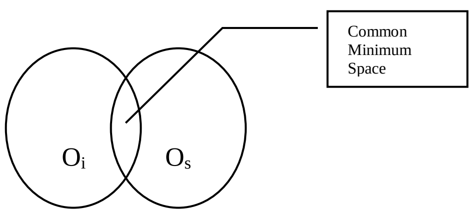

Fig. 4: Common Minimum Space

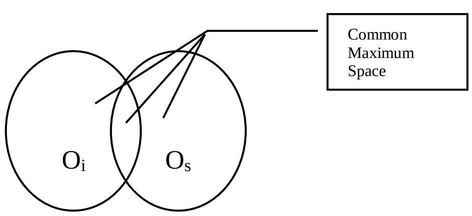

Fig. 5: Common Maximum Space

5.2. C_{min} or C_{max}

Depending on the level *L* of integration the conditions in any integration of systems can be either general or special. If two domains D_{ik} and D_{sk} of a domain *D* represented by sets S_{ik} and S_{sk} meet common minimum or common maximum constraints C_{min} or C_{max} , depending on the condition the user chooses, then the user decides on the level *L* of integration. C_{min} is a set of common minimum constraints that are necessary and sufficient for the integration of D_{ik} and D_{sk} to result a D_{is} (integrated system) and is given by

$$D_{ik} \cap D_{sk} \rightarrow D_{is}$$

which is represented in the Fig. 5. The common minimum space is determined by the necessary and sufficient condition of being able to produce an expected performance. C_{max} is a set of common maximum constraints that are necessary and sufficient for the integration of D_{ik} and D_{sk} to result a D_{is} and is given by

$$D_{ik} \cup D_{sk} \rightarrow D_{is}$$

Comparing the C_{min} and C_{max} it is known that C_{max} needs more comparison of components of ontologies than C_{min}.

Let O_i be an ontology representing indigenous knowledge of the system under consideration and let O_s be an ontology representing scientific knowledge of the same system. If minimum number of conditions for integration is met, then O_i and O_s are integrated to produce an integrated ontology O_{is}. In the case of maximum number of conditions are to be met for C_{max}. C_{min} restricts the horizon for consideration while C_{max} opens a wider possibility for integration. The C_{min} and C_{max} situations are represented in the diagram for the interaction of two ontological systems for a single domain (Fig. 9).

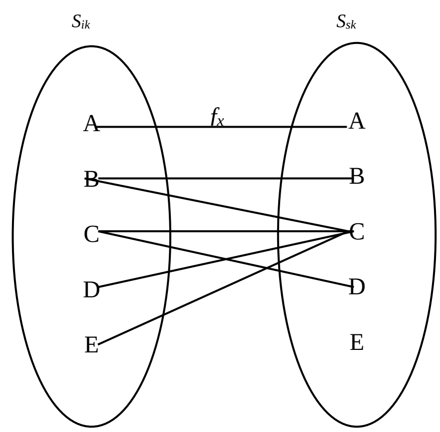

Fig. 6: Two sets S_{ik} (set indigenous knowledge) and S_{sk} (set scientific knowledge) with components

Consider two sets S_{ik} and S_{sk} representing the sets of indigenous knowledge and scientific knowledge respectively (fig. 6). Mapping function can be defined as valued function f_x where *x* represents cardinalities of the mapping function. In fig. 6 for example in the set S_{sk} the component *C* has relation to *B*, *C*, *D*, and *E* of S_{ik}. An integration process might consider of dropping *B*, *C*, *D*, and *E* in S_{ik} since they can be very represented by *C* of S_{sk}. The precondition is that the dropping of the components of a set does not affect the performance of the whole system but enhances its performance. Focusing now *D* in S_{sk} which has no relationship with any component in the set S_{ik} brings another issue of such stand alone components. These components might be important and inevitable ones in considering a better performance of the system. But if an integrator or amalgamator evaluates this component not as inevitable for the enhancement of the sustainability component of the system, then the integrated system drops this component. Fig. 7 represents such a comparison made between two ontologies. Let us consider D and E as the necessary components for achieving sustainability goal, and then they are retained in the integrated ontology.

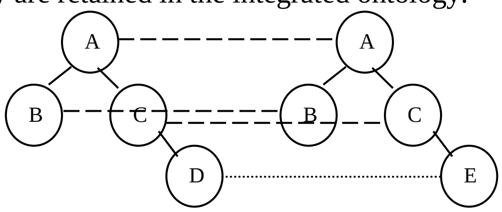

Fig. 7: Finding Sustainability Components in Two Ontologies

A simple algorithm for the integration of ontologies by IK and by SK can be presented in the following way

1. *Consider the components x_i in O_i and y_i in O_s.*
2. *Create a tree separately for O_i and O_s.*
3. *If a component x_i in O_i is equivalent to a component y_i in O_s, then check for semantic and functional equivalence and if x_i with other components give a 'high sustainability', then keep x_i else keep y_i of O_s and consider the other vertices linked to x_i and y_i.*
4. *The final result is an integrated ontology for a sustainable growth*

The two ontological systems interact through a correspondence module (Fig. 8). Query and data processing are monitored by the mediator module.

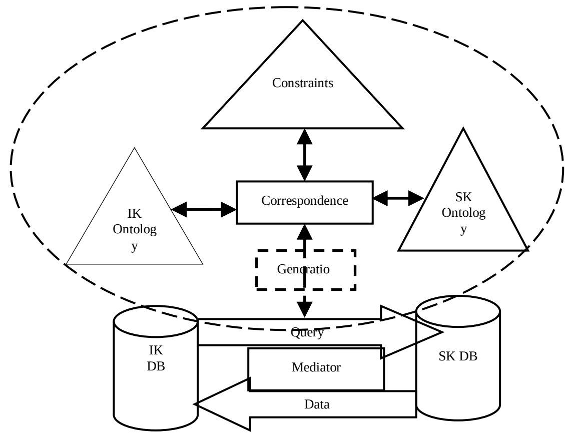

Fig. 8: Mediator corresponding and generating a shared ontology (Adapted from Laurini)

6. Conceptual proposal for an Integrated System Design

The proposed Knowledge Based System (Fig. 10) has the following components:

- Knowledge Engineering and Management Section
  - Indigenous Knowledge Acquisition, Extraction Storage System
  - Scientific Knowledge Acquisition, Extraction, Storage System
- Sustainability Conditions Base
- Integrator System (integrates two ontologies of a domain)
- Intelligent System Section
  - Indigenous Techniques Acquisition, Extraction, Storage System
  - Scientific Techniques Acquisition, Extraction, Storage System
- A Resolver Module
- A Graphical User Interface (GUI)

7. Conclusion

The paper discusses the conditions for the need of integrating indigenous and scientific knowledge. Ontological framework is suggested as the system for representing both IK and SK. After studying various methods and conditions of integration and mapping, sustainability is proposed as the main condition and the goal of the proposed KBS architecture. Different levels of integration are not discussed in detail as the main concern of this work is to focus on sustainability issue. The overall architecture of a KBS with an integrator and a resolver that takes knowledge bases and techniques of IK and SK for integration has been proposed. The problem of integrating two systems is not as simple as one might think since each system of knowledge has its own philosophy, world view, belief system, ideas, components, methods, and strategies. But to achieve sustainability one has to consider the possible avenues of integrating IK and SK because they produce a better effect on the systems and have a higher degree of sustainability. The future work can be developing systems and modules proposed in the architecture.

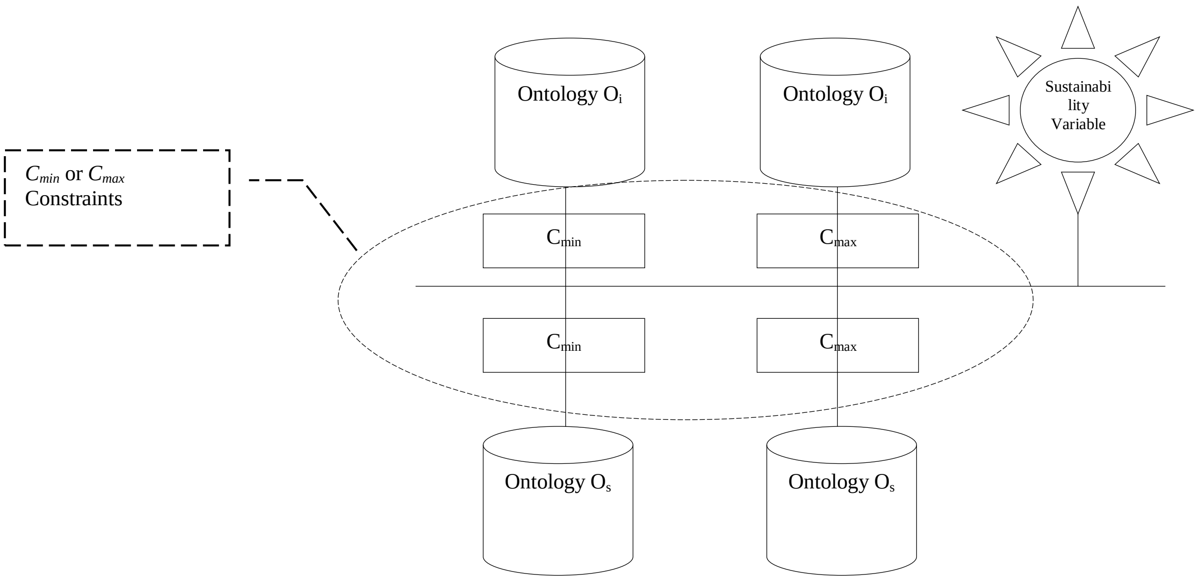

Fig. 9: Matching in Sharing of Ontology (Adapted from Laurini)

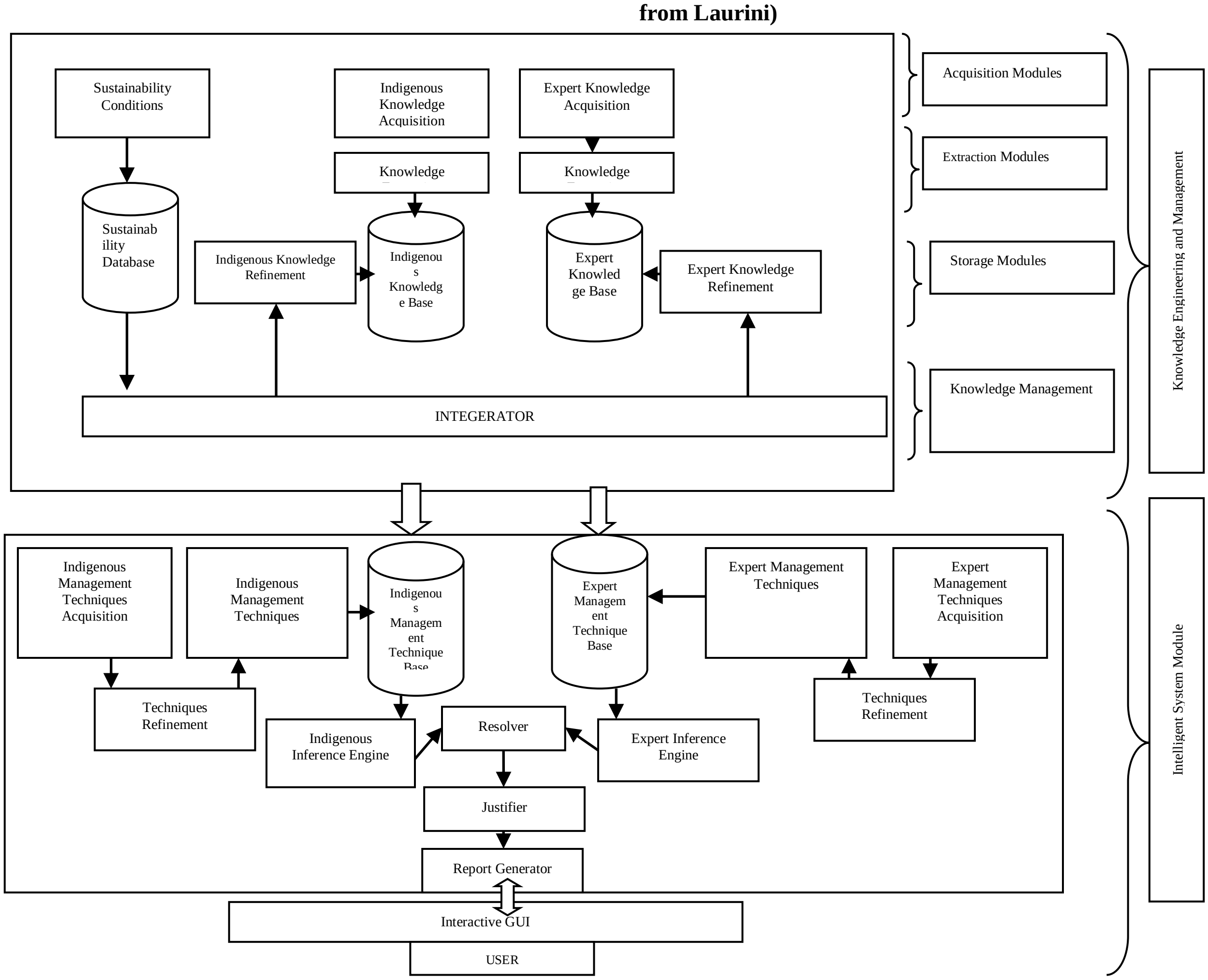

Fig. 10: Conceptual Proposal of a KBS with integration of IK and SK

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