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On Computing Ontology for Mental Factors

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Abstract

Ontology has introduced a new paradigm for software development. Nowadays, Ontologies has become a key theme of areas like Semantic Web, Web Services and Multi Agent Systems. However, a few research projects are carried out to develop a comprehensive Ontology for modeling of mental factors. This has been a barrier for modeling of computer systems concerning human emotions and sensations. We have exploited Buddhist theory of mental factors and developed a Mental Ontology environment to model systems involving mental factors. Our implementation introduces a base class mental factor with various feature and behaviors as per Buddhist theory of mind. This base class can be extended to create an arbitrary mental factor. The paper also explains how the developed mental Ontology environment can be used by an Ontology developer in Multi Agent System.

Keywords: Ontology, Semantic Web, Agent Based Systems, Mental Factors.

1. Introduction

For many centuries, Ontology has been recognized as the artifact for enabling communication among humans. With the ever increasing growth of the World Wide Web, people are now interested in machine-machine communication with limited or no human intervention. As such, many researches are involved in the construction of Ontolgies to enable interoperability of the resources available in various data formats running on heterogeneous hardware and software environments on the next generation of the World Wide Web, known as the Semantic Web. Some application areas of Ontology include knowledge management [1], automated data integration and maintenance in web portals [2], e-learning [3] and e-commerce [4]. These applications necessarily involve manipulation and sharing of information among various sources distributed over complex networks. At present, such systems are developed by looking at the data and knowledge sources from a very rigid view that describes the world through objects, entities, relations, attributes, etc. However, no such systems are generally capable of capturing mental attributes such as human, interest, desire, dissatisfaction, fear, etc. to make Ontologies more comprehensive and meaningful, especially when human being are involved in transactions.

Currently a few researches have been conducted to model Ontology for modeling of emotions. These researchers concentrate on building of Ontologies merely through physical means such as facial expressions without considering of mental attributes [5]. However, researchers have identified the necessity of developing a comprehensive computing Ontology for emulating emotions on machines [6]. Undoubtedly, such research will expand horizons of many areas including humanoid robots, unman vehicles, multi agent systems, man-machine co-existence systems and many other agents software that directly communicate with humans.

This paper presents our exploitation of Buddhist theory of mental factors and the construction of Ontology for mental factors that can be used for design and development of applications concerning emotions. The rest of the paper is organized as follows.

Section 2 provides with an overview of the current research in the area of Ontology. Section

3 describes the Buddhist theory of mental factors. Section 4 reports on the design, the implementation and the application of Mental Ontology. Section 5 concludes the paper with a discussion of novelty and further work of this research.

2. Overview of Ontological Modeling

Although there is no general definition to the Ontology, it is commonly accepted as a model, where great philosophers and computer scientists try to implement the reality of the world. Philosophers define Ontology in terms of concepts and their relationships. However, computer scientists, still prefer to have object oriented way of defining it in terms of classes. Therefore in computer paradigm, Ontology consist of classes of objects, such as chair, desk, truck , customer, supplier, etc , classes of attributes like color, idnumber, material type, etc and classes of behaviors which specify allowable intercommunication and privilege actions corresponds to the objects. Ontological modeling had gained advantage by separating its structural representation from actual implementation.

Since there is no general agreement on the Ontology definition, some computer scientists look at Ontological modeling from object oriented aspect. Even though there is a similar structure for both object oriented modeling and Ontological modeling, we see a great difference in evaluation procedures. For an example, at the evaluation process, object oriented evaluates the systems in terms of transactions and object interactions where as ontology evaluates the system in terms of knowledge representation and knowledge evaluation.

However, Gruber's definition on Ontology [15], "*an explicit specification of a conceptualization"* has become the frequently used definition in computing. According to the Buddhist philosophical view, conceptualization or the perception of a particular domain depends on the physical and mental states of a viewer. This has been proven by the current research where Ontology building has now become a collaborative task of different domain experts and stakeholders. Even though this can be taken as a solution at the implementation level, evolution and emergence of new knowledge in Ontology is still need to be considered.

In the next section, we explain some ongoing major researches in Ontological modeling.

2.1 Major Research Areas in Ontology

Researches on Ontology based modeling have been carried out with different perspectives by different domains expertise. The underground motivation of all these researches is either knowledge representation, knowledge process and knowledge evolution. Review of this section is limited to two key research areas, namely Semantic Web and Agent Based systems, where knowledge representation, processing and evolution are crucial.

Semantic web is an extension to the current Web, which attempt to enable the machine-machine communication with or without human intervention. According to literature, Semantic Web research has two main directions, namely, (a) converting existing web pages into machine-operatble format and, (b) creating new web pages with machine understandable format.

Multi Agent Systems is yet another area where the concept of Ontology can play an immense role in supporting communication and sharing problem solving knowledge among related entities. Many researchers have cited the value of Ontology as an artifact for supporting over all functionality of a Multi Agent System. Many systems including aircraft maintenance, logistic planning [7] and industrial automation [8] have shown the potential of the use of Multi Agent Systems Technology from an Ontological viewpoint.

Web Service [10] and Knowledge Management [1] are also some other areas where Ontological modeling has been successfully applied.

At present there are hundreds of tools and software environments for development of Ontology based systems. Among others, OntoWeb [9] research group has done critical review of these tools and has evaluated all these tools in terms of interoperability, knowledge representation, inferences services attached and usability. For their evaluation, tools have been categorized as (a) Ontology development tools, (b) Ontology merge and integration tools (c) Ontology evaluation tools (d) Ontology based annotation tools (e) Ontology storage and

querying tools (f) Ontology learning tools. According to their review, neither these tools interoperate and nor they covered the life cycle of the ontology development. Karunananda and Rzevski [11] have also pointed out that these tools are unable to model Ontology evolution, which is an essential feature of Ontolgoies in many domains.

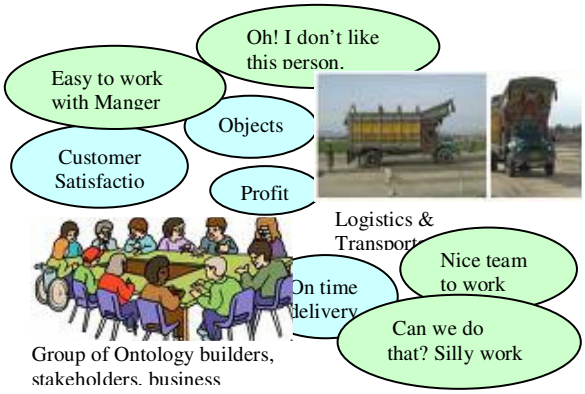

Figure 1: Ontology Building Environment.

In fact, Karunananda and Rzevski [11] have identified two major issues in Ontology development; (a) Currently Ontology developers usually implement their own worldview. (b) Ontology is only constructed as permanent structures without considering the emergence or evolution of knowledge. In their research, they have identified the necessity of concerning mental aspects in Ontology building (Figure 1).

As per Figure 1, usually any environment can be characterized by two main attributes, namely physical attributes, related to perception of particular domain, and mental attributes, related to the mental states of each ontology builders, stakeholders, etc. Therefore success of the task depends on the interactivity among group members. The Ontology is the device for enabling such interactions.

High interactivity among members guarantees the knowledge evolution and emergence. Nevertheless, this interactivity depends on the personal view about other group members. Sometimes Personal Manager (PA) will like to work with Developer (D) than Assistance Manager (AM). In that case, the productivity is high when PA interacts with D than AM. Therefore, it is necessary to implement mental states of each agent or any other entities, which involve with Ontology, then it, will guarantee the evolution and emergent of knowledge in any environment.

2.2 Research in Mental Ontology

Over many years most of the Ontology related research have focused on knowledge engineering and knowledge processing in terms of physical attributes in respective domains, but few research have been done in relation to development of mental Ontologies.

In the recent past, Kansei Engineering has emerged as a method of translating feelings and expressions into product parameters. Using this technology Japanese has raised a project called Kansei, which contains modeling and implementation of cognitive science as a one part of the project [12].

Research has also been conducted to build Buddhist Ontology of mental factors for Kansei systems [6]. This study has identified Buddhist classification of mental factors and their relationships. Further, a Buddhist mental Ontology pertaining to humanization of e-learning environments has also been developed [13]. These works primarily consider a sub set of mental Ontologies describes in Buddhist Philosophy. As such, development of full pledge comprehensive mental Ontology remains as a research challenge.

Karunananda and Rzevski [11] have identified full spectrum of mental Ontology in Buddhism. They have also explained how a computer model of this particular Ontology can be constructed. In their XML description, it was explained how each agent can be defined in terms of physical and mental attributes. For example, mental factors such as satisfaction, motivation, confidence, can be incorporated together with the same physical attributes such as agency, agent_id, and task. However, that work has not yet developed a computer model of mental Ontology.

Our research has taken steps to develop a full scale general purpose mental ontology as defined in Buddhist Philosophy.

3. Buddhist Ontology

The Buddhist philosophy analyzes the mental and physical phenomena of all beings under Abhidhamma Pitaka [14]. Therefore, Buddhist Ontology of the world describes both physical and the mental aspects. According to Buddhism, the mental phenomenon is sub divided as mental factors and consciousness. In fact, consciousness themselves are some valid combinations of mental factors [14]. As such mental factors characterize a given consciousness. Buddhism defines eighty nine distinct consciousnesses that are formed by fifty two different mental factors. Since mental factors work as the basis for consciousness too, the study of mental factors is fundamental to modeling of a Mental Ontology.

3.1 Classification of Mental Factors

The Buddhist philosophy has identified fifty two mental factors that characterize thoughts or consciousness. In other words, each consciousness can be seen as a combination of mental factors. Buddhism classifies these 52 mental factors into four categories, namely, universals, particulars, unwholesome and wholesome [14].

Seven mental factors: Contact, Feelings, One pointed ness, perception, Psychic Life and Attention appear in all consciousness, and are called Universal. According to the Buddhist philosophy the consciousness with only seven mantel factors cannot be occurred and at least human being needs thirteen (13) mental factors to form the simplest possible consciousness. Other six essential mental factors are called particulars, namely, Initial Application, Sustained Application, Deciding, Interest, Effort and Intention.

Remaining thirty-nine (39) mental factors are categorized as unwholesome and wholesome mental factors. There are 14 unwholesome mental factors that form the consciousness pertaining to bad thoughts and actions. In contrast, 25 wholesome mental factors form consciousness regarding good actions and thoughts.

Buddhism has identified not only different class of mental factors, but also the relationship among these mental factors. In depth study of such relationships are essential for the development of a Mental Ontology.

3.2 Relationships among Mental Factors

A mental factor alone doesn't provide any meaning to the consciousness, until it is associated with other mental factors. Therefore, it is necessary to identify the valid combination of mental factors, which characterizes the consciousnesses. The Buddhist philosophy has precisely defined the relationships among mental factors as a set of rules. As such mental factors categorized under universal category, should occur in all the states of consciousness, while mental factors categorized under unwholesome category can occur in only in unwholesome states of consciousness. Further, it classifies unwholesome mental factors namely dullness, lack of moral shame, lack of moral fear and restlessness should occur in each unwholesome states of consciousness. Some rules related to relationship among mental factors are listed (List 1) below.

- **Rule 1:** All universal mental factors occur in all states of consciousness.
- **Rule 2:** Dullness, lack of moral shame, lack of moral fear and restlessness should occur in each unwholesome states of consciousness.
- **Rule 3:** All mental factors either exist in wholesome or unwholesome states of consciousness
- **Rule 4**: All beautiful mental factors occur in the wholesome states of consciousness.
- **Rule 5:** All the unwholesome mental factors occur in the unwholesome states of consciousness.
- **Rule 6:** A mental factor Dullness causes the other mental factors: Greed, Error, Hate, Special doubt and Restlessness also to be arisen in the state of consciousness.
- **Rule 7:** Sloth and Torpor both occur together in a consciousness.

List 1: Some Rules of Mental Factors

3.3 Relating mental factors with physical world

The Buddhist philosophy does not merely talk about the mental factors, but their relationship with the physical aspects of living beings. There are various ways to associate mental factors with physical aspects. For example, a visual object in the physical world can be sensed by the eye, which belongs to physical body of a human being. When an eye contacts with a visual object, in the first place, one's mind forms a consciousness that comprises seven universal mental factors to begin the sensing of the object. As such some collections of metal factors have a mapping to corresponding physical aspects.

Buddhism has broadly classified mental factors into five categories, namely, doors, feelings, functions, objects and roots. Under each of this category there are particular set of mental factors. This classification is too broad and describes how certain groups of mental factors map to physical aspects and some specific types of consciousness. Here doors and objects are physical aspects, while feelings and roots are mental aspects. Each consciousness also has a specific function. In order to expand the Mental Ontology to be more comprehensive, it is appropriate to introduce the Ontology contacting the above five categories. This inclusion enables demonstration of relationship with not only physical aspects, but also the some extra features of consciousness.

We postulate that mental factors can be used as the basis for modeling of mental (consciousness) and physical phenomena in the world.

4. On computing Mental Ontology

In order to model the Mental Ontology, we identify each mental factor as an Object having specialized attributes and behaviors.

4.1 How to model a Mental Factor

A mental factor is attributed by different characteristics, such as object type, category type and general states etc. List 2 provides comprehensive details about some of the identified attributes the mental factor object. A mental factor can arise or take away its position from the state of consciousness and also perform further actions like change the form of appearance and change the associate weight etc.

- **Object type:** Basically the class it belongs to,
- **Group type:** Either it is universal, particular, unwholesome or wholesome
- **General states:** Either it is optional or mandatory to be occurred with other mental factors
- **States in the group:** whether it is mandatory or optional within the group, for example, mental factor Greedy should occur with other unwholesome mental factors but not with all mental factors.
- **Is Dominant:** To specify whether mental attribute is leading attribute. For example Greedy is leading attribute in unwholesome consciousness.
- **Is Dominant with Constraint:** To specify whether mental attribute is a leading attribute if some conditions are satisfied.
- **Allowable Forms:** A mental factor may appear in different format. For example, Greedy can appear in different forms such as desire, attachment, lust, love, gluttonous etc.
- **Forms Appear Constraint to Others:** A mental factor can take different form based on other factors and their weights.
- **Is Subject to the Doors:** Specify whether mental factor is subjected to a door like ear, eye, body, etc.
- **Subjected Doors:** If mental factor is subjected to the doors, then specify.
- **Disjoints Mental Factors:** Specify disjoint mental factors.
- **Associate Mental Factors:** Specify associate mental factors.
- **Constraints on Associated Mental Factors:** Whether associations are bound to specific constraints. Need to specify the weight of each mental factor also.
- **Directly Opposite Mental Factors:** Specify whether a given mental factor has completely opposite mental factors. For an example Greedy has an opposite mental factor called Disinterestedness.

- **Active Status:** Specify whether mental factor is active at the time of decision making.

List 2: Some Attributes of a Mental Factor

List 3 shows identified behaviors of mental factors. These behaviors are important to model the change of mental factors under different circumstances.

- **Occurs:** A mental factor can initially occur with others.
- **Destroy:** A mental factor can take away its position.
- **Change Appearance:** A mental factor can change its form. For example, Greedy can appear in different forms such as desire, attachment, lust, love, gluttonous etc.
- **Change Associate Weight:** A mental factor can change its associate weight with other mental factors.
- **Prompted Action:** A mental factor can cause different actions to be arisen. For example, Greedy can cause to thief, mislead, and lie.
- **Caused Action:** A mental factor may be arisen because of actions occurred in the environment.

List 3: Some Behaviors of a Mental Factor

The class diagram of the mental ontology is shown in Figure 2. The Mental Factor is the base class of the system and each specific mental factor can extend the base class.

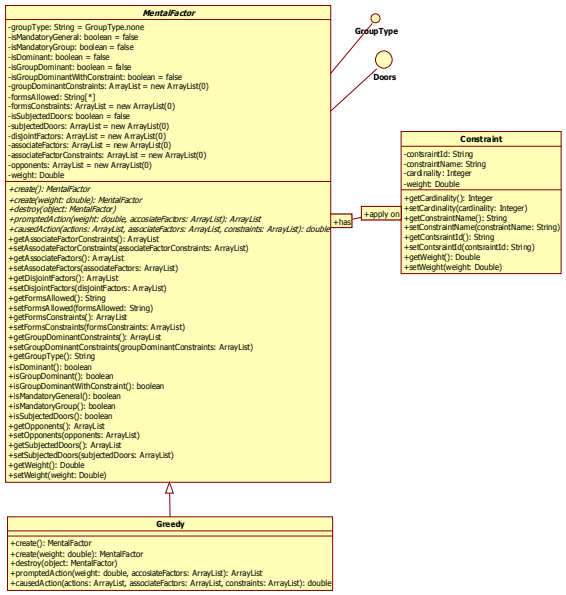

Figure 2: Class Diagram of the Mental Ontology

Following Java code segment shows the implementation of mental factors. List 4 shows the code segment of the base class for the all mental factors.

```
package mentalFactor;

import java.util.ArrayList;

import references.GroupType;

public abstract class MentalFactor{

/* Object belongs category*/
protected String groupType = GroupType.none;

/* Object is mandatory to be occured with other mental facotors*/
protected boolean isMandatoryGeneral= false;

/* States in the group - mandatory within the group*/
protected boolean isMandatoryGroup = false;

/*Specify whether Dominant in the group */
protected boolean isGroupDominant = false;

/*Specify whether Dominant in the group with some constraint*/
```

```
protected boolean isGroupDominantWithConstraint = false;

/*Constraints on Group Dominant - ArrayList accepts the Object of type Constraint*/
protected ArrayList groupDominantConstraints;

……
……...

/*Forms Appear constrained to the others - ArrayList accepts the Object of Type Constraint*/
protected ArrayList formsConstraints;

/*Specfy mental factor is Subjected to the Doors*/
protected boolean isSubjectedDoors = false;

/* If any door the mental factor is subjected*/
protected ArrayList subjectedDoors;

/* Disjoint Mental Factors - ArrayList accept the Objects of type Mental Factor*/
protected ArrayList disjointFactors;
/*Associate Factors - ArrayList accept the Objects of type Mental Factor */
protected ArrayList associateFactors;

/*Associate Factors with Constrained- ArrayList accept the Objects of type AssociateFactorConstraint */
protected ArrayList associateFactorConstraints;

 /*Weight Occur in*/
protected Double weight;

/**
   * Method will create the mental Factor
   * @param weight
   * @return
   */
public abstract MentalFactor create(double weight);

/**
 * Method will destroy the Menetal Factor
 * @param object
 */
public abstract void destroy(MentalFactor object);

/**
  * @param weight specifies the weight associate with
  * @param accosiateFactors in the event
  * @return list of prompted actions
  */
public abstract ArrayList promptedAction(double weight, ArrayList accosiateFactors);

/**
  * @param actions specify the action caused
  *@param associateFactors define associate factors
 * @param constraints define the constraint on it
 * @return proposed weight of the mental factor
 */
public abstract double causedAction(ArrayList actions, ArrayList associateFactors, ArrayList constraints);

}
```

List 4: Code Segment of Base Class

The above base class of mental factors can be extended to create any specific mental factor. List 5 shows how the base class of mental factors been extended to create Greedy class.

```
package mentalFactor;

public class Greedy extends MentalFactor{

/** Method will create mental factor greedy
   */
public MentalFactor create() {
        new Greedy();
}

/** Method will create mental factor greedy
  */with weight
public MentalFactor create(double weight) {
         new Greedy(weight);
}

super.groupType = GroupType.UnWholesome;
super.isMandatoryGeneral = false;
super.isGroupDominant = true;
……..
super.associateFactors = new ArrayList(0);
super.associateFactors[0].add(Dullness);
super.associateFactors[1].add(Envy);
super.associateFactors[2].add(LackOfMoral);
super.associateFactors[3].add(Error);
……
```

```
super.disjointFactors = new ArrayList(0);
super.disjointFactors(0).add(Disinterestedness);

}
```

List 5: Code Segment of Greedy Class

As shown in Figure 3, the Greedy Class groupType is set to the Unwholesome to specify Greedy belongs to the unwholesome category, and associated mental factors related to the Greedy have been assigned to the associateFactors list. As such all the mental factors and their association can be implemented.

Figure 3, shows screenshot of the implemented mental ontology development environment.

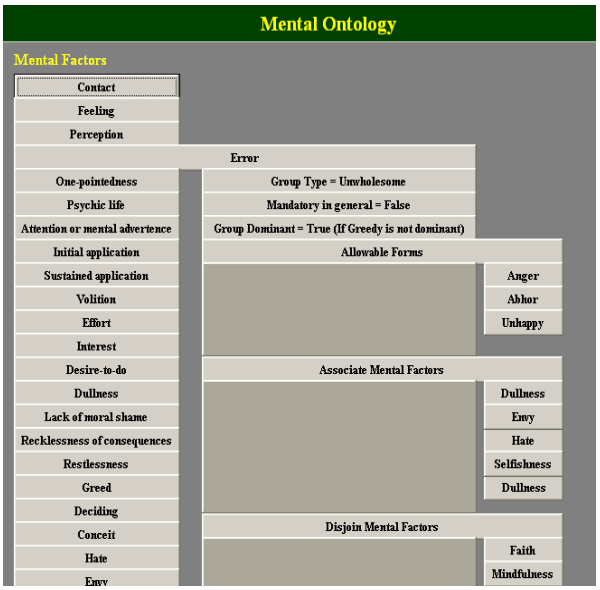

Figure 3: Mental Ontology

4.2 How Mental Ontology works

Here we briefly explain how our Mental Ontology environment can be used model real world systems involving mental conditions such as emotions. Consider agent based intelligent e-commerce system that executes electronic trading between supplier and consumers. An individual agent has been assigned to represent each demand made by consumer and each supplier. The task of demand agent (DA) is to find the best possible matching and the task of supplier agent (SA) is to supply products with maximum profit. Supplier agents are also keen on current demand and other competitive products in the sale. Consider a situation where demand agent (DA1) identifies two competitive products from two different supplier agents (SA1, SA2). This interaction will definitely cause hidden competition between SA1 and SA2 and both of them may want to throw out other from its way. This is a common scenario for all Multi Agent Systems developers. Let us discuss how our Mental Ontology can be used for modeling agents in such a scenario.

Assume that a Multi Agent System (MAS) developer wants to develop his agent, SA1, to work with more powerful agents, say SA2, doing the same task. As such, the developer wishes to consider mental states of SA1. For example, SA1 may be afraid of SA2. Now the MAS developer can use the mental ontology and identify the fear as a form of Error and also associated with mental factors including anger, abhor, unhappy, envy, selfishness, dullness and greedy. Thus the MAS developer can address the fear in terms another mental factor such as abhor, which encourages SA1 to be detached from SA2. In other words, SA1 will be restricted to interaction with SA2. Alternatively, SA1 can go ahead with envy and cooperate with another agent who is also a competitor for SA2. In this manner, MAS developer can introduce various strategies to own agent so as they can deal with agents in competitive environments. Of course, the agent that works in cooperate environments can also be modeled with mental factors pertaining to kindness, sympathy, happiness, etc. Furthermore, less active agents can be motivated through the interaction with the agents who have desire to do things.

The key point in our research is that a mental factor can be used as means of modeling the performance of an agent, and handled on the basis of associated mental factors, instead of direct manipulation of the mental factor. Since people are generally unaware of associated mental factors, the above process could not be captured. Our mental ontology provides a solution for extensive manipulation of mental factors.

5. Discussion

Our literature survey identified the necessity of implementing mental aspects of Ontology as a solution to the current issues in Ontological

modeling. Therefore, we exploited the Buddhist philosophy and postulated that the mental factors can be used to build the Mental Ontology. In our research, we defined mental factors as a class with various attributes and behaviors. A base class has been designed and implemented with the use of Java. It was shown that the base class can be extended to obtain any mental factor. Further, the base class can also be modified to incorporate more attributes and the behaviors that we will identify in our ongoing research.

Further work of this project includes development of a Mental Ontology plug-in for the existing environments for Ontological Modeling.

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