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An Ontology Based Approach To The Integration Of Heterogeneous Information Systems Supporting Integrated Provincial Administration In Khon Kaen, Thailand

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ABSTRACT

Information systems are a necessity to the administration of organizations. In a recent reform to the Thai administration, the governor of each province is entrusted with the full responsibility for the strategic planning and execution of the Integrated Provincial Administration (IPA). This presents a big challenge and many difficult problems for a potentially fast growing, both economically and demographically, province, such as Khon Kaen. To provide the administrator of the province with reliable and up to date information, the Provincial Operation Centre (POC) has been set up and assigned the task of collecting all required information from disparate information systems, many of which are legacy systems. This information lacks interoperability and integration of data due to many different structures and semantic heterogeneity encountered in many information systems. This research is a part of a collaborative data sources community development project. It attempts to aid high-level decision makers by using ontology to resolve heterogeneities among many disparate data sources. After relevant data sources are identified, they are analysed to reveal important and corresponding concepts, attributes and relations. They are then used in the creation of ontologies to resolve schematic and semantic conflicts in the data sources. The integration of many heterogeneous information systems will provide a unified view of information facilitating the provincial administrator in his decision making.

Keywords: Ontologies, Semantic Heterogeneity, Schema Integration, Integrated Provincial Administration, Collaborative community development

INTRODUCTION

Thai public administration, as generally perceived, comprises of the central administration, regional administration and local administration. Over the years, an effort has been made to reform the Thai administration to be more efficient and responsible to the public. The CEO (Chief Executive Officer) Governor administration model is systematically introduced. The governor now becomes an assistant to the Prime Minister in the national administration at a provincial level, entrusted with bringing National Strategies and Nation Agenda into practice in a province. This reform is relevant

to the framework of the strategic management with the focus on administration efficiency. Therefore, the governor has to take the role of the CEO exercising both the strategic leadership and official power. The leadership is implemented in working development, procedures, administrative structure, decision-making and coordination. The efficiency of CEO Governor supporting machinery should be improved in term of personnel, working systems, administrative information system, strategy planning, provincial development plans and follow-up and evaluation systems. (Sriviha et al., 2003)

The core concept of Integrated Provincial Administration (IPA) is the strategic government unit at a provincial level, integrating the area functions from every part of public sectors of the province under the CEO Governor. Therefore, the strategic plan must align its organization and budget structure with organizational priorities, missions, and objectives. According to the requirements of the Government Performance and Results Act 1993 (Act of Integrated Provincial Administration, 2003), a strategic plan should include a mission statement, a description of the agency's long-term goals and objectives, and strategies or means the agency plans to use to achieve these general goals and objectives. The strategic plan may also use SWOT analysis to identify with internal and external factors data that could affect the achievement of long-term goals. Thus, the information from every part of public sectors of the province is essential for supporting the SWOT strategic plan.

There are many problems in managing the information systems in the Thai Public Sectors (Wattana et al., 1996; Bunyong, 1997; Malaivongs, 1998; Kumthongmak, 1998; and Viravan et al., 2000). These include inadequate data, which is partly the result of insufficient budget for data gathering and processing; data is not systematically kept; unwillingness to disclose data due to the lack of proper definition of secrecy; inability to directly exchange data because of differences in data formats, as a result of development and design autonomy; uncertainty about the quality of data; uncertainty about the accuracy of the information summarized by those at the lower levels; lack of coordination with agencies in joint-development as well as lack of improvement in information management.

Information systems are an essential input to a modern organization administration. In order to manage an organization effectively, decision makers must be able to select and utilize the most suitable type of information system for their organization. This is also true in any province, where the responsibility for the development of strategic planning is assigned to the province. Particularly in a potentially fast growing, both economically and demographically, province such as Khon Kaen, where more complicated problems are expected to emerge, it is necessary for the province executives to have a reliable, up to date, and well designed set of provincial management information systems available for Strategic Plan. There is also an indirect effect caused by inadequate information systems. That is, the degradation of the population's quality of life. How can people's problems be effectively tackled if the information systems are inaccurate, unreliable and not current?

In Khon Kaen Province, in an attempt to provide the province executives with reliable and up to date information, the Provincial Operation Centre (POC) has been set up and assigned the task of collecting all required information from disparate information systems, many from Public Sector Units, which are legacy systems. This information lacks interoperability and integration of data due to many different structures and semantic heterogeneity encountered in many information systems. This research is part of a collaborative data sources community development project. It attempts to aid high-level decision makers by using ontology to resolve heterogeneities among many disparate data sources in Provincial Administration Domain. After relevant data sources are identified, they are analysed to reveal important and corresponding concepts, attributes and relations. They are then used in the creation of ontologies to resolve schematic and semantic conflicts in the data sources community. The integration of many heterogeneous data sources will provide a unified view of information facilitating the provincial executives in their decision making.

RELATED WORKS

Heterogeneity and Integration

This problem was know in the 1980s (Batini, Lenzerini, and Navathe, 1986) and today it is one of many popular areas of research among the Information Systems (IS) communities. Interoperability through integrating of heterogeneous information systems involves both schema and semantic integration (Bishr, 1997 ; Harvey, 1999 ; Rodrguez, 2000 ; Hakimpour & Geppert, 2001, 2002, 2005 ; Kohler, 2003).

A number of researchers (Kim & Seo, 1991; Kashyap & Sheth, 1996a, 1996b; Sheth, 1999; Cui & O'Brien, 2000; Hakimpour & Geppert, 2001, 2002, 2005) have classified heterogenities into two main types: structural heterogeneity and semantic heterogeneity. Structural heterogeneity means that different data systems store their data in different structures i.e. different data models. Semantic heterogeneity involves discrepancies in the meaning of related data among heterogeneous systems. For example, two schema elements (i.e., classes or attributes) in two data sources can have different names, but the same meaning. Thus, during integration, these two elements may be treated differently even though they may refer to the same concept. Different interpretations of data cause semantic heterogeneity which in turn is a barrier to interpretations of schema.

Bergamaschi et al. (1998); Palopoli et al. (1999) and Madhavan et al. (2001) proposed schema integration approaches by using Thesaurus. Bergamaschi et al. (1998) introduced an approach for extracting similarity relations; synonym, hypernym and hyponym from the schema structure of component databases. They presented an algorithm to integrate schema definitions into a global schema based on the extracted relations. Madhavan et al. (2001) proposed an approach for schema matching in Cupid project. This approach used both the similarity of the terms in the schema definitions (language similarity) and the structure of the schema into structural similarity. Cupid project improved the Thesaurus with a coefficient for every entry in it. It also categorized schema elements into clusters – which is similar to the approach in Bergamaschi et al. Palopoli et al. (1999) proposed the improvement of schema definitions of the component databases using knowledge of domain experts. This approach required two dictionaries, a synonymy dictionary like a Thesaurus, and an inclusion dictionary extracted from schema or domain experts. Similar to Cupid project, domain experts customize both dictionaries by fuzzy coefficients.

Ontology and Semantic-Based Integration

In the Thesaurus approach, domain experts customized a Thesaurus for an application domain. Thesaurus neither supports intercommunity communication, nor helps better communication across application domains. Hakimpour and Geppert (2001, 2002, 2005) argued that there was a weak point in the thesaurus approach compared to the Ontology approach. Ontologies provided the similarity relations, intensional relation or conceptual relation; whereas a Thesaurus synonym and hyponym customized by domain experts, only used a limited number of known relations among terms. Ontology plays a role at the conceptual level by defining concepts. They distinguished and emphasized the difference between the ontological characteristics of attributes and representational and implementational characteristics, such as domain, uniqueness and cardinality present in the relation definitions.

Ontology approach has been proposed to solve the problems that arise from using different terminology to refer to the same concept or using the same term to refer to different concepts. Ontology was introduced by Gruber (1993a) as an "explicit specification of a conceptualization". Explicit specification means that the concepts and relations of the conceptual model have been given explicit names and definitions (Visser and Schlieder, 2002). An ontology is thus considered to be suitable for information integration tasks because of its potential to describe the semantic of data sources and to solve the data meaning heterogeneity problems (Goh, 2003; Cui and O'Brien, 2000). Ontology is considered to provide definitions for the term used to represent knowledge (Gruber, 1993a;1993b; 1995), which consist of concepts, relations and their taxonomic hierarchies, also express constraints. (Guarino, 1998a). Ontology's role reflects a community's consensus on

a useful way to conceptualize a specific domain (Erickson, 1997 ; Bishr et al., 1999 ; Kottman, 1999 ; Hakimpour and Geppert, 2001, 2002, 2005 ; Hakimpour and Timpf, 2001).

Ontology consists of definitions of terms; includes concepts with associated attributes, relationships and constraints defined between the concepts and entities that are instances of concepts. Ontology has been attracting attention in the integration of information systems and database domain (Guarino, 1998b ; Welty and Smith(eds.), 2001). Ontology was used to capture the semantic content of each data source and unify the semantic relationships between their data structures such as the attribute properties and relation names. Hakimpour and Geppert (2001, 2002, 2005) ; Hakimpour and Timpt (2001) applied ontologies to resolve semantic heterogeneity problems of Spatial Database. Explicit and formal definition of semantics of the terms led many researchers to apply ontologies to solve semantic heterogeneity. Guario (1998a); Welty and Smith (eds.) (2001); Cui ; Jones and O'Brien (2002) pointed out a solution to the problem of semantic heterogeneity by specifying the meaning of the terminology of each system and defining a translation between each system terminology and an intermediate terminology. They specified an intermediate terminologies using ontologies, and the translation between them using ontology mappings.

A number of works focused on semantic issues by using ontologies for data sources integration. Carnot is one of the pioneering projects in the domain of integration and addresses semantic integrity (Singh et al., 1997). Carnot uses the Cyc ontology, that Lenat (1995) called common-sense knowledge base and Woelk et al. (1996) called knowledge extracted from schema definitions for semantic integration. KRAFT Project (Knowledge Reuse And Fusion/Transformation) began with the objective of defining a generic architecture for knowledge fusion. Knowledge fusion refers to the process of locating and extracting knowledge from multiple, heterogeneous on-line sources, and transforming it so that the union of the knowledge can be applied in problem-solving. KRAFT uses shared ontology as a basis for mapping between ontology definitions and communication between agents (Jones, 1998). This approach extracted the vocabulary of the community and the definition of terms from documents existing in an application domain. In Visser et al. (1999) illustrate a three phased approach they used to extract and build local ontologies from an application domain in KRAFT project. They propose an approach to build ontologies based on analysis of the technical texts available in the domain. Shared ontology is chosen to make shared ontology as expressive as the union of the ontologies. KRAFT detects a set of ontology mismatches and establishes mapping between the shared ontology and local ontologies. The same approach can be seen in COIN project. The COIN project (COntext INterchange) presents a suitable architecture for semantic interoperability. COIN introduces a new definition for describing things in the world. It states that the truth of a statement can only be understood with reference to a given context. Here, the notion of context is useful to model statements in conflicting heterogeneous databases. Using this definition, COIN creates a framework that constitutes a formal and logical specification of the COIN system components. The framework has three components, which have been previously introduced in the architectural analysis: a domain model, elevation axioms and context axioms. Each information source has a set of elevation axioms and a set of context axioms, and both converge in a unique domain model. Therefore, the most appropriate approach to describe the COIN system is the hybrid ontology approach. The domain model is a collection of source's primitive types, such as strings or integers, and semantics types that define the application domain corresponding to the integrated data sources. Primitive objects and semantics objects are instances of primitive types and semantics types respectively. Semantics objects may have properties called modifiers that serve as annotations to make the data's semantics of different contexts explicit. Also, semantics objects may have different values in different contexts. The elevation axioms act as a mapping between attributes in the source and semantics types in the domain model. Also, they codify the integrity constraints of the sources, which are useful for producing optimal queries. The context axioms define alternative interpretations of the semantics objects in different contexts. Every source is associated with exactly one context, but several sources may share the same context. These axioms are divided into two different groups: 1) axioms that define the semantics of data at the source in terms of values assigned to modifiers, which correspond to semantics objects, and 2) axioms that define how values of a given semantics object are transformed between different contexts. COIN has a different representation of an ontology but it is based on an hybrid ontology

approach. Therefore COIN can be compared with KRAFT, in which a change in one source will generate changes in some components to represent the new mappings. In COIN, elevation and context axioms have to be defined to access the new information (Buccella, Cechich & Brisaboa, 2003).

Ontology Approaches for Integration of Heterogeneous Data Sources

Many approaches exist for the integration of heterogeneous data sources. Wache et al. (2001) categorized different methods using ontologies into three major approaches. Single ontology approach: one global ontology provides a shared vocabulary for the specification of the semantics. All information sources are related to the global domain ontology. The global ontology can be a combination of several ontologies. Multiple ontologies approach: the semantics of an information source is described by its own ontology. There is no common vocabulary, so inter-ontology mapping is needed to identify semantically corresponding terms of different source ontologies, taking into account different views on a domain. Hybrid approach: information sources are described by local ontologies that are built from a global shared vocabulary that contains basic terms of a domain. The single ontology approach is the simplest one. The drawback of the multiple ontologies approach is the lack of a common vocabulary that requires inter-ontology mapping. The advantage is that it facilitates the adding and removing of information sources more easily. The hybrid approach constitutes a good compromise and overcomes the drawbacks of the single or multiple ontology approaches. Similar to multiple ontology approaches the semantics of each source is described by its own ontology. But in order to make the source ontologies comparable to each other they are built upon one global shared vocabulary. Another advantage of a hybrid approach is that new sources can easily be added without the need of modification in the mappings or in the shared vocabulary. It also supports the acquisition and evolution of ontologies. The use of a shared vocabulary makes the source ontologies comparable and avoids the disadvantages of multiple ontology approaches. Buccella; Cechich & Brisaboa (2003) used the hybrid ontology approach in data integration of Federated Database.

RESEARCH METHODOLOGY

The research framework is concerned with the use of ontology to resolve heterogeneities among many disparate data sources from various government agencies and communities in Khon Kaen Province, Thailand. The life-cycle model (Figure 1), based on the Hybrid approach for the integration of heterogeneous data sources, consists of the following four phases.

1. Identify relevant data sources from public sectors, communities and the POC in Khon Kaen. Preliminary analysis is then performed to understand the nature of conflicts due to schematic and semantic differences. An appropriate application area (within the Integrated Provincial Administration (IPA) Domain) is selected based on similarities of data and data sources classification, such as demography, society, education, public health, economy, infrastructure, natural resources, etc.

2. Ontology building phase. Each selected data source is analysed to extract important concepts, attributes, and relations with other data sources. They will be used in the creation of ontologies to resolve schematic and semantic conflicts in the data sources. The sub-area of this research is the occupation and revenue of the communities under the demography domain. Data sources are mainly from Rural Community Development Office, Municipality, Employment Office, and Labour Office.

3. Integration phase. A model for the integration of heterogeneous data sources is developed to support Integrated Provincial Administration.

4. Evaluation of the system. One aim is to determine its capabilities of the proposed solution in helping decision making processes.

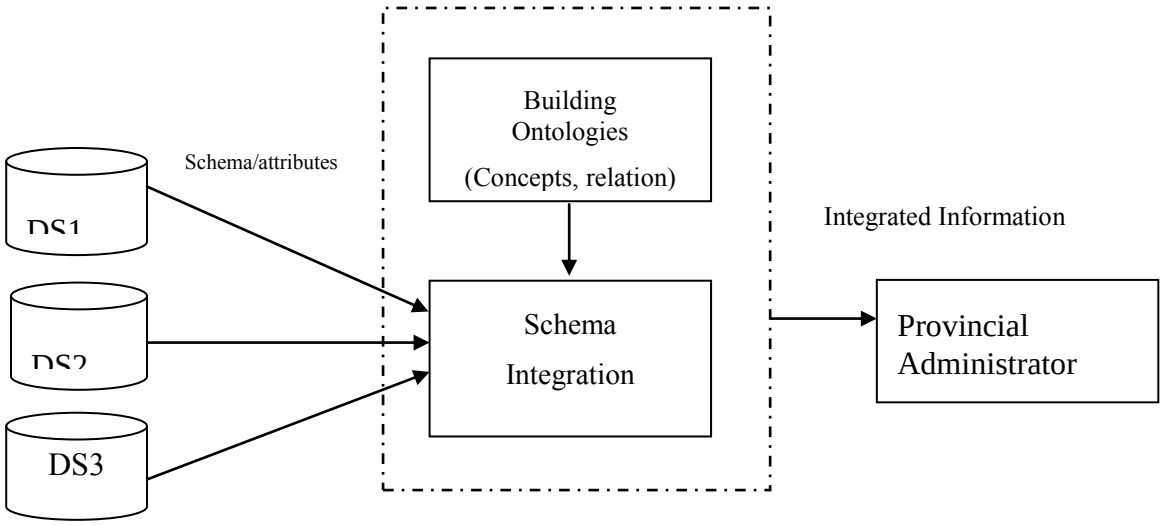

Figure 1: Research Framework

ONTOLOGY BUILDING

Information Systems supporting Integrated Provincial Administration (IPA) Domain consists of seven main classes (concepts) (Figure 2): Demography & Labour, Society, Education, Economy, Infrastructure, Politic & Government, and Natural Resources.

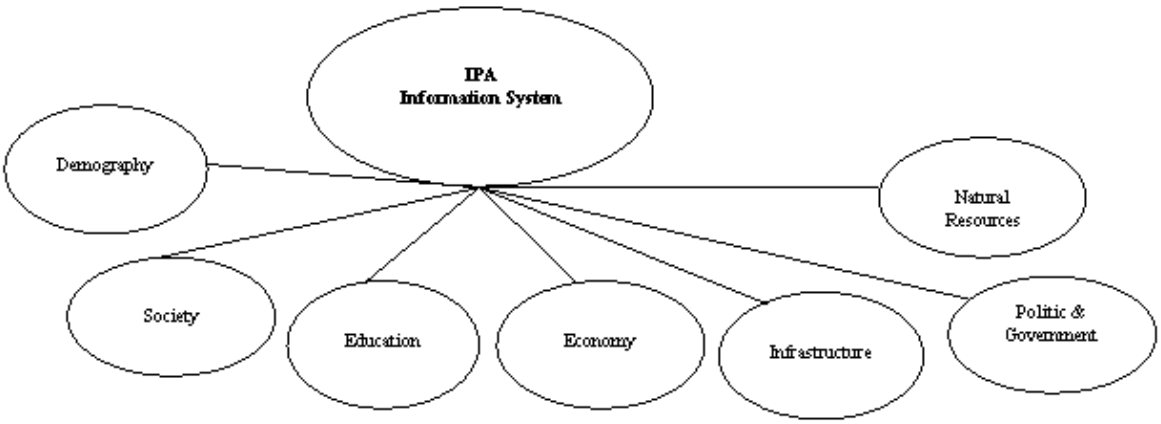

Figure 2: Integrated Provincial Administration (IPA) Domain

The Demography sub-domain is further selected for this research. Concepts in Ontology Demography Domain is then classified into six sub-concepts (sub-class) (Figure 3): Education ; Occupation; Income; Labour; Public Health and Properties.

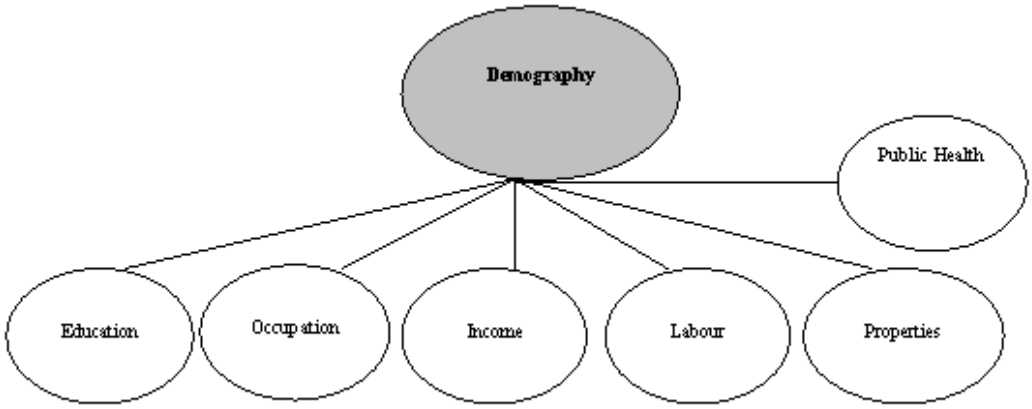

Figure 3 : Concepts (classes) in Demography sub-domain

Figures 4-6 show the subclasses of occupation, income, and labour respectively. Relationship between the two sub-classes income and labour is also indentifed.

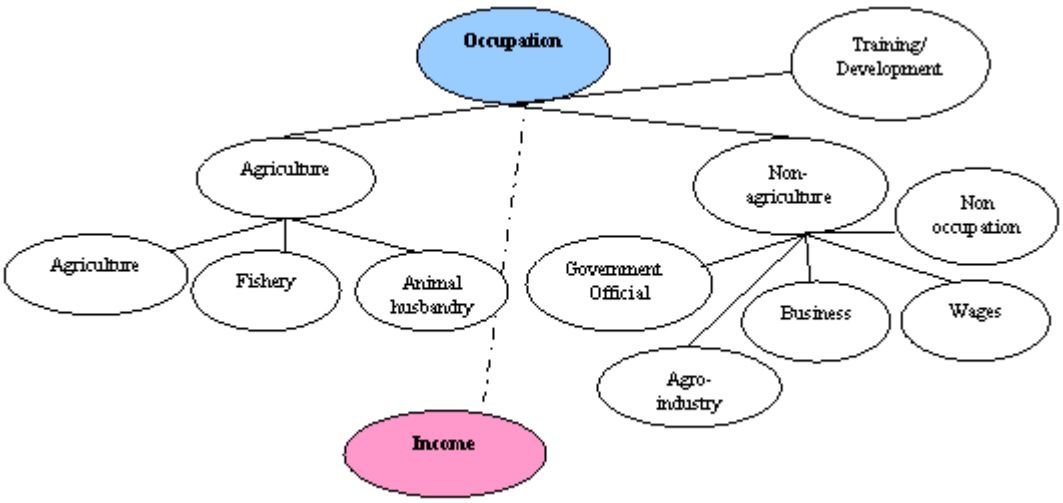

Figure 4: Sub-class Occupation

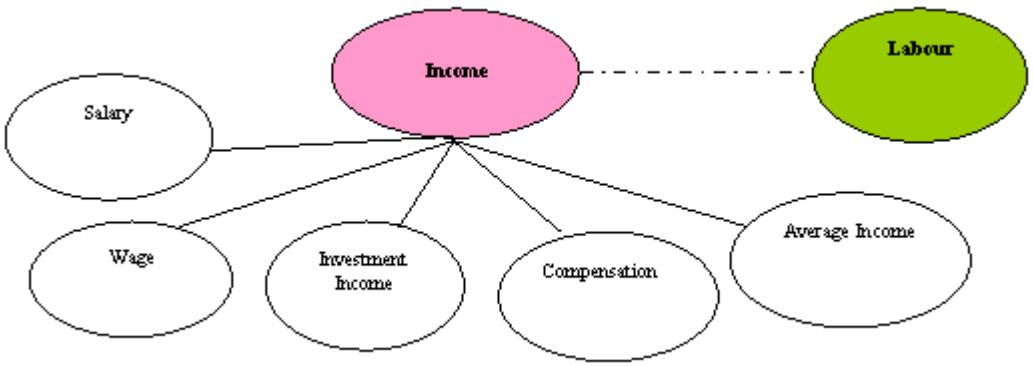

Figure 5: Sub-class Income

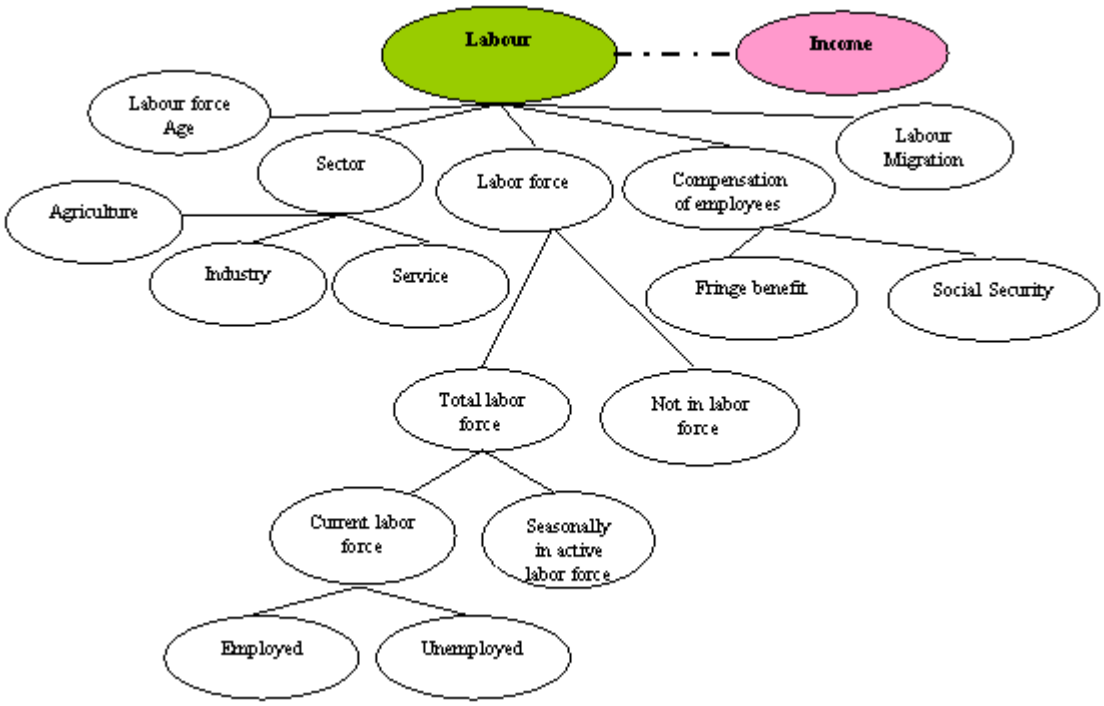

Figure 6: Subclass Labour

DISCUSSION AND CONCLUSION

Khon Kaen Provincial Operation centre (POC) has been set up and assigned the task of collecting all required information from disparate information systems for supporting the Integrated Provincial Administration (IPA). These information systems lack interoperability and integration of data due to many different structures and semantic heterogeneity encountered in many information systems. This research is a collaborative development project incorporating many disparate data sources from communities and Public sectors of Khon Kaen Province. It attempts to aid provincial administrator by using ontology to resolve heterogeneities among many data sources. Relevant data sources are identified, which are then analysed to reveal important and corresponding concepts, attributes and relations. Hybrid Ontology approach is selected to resolve schematic and semantic conflicts in the data sources. The paper presents an example of the building of ontologies for the occupation, income and labour sub-classes. The result shows common attributes that can be integrated in the later phases of the model. Future works are planned for complete integration of many heterogeneous information systems that provide a unified view of information facilitating the provincial administrator in decision making and resolving the misinterpretations of data attributes from difference data sources. This would contribute towards a reliable, up to date, and well designed set of provincial management information systems available for Strategic Plan for Integrate Provincial Administration.

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