Rice Production Knowledge Management: Criteria for Ontology Development

A. Thunkijjanukij[1], S. Panichsakpatana[2,*], A. Kawtrakul[3] and U. Veesommai[4]

[1]Thai National AGRIS Centre, Kasetsart University, Bangkok 10900, Thailand
[2]Department of Soil Science, Faculty of Agriculture, Kasetsart University Bangkok 10900, Thailand
[3]Department of Computer Engineering, Kasetsart University, Bangkok 10900, Thailand
[4]Department of Horticulture, Faculty of Agriculture, Kasetsart University Bangkok 10900, Thailand

*Corresponding author. Email: agrsmp@ku.ac.th

Abstract

This research was a pilot project aiming to develop criteria for plant production ontology construction using Thai rice as a case study. Rice was chosen as the topic because of its importance to Thai society and the accumulated knowledge on it within Thailand. The Thai rice production ontology construction contained three criteria, namely, criteria for defining concept, criteria for defining term, and criteria for defining relationship. Criteria for defining concept were: criteria for classify organism, non-organism and soil concepts. Criteria for defining term were: criteria for terms classification and criteria for assigning term format. Criteria for defining relationships were criteria for defining equivalence relationships, hierarchical relationships and associative relationships. The Delphi Technique which was the research technique used to reach consensus on the desirability criteria without face-to-face contact with the selected experts was used. Data were collected from 27 domain specific experts. The total criteria (119 items) from rice production ontology construction were analyzed to identify the desirable criteria, which rated totally agree (score level 5) and very agree (score level 4). All of the 27 experts arrived at 21 items of the criteria (inter quartile range = 0). To establish a consensus, there were no significant differences between the two rounds of responses. Most of the experts reached a consensus of the criteria for constructing the rice production ontology with a high level score.

This study had implications for guiding the construction of other plant production ontologies for research knowledge management. These criteria would facilitate agricultural information specialists and agriculture domain experts to develop their own domain ontologies. Finally, the developed ontology would be a knowledge base for plant production research knowledge management in Thailand.

Keywords: criteria, rice production, plant production, ontology development**,** knowledge management

Introduction

Rice is the world's most common staple food. For more than half of mankind, in 118 countries, rice is the main component of their diet. The world production of rice is 605 million tons of paddy per year, equal to 403 tons of milled rice. Half of this is grown in China (30%) and India (21%). Thailand is the biggest exporter with 38% of the total worldwide rice export (Dooren, 2005). Rice is the major crop in Thailand and comprises the largest area (24 million acres), rainfed rice farming accounting for about 83% of all rice production in Thailand. Rice farmers are also one of the major employers with more than 26% of the population involved in rice farming (17 million people). The export value of rice is around 100,000 million Baht. (Office of Agricultural Economics [OAE], 2008).

Because of its importance, rice is considered a 'strategic resource' in Thailand and has been assigned as one of the high priority topic in the National Research Strategic Plan (Office of the National Research Council of Thailand, 2008). Research information is one of the critical factors for research development both in terms of research policy formulation and enhancing researchers' capabilities. Therefore all of past studies and investigation results have been regarded as a valuable part of the knowledge base for research development.

Unfortunately, the research knowledge repositories for rice production and plant production are not well organized and utilized. This is a main obstacle for research policy administrators and researchers to make use of the previous studies. Knowledge assets are the primary factor of production in the current economy and also contends that managing information is a critical and challenging task. Knowledge assets could be a key to developing a competitive advantage of organizations. Among the advantages, knowledge management provides an opportunity for organization to develop processes that would help prevent them from continually reinventing the wheel. Intellectual capital offers a unique competitive advantage to an organization (Drucker, 1994).

Accordingly, ontology plays a critical role in knowledge creation process and knowledge management process. In other words, ontology is a representative of knowledge and therefore can also be a basis for recording and retrieving knowledge. As a transfer of knowledge from someone to another requires either socialization or combination process, there is therefore a need for some kind of media or tools for doing the transfer. In addition, if that knowledge sharing is to be most efficient it is essential that the people in that respective community share some basic understanding as to the concepts and tools that represent the knowledge. Ontology as a knowledge representative is such a tool. It helps make knowledge retrieval process more intelligent.

An ontology is a formal and explicit description of concepts (concept is something formed in the mind; a thought or notion). It is a collection of concepts, represented by terms in several languages, and relationships between them. Developing and ontology is a complex task that requires a high degree of analytical and abstract thinking. An important role of ontologies is to serve as schemata or 'intelligent' view over information resources. Thus they can be used for indexing, querying, and reference purposes over non-ontological datasets and systems.

One of the main barriers to effective knowledge sharing by using ontologies is the inadequate documentation of existing knowledge bases and ontologies. To address these problems all important assumptions in ontology development should be documented for criteria and guidelines. Therefore, criteria and guideline will considerably facilitate the construction of a well-structured ontology for related issues in the broader domain.

Up to now, criteria for developing an ontology on a specific plant or crop production has not been constructed. So the objective of this research was to develop criteria for rice production ontology construction. This research is therefore a pioneer and pilot work to develop a criteria for plant production using the rice production as a test case study. This criteria will be a guideline for other agricultural ontology development in the future and through this efficiency of agricultural knowledge management will be improved.

Materials and Methods

As the ontology development process requires information organization, its proper documentation is important not only to facilitate construction, but also for the maintenance and the reuse of this ontology. The documentation in this research was created as criteria which will be described below. For rice production ontology construction guidelines (Thunkijja et al., 2008), and rice production ontology construction process were not included in this paper.

Material for Criteria Construction

Knowledge resources used for developing the rice production ontology construction criteria can be described as follows.

1. Domain specific experts. 27 experts specialized in the related subject of rice production were invited to validate the created criteria.

2. Domain specific knowledge materials, such as, rice production text books, related subjects dictionary, rice production websites, Thai AGROVOC Thesaurus (Thai National AGRIS Centre, 2004; http://pikul.lib.ku.ac.th), AGRIS/ CARIS Subject categorization schemes (FAO, 1998).

3. General ontology construction guideline (Pinto and Martins, 2004; Noy and McGuinness, 2001; Uschold and Gruninger, 1996).

4. Tools for knowledge modeling, such as, CmapTools version 4.08 COE (http://cmap.ihmc.us/) and Mind Manager version X5.

Criteria Construction Process

The concepts of the rice production ontology was categorized as classes to provide an initial comprehensive framework that will incorporate every other relevant concepts. The rice production ontology construction criteria for defining concept categories followed the plant production knowledge model applied from Beverly et al. (1993)'s whole plant model.

The process of creating criteria was done according to three stages:

Stage 1–Defining the criteria. An ontology was a data model that provides an organizational framework that allows reasoning about knowledge. The criteria for constructing an ontology should be defined as:

a. Criteria for defining concept
b. Criteria for defining term, and
c. Criteria for defining relationship

Stage 2–Formulating preliminary set of criteria and applying them to the working process of rice production ontology construction. Those criteria, as a result, was modified and adjusted according the ontology construction process.

Stage 3–Testing and evaluating the criteria. The criteria were presented to domain specific experts and information specialists who were knowledgeable about rice production, albeit unskilled about ontologies. Then the criteria were revised. The Delphi technique made use of domain specific expert to suggest and confirm the criteria. Questionnaires were designed to address the ontology construction criteria. The questionnaire was aimed at a target population consisting of professionals in subject of agricultural sciences and plant production. Inputs from the experts provided additional credibility of the research effort and helped refine the criteria. Then the criteria were modified and used for refining the rice production ontology.

To develop the rice production ontology criteria, there was a need to integrated knowledge from research literature together with expert opinions. The ability to make effective decisions to validate the criteria led using the consensus methods such as the Delphi Technique.

Delphi Approach

The Delphi technique was an appropriate method for this research because it provides a standardized procedure for collecting and refining qualitative and quantitative data. This technique could develop sensitizing concepts or understanding from descriptive data and used statistical measurement (Hasson et al., 2000).

The Delphi technique was designed to utilize three rounds of sequential individual questionnaire iterations to elicit and refine group judgments from a selected group of experts in a specific area to reach consensus on the desirability of certain events or outcomes without face-to-face contact. The end product was a consensus among experts by use of statistical information and included their commentaries on each of the questionnaire items, usually organized as a written report by the Delphi investigator (Delbecq et al., 1975; Helmer, 1967). As this technique used a group of experts to deliberate a research issue or a problem anonymously, it overcame some of the interpersonal obstacles associated with group decision-making. The technique had much to offer in terms of gaining opinions from a wide range of idea. However, this could generate large amounts of data. Duffield (1993) and Jerkins and Smith (1994) revised this approach by providing pre-existing information for ranking or responding in round one.

The criteria in this study were defined by documentary review and collected from the process of constructing the ontology. Thus the Delphi approach was revised by providing criteria for rice production ontology construction as pre-existing information for round one.

Developed the Questionnaire

The questionnaire was developed as pre-existing data based on the rice production ontology which was designed through the process of knowledge capture both tacit and explicit knowledge and process of knowledge summarization. All of them were close-ended with open-ended suggestion. The score of agreement was arranged in five levels, namely, 5=totally agree, 4=very much agree, 3=moderately agree, 2=slightly agree, and 1=least agree. The questionnaire had 119 questions regarding ontology construction criteria and divided the criteria in to 4 main topics as: criteria to define concept of rice production process, criteria for classification, criteria to define name entity and criteria to define relationship.

To prevent potential misunderstandings and ambiguity, three experts tested the questionnaire. The questionnaire was evaluated and modified as necessary before sending to the participants.

The participants of the Delphi technique group of this research were experts in agricultural sciences. Twenty seven experts were invited from three organizations namely, Faculty of Agriculture, Kasetsart University; Rice Department, Ministry of Agriculture and Cooperatives (MAC); and Department of Agriculture, MAC.

The round-one questionnaire was sent to the panelists. The experts were asked to perform three tasks: 1) reviewing the list of defined criteria, 2) rating each competency using a 5-point rating scores, 3) suggesting any competency criteria which was necessary but not existed, and 4) returning the questionnaire by a certain date.

The round-two questionnaire contained the same list of competencies questions and used the same 5-point rating score as the round one. The participants received also their previous ratings as well as the group median and inter quartile range for each competency. Participants were requested to review, and rate the items again.

Data Analysis

The questionnaires were posted to the 27 experts for two rounds. The responses were summarized by descriptive analysis and statistical analysis method. Median, mean, inter quartile range were calculated. The median and means of the round two responses were rank-ordered. A list of desirable competencies specified to be criteria was made as a result of rice production ontology constructing criteria.

Results and Discussion

The criteria were developed by integrating explicit knowledge and tacit knowledge and using consensus methods for validation. Criteria for rice production ontology construction were described as follows.

Criteria for Defining Concepts

Concepts for constructing rice production ontology should be defined into three concept categories as: conceptual entity concept, object entity concept and functional entity concept. The concept categories comprised of 6 conceptual entity concepts, 2 object entity concepts and 5 functional entity concepts. Object entity concepts were divided to organism and non-organism object entity concept. Functional entity concepts were classified as: plant production process, breeding method, protection process, infecting process and physiological functional entity concepts. The plant production process entity concept was divided into cultivation process, harvesting process, soil preparation process, fertilizing process, irrigation process, propagation process and seed processing functional entity concepts (Table 1).

Object entity concepts were defined into two groups as: organisms and non-organisms. Criteria for classifying the organism and non-organism concepts were detailed as follows:

The classification of organisms for the rice production ontology followed the biological taxonomic classification proposed by Woese et al. (1990). Organisms related to rice in the rice production ontology are classified as:

a) Classification of plant, classification in taxonomic levels were Kingdom, Family, Genus, Species, Subspecies, Variety or Cultivar.

Table 1 Rice production ontology concept categories.

Conceptual entity concept	Object entity concept	Functional entity concept
Taxonomic unit	Organism	Plant production process
..biological taxonomic unit	..plantae	..cultivation process
..soil taxonomic unit	..animalia	..harvesting process
….soil series	..fungi	..soil preparation process
Behavior	..bacteria	..fertilizing process
..animal behavior	..virus	..irrigation process
..plant habit	Non-organism	..propagation process
Composition	..environmental factor	..seed processing
..plant anatomy	….water	Breeding method
..chemical composition	….light	Protection process
Property	….weather	..control method
..biological property	….pollutant	Infecting process
..soil property	..geographical area	Physiological function
Type	..plant nutrient	..growth period
..organism type	..soil	
..non-organism type	..soil amendment	
Appearance	..agricultural substance	
..duration	….fertilizer	
..disorder	….pesticide	
..disease	….plant growth regulator	
..symptom	..product	

b) Classification of animal, fungi and bacteria. The classification in taxonomic levels were Kingdom, Class, Order, Family, Genus, Species.

c) Classification of virus. The classification in taxonomic levels were Virus group, Family, Genus and Virus name.

The classification of non-organism concepts. The non-organism concepts order were categorized according to its order in group or category that it belonged.

Criteria for classifying soils. For developing the rice production ontology, the soil classification followed the "Keys to Soil Taxonomy" (USDA, 2006). The classification of soils taxonomy were Soil Order, Soil Suborder, Soil Great group, Soil Subgroup, Soil Family and Soil Series.

Conceptual entity concepts were concepts which presented characteristic or properties of object entity concepts. The more connections between object entity concepts and conceptual entity concept existed, the more properties of object entity concept were defined. These concepts and relationship were useful for concept-based search and contextualization of knowledge. There were some examples of conceptual entity concept classification presented below.

Conceptual entity concept in term of "biological taxonomic unit": organisms were classified hierarchically, each concept in the hierarchy must be connect with conceptual entity concept in term of "biological taxonomic unit" through the relation "hasTaxonomicLevel". This connection would facilitate the reasoning about the taxa of each organism concepts, for example:

concept[*Poaceae*] hasTaxonomicLevel concept [Family]

concept[*Oryza*] hasTaxonomicLevel concept [Genus]

Conceptual entity concept in term of "Type". Most of the organisms and non-organisms were defined by characteristic or properties and related with conceptual entity concepts in term of “Type”, for example:

concept[rice] hasRelatedType concept[cereal crop]

concept[brown planthopper] hasRelatedType concept[insect pest]

In the ontology there were some classification defined by type or properties, as described below.

Classification of rice defined by characteristic, such as:

Rice type defined by harvesting date: early maturity rice ,medium maturity rice, and late maturity rice.

Rice type defined by irrigation: irrigated rice, and rainfed rice.

Rice type defined by growing area: lowland rice , deepwater rice, floating rice, upland rice ,and high land rice (high land paddy rice and high land upland rice).

Rice type defined by photoperiod sensitivity: photoperiod sensitive rice, and photoperiod insensitive rice.

Rice type defined by seed starch composition: waxy rice or glutinous rice, and non-waxy rice or non-glutinous rice.

Classification of organisms related to rice. The types of animals related to rice have been defined as example below:

Beneficial animals: pollinator and natural enemy.

Noxious animals: noxious mammal ,noxious bird ,noxious mollusca ,noxious crustacea, pest mite, nematode and insect pest (defined as: root eating insect, stem eating insect, leaf eating insect, flower damaging insect, fruit damaging insects, seed damaging insect; chewing insect, sucking insect; vector insects, etc.).

Classification of plants defined by type, such as:

Useful plants: food crop ,feed crop, medicinal crop, spice crop, fiber crop, fuel crop, oil crop, rubber plant, dye plant, gum plant, ornamental plant, soil reclamation plant, cover plant ,protective plant, erosion control plant ,structural plant, trap crop ,pesticide crop, etc.

Noxious plants: such as weeds defined by characteristic as narrow leaf weed ,broad leaf weed, aquatic weed. Weeds defined by growing season as annual weed and perennial weed.

Classification of microorganisms defined by type as:

Useful microorganisms: nitrogen fixing microorganism ,biological control microorganism.

Noxious microorganisms: pathogenic fungi, pathogenic bacteria and pathogenic virus.

Classification of non-organisms related to rice, such as type of agricultural substances identified in the rice production ontology that were:

Pesticides defined as avicide, rodenticide, molluscicide, insecticide ,acaricide, nematicide, fungicide ,bactericide ,herbicide ,pesticide synergist and biopesticide (botanical pesticide, microbial pesticide).

Fertilizers defined as inorganic fertilizer, organic fertilizer, biofertilizer, organomineral fertilizer, liquid fertilizer, liquid gas fertilizer, slow release fertilizer. Inorganic fertilizers were defined as single fertilizers (such as: nitrogen fertilizer, phosphate fertilizer, potash fertilizer, sulfer fertilizer ,calcium fertilizer, magnesium fertilizer, micronutrient fertilizer), compound fertilizers (such as: NPK fertilizer, nitrogen phosphorus fertilizer, nitrogen potassium fertilizer, phosphorus potassium fertilizer and organic fertilizers (such as compost, farm manure, green manure).

Functional entity concepts, such as cultivation process, fertilizing process, soil preparation process, etc. would be categorized according to its function order.

Criteria for Defining Term

Criteria for terms classification: all terms which represent concepts should be identified with either one of the following groups.

a) A preferred term is term which is preferably lexicalized the concept. The preferred term was the main term representative of a concept when that concept could be described by various different terms. There was only one term designated as the preferred term. The other terms were considered as non-preferred terms or synonyms. Acronyms, abbreviation names, or symbols were not used as preferred terms. Preferred terms were selected from related thesaurus, dictionaries or terms that were accepted or recommended by experts in that domain.

b) Non-preferred terms or synonyms were terms with the same meaning as the preferred term but were not selected as main concept representatives. Some of the non-preferred terms were also called synonyms. Non-preferred terms or synonyms could be in the form of term variants such as spelling variants, acronym, abbreviation names, terms in singular or plural, common names, local names, scientific names, trade names, chemical symbols, chemical formulas, etc.

Criteria for defining term format**:** general practice dictated that terms which were used as preferred term for representing concepts must be standardized as follows:

Common word must be singular and noun word or noun phrase, except the specific defined plural or singular noun.

Non-capitalize these terms except specific names, such as: scientific names, soil series names, cultivar names, trade names, geographical names.

Bi-lingual terms: Terms representation in English and Thai for all name entity was defined. Latin was used for scientific names.

Organisms: Scientific names representing plants, animals and related organisms were used. Common names in English and local names in Thai were defined as synonyms.

Non-organisms: The most accepted name entity in the subject domain were used as preferred term and the less defined as synonym (non preferred term).

Soil: Soil Series names defined by the Land Development Department (2008) were used to represent soil series in Thailand.

Agricultural chemical substances: Substance common names in Thai and English were used for representing and substance trade names as synonyms.

Plant nutrients: Element names were used represent plant nutrients. Chemical symbols and chemical formulas were defined as synonyms.

Criteria for Defining Relationships

Criteria for defining equivalence relationships: Terms in the same concept by using equivalence relations as described in Table 2.

Table 2 Relations and inverse relations of the equivalence relationships.

Relation	Inverse relation
hasLexicalization	isLexicallizationOf
hasSynonym	isSynonymOf
..hasCommonName	isCommonNameOf
..hasLocalName	isLocalNameOf
..hasChemicalSymbol	isChemicalSymbolOf
..hasChemicalFormula	isChemicalFormulaOf
..hasTradeName	isTradeNameOf
..hasTranslation	isTranslationOf
..hasAcronym	isAcronymOf
..hasAbbreviation	isAbbreviationOf
..hasSpellingVariant	isSpellingVariantOf
..hasPlural	hasSingular

Criteria for defining hierarchical relationships: concepts in the same tree were linked by using hierarchical relation. It was a hierarchical linkage like the subclass and superclass or mother and child concept relation. The hierarchical relationship had only one relation, which was the “hasSubclass” and had inverse relation “isSubclassOf”.

Criteria for defining associative relationships: interconnections between concepts in different hierarchies were created. They could be related in different ways and could be divided into functional relationships and conceptual relationships (Table 3).

Evaluation Criteria Results

Based on the documents review and the Delphi technique two round responses, the total criteria (119 items) from rice production ontology construction were analyzed to identify the desirable criteria, which rated totally agree (score level 5) and very agree (score level 4). All of the 27 experts arrived at 21 items of the criteria (inter quartile range = 0). To establish a consensus, there were no significant differences between the two rounds of responses. Most of the experts reached a consensus for the criteria for constructing the rice production ontology with a high level score because the predefined criteria were summarized from literature review and interviewed domain experts.

Table 3 Example of relations and inverse relations of associative relationships.

Relation	Inverserelation
hasFunctionallyRelatedTo	isFunctionallyRelatedOf
..hasPlantProductionProcess	isPlantProductionProcessOf
….hasCultivationProcess	isCultivationProcessOf
…...hasCultivationMethod	isCultivationMethodOf
….hasSoilPreparationProcess	isSoilPreparationProcessOf
……hasSoilPreparationMethod	isSoilPreparationMethodOf
hasAffectingFactor	isAffectingFactorOf
..hasEnvironmentalFactor	isEnvironmentalFactorOf
..hasInjuriousFactor	ishasInjuriousFactorOf
….hasPathogen	isPathogenOf
….hasPest	isPestOf
….hasWeed	isWeedOf
..hasVector	isVectorOf
..hasHost	isHostOf
..hasIncreasingFactor	isIncreasingFactorOf
..hasDecreasingFactor	isDecreasingFactorOf
….hasControlFactor	isControlFactorOf
…...hasBiologicalControlAgent	isBiologicalControlAgentOf
……..hasNaturalEnemy	isNaturalEnemyOf
…...hasControlSubstance	isControlSubstanceOf
hasConceptuallyRelatedTo	isConceptuallyRelatedOf
..hasProperty	isPropertyOf
..hasRelatedType	isRelatedTypeOf
..hasTaxonomicLevel	isTaxonomicLevelOf
..isResistantTo	isHarmlessFor
..isSusceptibleTo	isHarmfulFor
..hasAppearance	isAppearanceOf
….hasSymptom	isSymptomOf
….hasDisease	isDiseaseOf
….hasDisorder	isDisorderOf
….hasAppearancePart	isAppearancePartOf

Sixteen experts suggested to revise some concept representatives. The least agreed criteria were the relation between rice and growth regulator (plant growth substance), fifteen experts (55.56%) defined level of agreement in middle level (level 3: agree). The reason was to plant growth regulator was not normally used for rice production or cereal crop but used for the other crops, especially fruit crop.

Based on the range of responses received, all criteria defined by numbers of experts and degree of agreement were summarized. There were 118 items of criteria that have the high level of agreement (level 5=totally agree and 4=very agree) by the judgments of at least 24 over 27 experts.

Conclusions

Criteria for rice production ontology construction were criteria for defining concept, criteria for defining term, and criteria for defining relationship. Criteria for defining concept were: criteria for classify organism concepts, criteria for classify soil concept, criteria for classify non-organism concepts. Criteria for defining term were: criteria for terms classification and criteria for assigning term format. Criteria for defining relationships were criteria for defining equivalence relationships, criteria for defining hierarchical relationships and criteria for defining associative relationships. The Delphi Technique was used for validating the created criteria with the support of 27 domain specific experts.

Contributions from this research should support knowledge service organization, research planning section, and research project managers in making decisions based on the knowledge base and create research knowledge management initiatives. This research effort also helps establish criteria for agricultural ontology construction, increase efficiency of research information retrieval system and enhance service quality for research knowledge management efforts.

Developing domain specific ontologies is the biggest challenge information retrieval and knowledge services. Therefore it is advisable that experts and information specialists in each specific knowledge domain should collaboratively start developing their respective ontology. Further more, collaboration among related organizations or ontology editors should be established, so that the developed ontology could be reused.

Acknowledgments

We thank for all the useful comments from domain specific experts, especially the professors; agricultural subject experts in Faculty of Agriculture, Kasetsart University; Information and Knowledge Management Officers in Knowledge and Communication Department, FAO and Dr. Dagobert Soergel in Maryland University. We are exceptionally thankful to the Thai National AGRIS staff who provided support in data collection and encouragement. We thank the anonymous reviewers for their careful revision and most valuable suggestions.

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Thunkijjanukij, A., A. Kawtrakul, S. Panichsakpatana and U. Veesommai. 2008. Lesson learned for ontology construction with Thai rice case study, pp. 495-502 In Proceedings of IAALD AFITA WCCA:

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Manuscript received 11 January 2009, accepted 20 March 2009