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Development of Exporting Fresh Fruits Ontology for Improving the Knowledge-Based System on the Domain of Export Process in Thailand

Thanisorn Tangarommun[1], Nattapon Kumyaito[2] and Klairung Ponanan[3]

ABSTRACT

Thailand's exports are crucial to the country's economic income, with agricultural products among the most important. Import-export firms mainly manage the export process because agriculturists hesitate to deal with complex procedures. Based on the complex procedures and lack of knowledge about the export process, new entrepreneurs and agriculturists often struggle to export their products directly. Therefore, a simplified system is needed for those seeking information on export procedures. To address this, the Exporting Fresh Fruits Ontology was developed to enhance the knowledge-based system for managing fresh fruit exports. This system involves three main steps: reviewing export processes and documents, generating ontology for the fresh fruit export domain, and developing the knowledge-based system. The Hozo Ontology Editor is the system's backbone, built using the Ontology-based Application Management (OAM) framework. The Exporting Fresh Fruits Ontology comprises 12 main classes, sub-classes, and attributes, capturing knowledge of the export process. It includes mappings between relational database entities and the ontology, capturing semantic information, and validating mapping consistency to eliminate errors. The results show that the Exporting Fresh Fruits Ontology performs well, achieving an average F-measure value of 0.98.

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1. INTRODUCTION

Thailand is an agricultural country, with about 50% of its population engaged in agriculture. Agricultural products are consumed domestically, while some are exported to other countries. As international markets recognize high-quality Thai products and remarkably fresh fruits, agricultural exports boost the economy. Thai fresh fruits are considered premium, with a high demand internationally, generating significant export income—amounting to USD 3,482.22 million in 2020 [1]. Based on these issues have attracted many exporters to the Thai fresh fruit market, with most export operations handled by export companies.

Although exporting fresh fruits is exciting for entrepreneurs, some still need to familiarize themselves with the export procedures. Due to the complexity of the procedures and a need for knowledge related to exporting fresh fruits, especially the agriculturists, they cannot export their agricultural products directly. Therefore, entrepreneurs and agriculturists must learn about export procedures, transportation methods, and other aspects of fresh fruit exportation. Fresh fruit export involves several variables, such as the export procedure, export documentation, modes of transportation, importer nation legislation, and other variables, such as fresh fruit export storage. Entrepreneurs and agriculturists may experience information overload and waste a lot of time searching when they use several data sources to look up information. A simple system is needed for new entrepreneurs and agriculturists who want to have details on exporting procedures.

Recent advancements in search engine technology

[1,3]The authors are with the Faculty of Logistics and Digital Supply Chain, Naresuan University, Muang, Phitsanulok, Thailand, E-mail: thanisornpun@hotmail.com and klairungp@nu.ac.th
[2]The author is with the Faculty of Science, Naresuan University, Muang, Phitsanulok, Thailand, E-mail: nattaponk@nu.ac.th
[3]Corresponding author: klairungp@nu.ac.th

enable efficient information retrieval from multiple sources. The Semantic Web, an extension of the current web, provides well-defined information, facilitating better collaboration between computers and users [2, 3]. A vital component of the Semantic Web is ontology, which defines domain-specific terms, relationships, and rules using the Web Ontology Language (OWL) [4-6].

Therefore, the ontology for exporting fresh fruits to improve the knowledge-based system on the export process has been developed to handle the fresh fruit export variables. The variables are determined by the fresh fruit export domain to the Semantic Web technology knowledge structure for comprehensive knowledge and efficient information retrieval. This paper presents a knowledge-based system for supporting new entrepreneurs and agriculturists exporting their products. The knowledge-based system consists of the ontology of exporting fresh fruits, a database of exporting fresh fruit, and recommendation rules, shown in the following sections.

2. PRRPOSED KNOWLEDGE-BASED SYSTEM

2.1 Overview of Thai Fresh Fruits Exporting Process

The value of Thai fresh fruit export has increased as it has grown in popularity in the international market. It is becoming an essential source of income for Thailand. The Department of International Trade Promotion launched the export procedure, which consists of the details of documents for exporting products. The exporter must prepare the related documents and examine the regulations of the import and export country in each procedure, as shown in Fig. 1. The process of exporting Thai fresh fruit consists of seven steps:

(1) Checking the privileges of international trade in order to ask for a certificate of origin. In this step, the exporter has to register for the permit ID Card of the Exporter or Importer, and then the product's characteristics must be checked to request the certificate of origin in the sixth step.

(2) Checking customs tax benefits, the exporter must request the privileges of tax benefits for the received tax break in the fourth step.

(3) Studying the regulations of importing countries and requesting a certificate from related institutes, the exporter must check the importing country's rules before requesting a certificate of product quality. Then, the exporter must register as an exporter of agricultural products outside the Kingdom and request a Health Certificate for fresh fruits.

(4) Filling in the Customs clearance form via the E-Customs system: The exporter must do the customs clearance, which consists of two processes: First, a customs clearance person registers personal

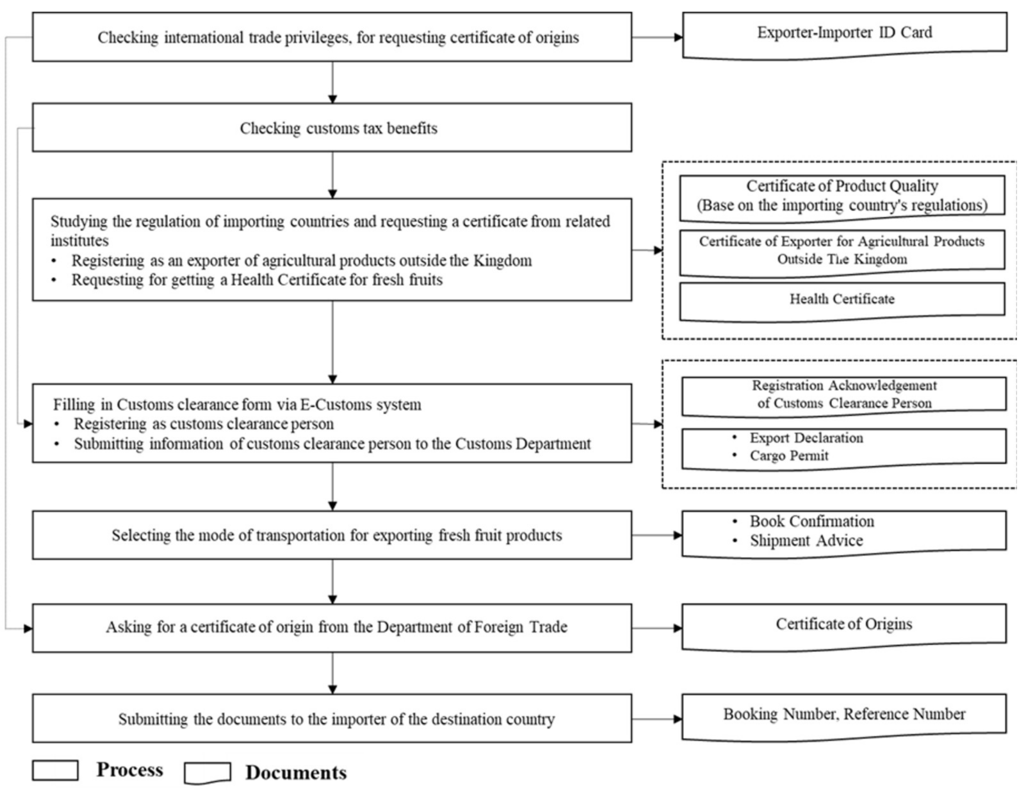

Fig.1: *Fresh Fruits Exporting Procedure.*

Adapted from: Department of International Trade Promotion

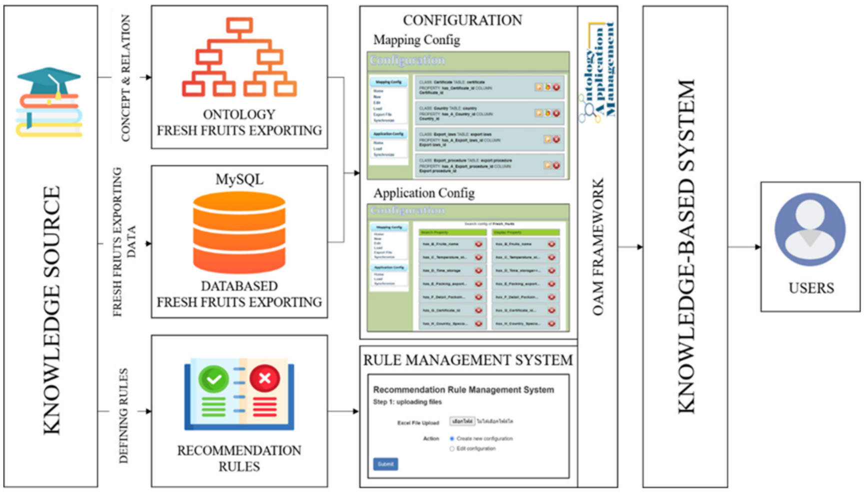

Fig. 2: *Framework of Knowledge-Based System.*

information via the E-Customs system. Then, the information about the customs clearance will be submitted to the Customs Department for permission in the next step.

(5) Selecting the mode of transportation for exporting fresh fruit products, the exporter should consider the available transportation mode from the origin country to the destination country.

(6) Asking for a certificate of origin from the Department of Foreign Trade; a certificate of origin will be allowed by the Department of Foreign Trade by using the certificate of product characteristic from the first step.

(7) Submitting the documents to the importer of the destination country, then the exporter sends related documents, such as the Booking Number or Reference Number, to track the products.

The complexity of the fresh fruit exporting process, with several documents in each process, will make a person unfamiliar with the export process unable to do all the steps themselves. For this reason, a knowledge-based system to support the exporting process is proposed. The knowledge-based system to support the exporting process is a form of artificial intelligence (AI) that aims to capture the knowledge of human experts to support decision-making in exporting fresh fruit. This system will easily support SMEs, startups, and agriculturists in studying exporting procedures.

2.2 Framework of Proposed Knowledge-Based System

The knowledge-based system consists of the ontology domain's fresh fruits exporting, database, and recommendation rules. Firstly, the ontology was generated to define conceptual knowledge of exporting fresh fruits. Secondly, the database of the exporting fresh fruits process was conducted by applying Navicat for the MySQL application to be sent out to the MySQL server. Thirdly, the recommendation rule is defined as advising information to the user, which is specific information in terms of the required scope for the user. Then, The Ontology-based Application Management (OAM) Framework was used to connect the ontology, the database, and the recommendation rule. The OAM Framework is an application development platform that aims to simplify the creation and adoption of a semantic web application [7-9]. The overview of the proposed knowledge-based system is shown in Fig. 2.

Ontology Application Management Framework (OAM) is an application framework designed to streamline the development of applications that leverage semantic web technologies and ontologies [10]. The OAM Framework offers a comprehensive solution for developing and managing applications that leverage semantic web technologies and ontologies, providing users with the necessary tools and resources to build sophisticated and interoperable systems [11].

3. METHODOLOGY

The knowledge-based system of the export process in Thailand consists of three main steps: Reviewing related data related to exporting processes and documents, generating an ontology domain, Knowledge-based system development. The Hozo-ontology editor is utilized as the backbone of this system [12]. The methodology of this study is presented in Fig. 3.

3.1 Reviewing Related Data

Knowledge of fresh fruit exporting is divided into two categories: (1) fresh fruit exporting and (2) fresh fruit storage for exporting. These categories are derived from explicit resources such as the Department of International Trade Promotion (DITP), National Bureau of Agricultural Commodity and Food Standards, and Office of Agricultural Economics in Thailand, as well as literature reviews and related work.

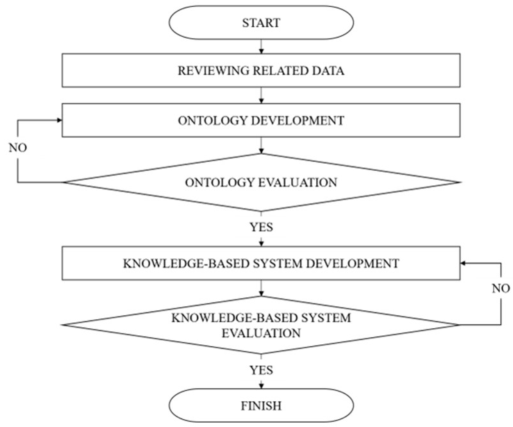

Fig.3: *Research Methodology.*

There is much research in developing an ontology for agricultural products that uses the average percentage of precision, recall, and F-measure to evaluate the ontology [11, 13-17]. By calculating the average percentage of precision, recall, and F-measure, researchers can comprehensively view the ontology's overall performance across various tasks. This approach helps identify strengths and areas for improvement in the ontology's structure and content, leading to better knowledge representation and retrieval in the agricultural domain. Winai Bangkhomned and Janjira Payakpate [11] developed the ontology by applying semantic search methods to manage knowledge on tropical fruit production, longan, in Northern Thailand. The ontology was evaluated by testing the information retrieval, which consists of three values, i.e., precision value, recall value, and F-measure value. The testing of information retrieval from the ontology using semantic searching showed a precision of 100% for the retrieved information, with a recall of 93.50% and an F-measure of 96.64%. These results supported further implementation of the Thai Longan Production Knowledge Service System.

Porawat Visutsak [17] developed the ontology knowledge based on durian pests and disease retrieval systems. The ontology was evaluated by testing information retrieval, which consists of three values: precision, recall, and F-measure. The experimental results yielded 100% precision, 88.33% recall, and 93.8% F-measure. The system provides eight classes of pests and diseases of 3 durian cultivars (Monthong, Chanee, and Kanyao).

Based on [11] and [17], ontology evaluation through testing information retrieval with three values, namely precision, recall, and F-measure, can enhance a system's efficiency in terms of objective evaluation, comprehensive assessment, and comparative analysis. Therefore, precision, recall, and F-measure have been selected in this study to evaluate the Exporting Fresh Fruits Ontology.

3.2 Ontology Development

Ontology is knowledge representation in a domain of interest by formally defining the relevant concepts, properties, and relations [2, 18]. It is widely acknowledged as the explicit form of a concept and relation that computer systems can understand. In this study, the ontology for exporting fresh fruits is designed according to the guidelines suggested by Noy [19, 20]. The domain of knowledge-based exporting of fresh fruits is divided into two sub-domains: (1) the export process and (2) the storage of fresh fruits for export. A Hozo-ontology editor is employed to develop ontology since it helps visualize ontology structures and generate OWL (Web Ontology Language) format output.

The top-down, bottom-up, and middle-out approaches are three distinct methodologies for developing ontologies, each with its characteristics, advantages, and considerations [17].

Top-Down Approach

Conceptualization: The top-down approach begins with a high-level conceptualization of the domain, often driven by domain experts or stakeholders.

Hierarchy Design: The development of an ontology starts with defining top-level concepts and relationships and then progressively refining the ontology structure.

Systematic Design: The ontology is designed systematically from general concepts to specific details, ensuring a clear and organized representation of knowledge.

Advantages: Provides a systematic and comprehensive understanding of the domain, facilitates alignment with organizational goals and requirements, and ensures consistency and coherence in ontology design.

Bottom-Up Approach

Data-Driven: The bottom-up approach starts with existing data or knowledge sources, such as databases, documents, or domain-specific terminologies.

Knowledge Extraction: Ontology development involves extracting relevant concepts, relationships, and patterns from data sources, often using automated or semi-automated methods.

Incremental Construction: The ontology is constructed incrementally based on the analysis of data sources, allowing for rapid prototyping and refinement.

Advantages: Leverages existing knowledge and data sources, facilitates rapid ontology development, and promotes collaboration among data owners and domain experts.

Middle-Out Approach

Hybrid Method: The middle-out approach combines top-down and bottom-up approaches, aiming to strike a balance between conceptual clarity and data-driven insights.

Iterative Process: Ontology development involves iterative conceptual modeling and data integration cycles, allowing for continuous refinement and improvement.

Integration of Perspectives: Incorporates domain expertise and existing data sources to create a holistic ontology that reflects theoretical principles and empirical observations.

Advantages: It offers flexibility and adaptability to varying domain requirements, balances theoretical and practical considerations, and promotes synergy between domain experts and data analysts.

In this study, the Top-Down Approach was considered for developing the ontology. The top-down approach provides a structured and systematic methodology for developing new ontologies in academic settings, ensuring conceptual clarity, alignment with research goals, flexibility for iterative refinement, interdisciplinary collaboration, and educational value. The top-down approach begins with a high-level domain conceptualization, allowing ontology developers to define clear and coherent conceptual structures. This clarity helps ensure the ontology accurately represents the domain's key concepts and relationships.

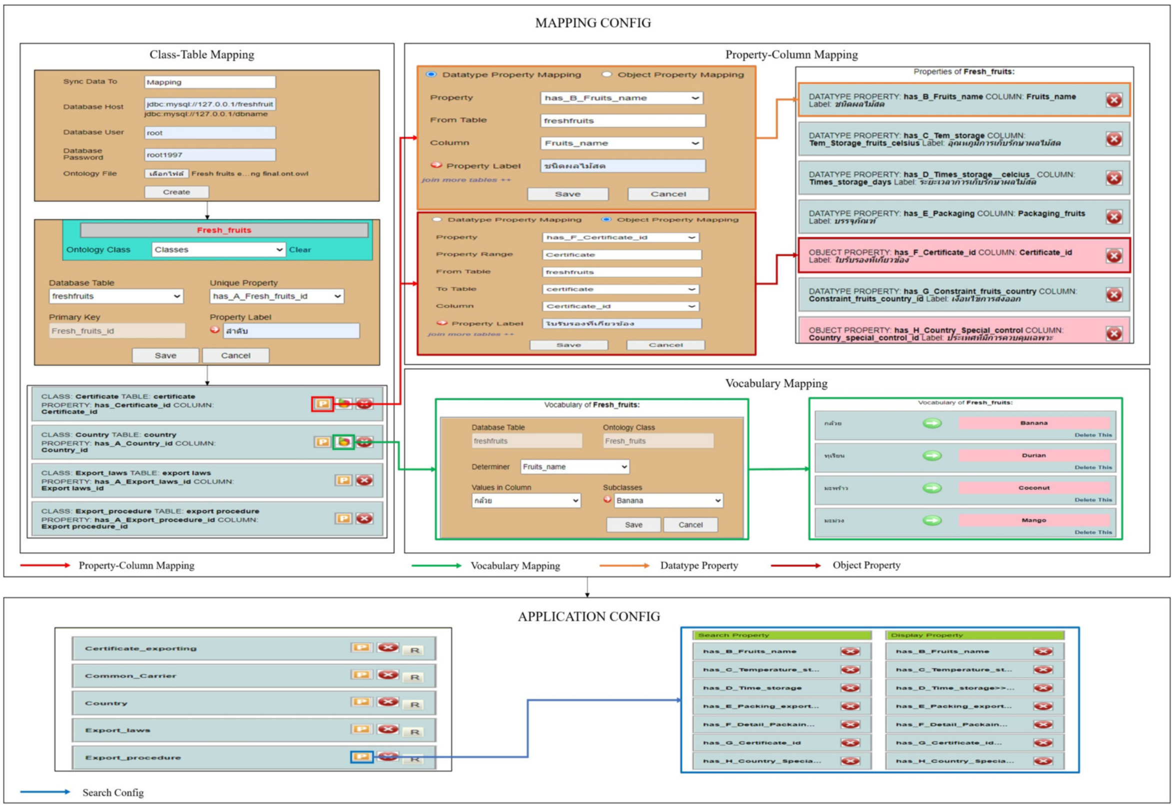

Fig.4: *Step of configuration between the exporting fresh fruits ontology and the database.*

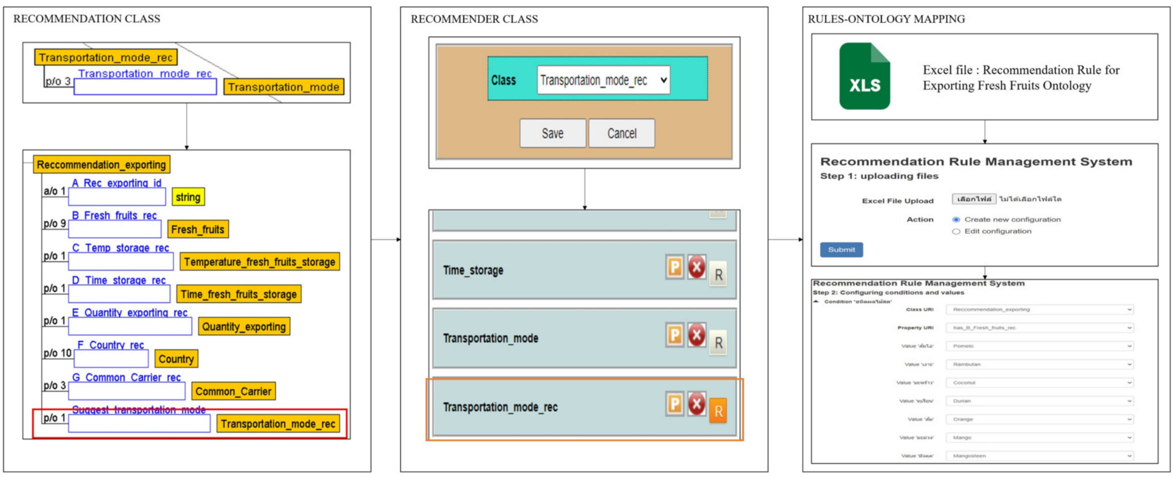

Fig.5: *The recommendation management system.*

The development of an ontology for exporting fresh fruits aims to enhance the knowledge-based system in the domain of export processes in Thailand. This approach starts with a high-level conceptualization driven by domain experts and stakeholders.

High-Level Conceptualization: The process begins with a broad understanding of the domain:

1) Engage Domain Experts: Collaborate with domain experts and stakeholders to gather insights into the domain.
2) Identify Top-Level Concepts (Classes): Define the major categories and entities involved in the export process of fresh fruits, such as "*Fresh Fruit*," "*Export laws*," "*Country*," and "*Export procedure.*"

Hierarchy Design: Develop the hierarchical structure of the ontology:

1) Define Top-Level Concepts (Classes): Establish the primary classes and their relationships. For example, under "*Country*," classes such as "*General country*" and "*Special control country*" should be included.
2) Progressive Refinement: Break down each top-level concept into more specific sub-concepts. For instance, under " *Special control country,*" define "*Singapore*," "China," and "*Japan.*"

3.3 Knowledge-Based System of the Export Process Development

The knowledge-based system has been developed using the Ontology-based Application Management (OAM) framework. The semantic search system provides an interface for showing information from a knowledge-based system. The knowledge-based system consists of two parts: the semantic search and recommendation management parts.

The configuration connects ontology and the database by mapping classes in ontology with database tables. The database tables consist of (a) Class-Table Mapping, (b) Property-Column Mapping, and (c) Vocabulary Mapping. Fig. 4 presents the application configuration that illustrates the display settings of the *Search Property* and Display *Property* applications.

The recommendation management system is designed based on data qualification scenarios to facilitate recommendations within the OAM Framework [7, 10]. The system is critical because it integrates data and rules to provide relevant transportation mode recommendations. The management system ensures that recommendations are consistent, adaptable, and integrated into the broader application framework. Based on Fig. 5 is an example of the recommendation class of transportation mode, i.e., "$Transportation\_mode\_recommendation$." The steps of the Recommendation Management System are as follows:

– Creation of the Recommendation Class in Ontology: This step involves creating a recommendation class within the ontology, "*Recommendation_exporting*" in Fig. 5. Ontology in this context refers to a structured representation of knowledge, defining various elements and their relationships. Each recommendation class has properties defined as "$part-of$" relations, linking the recommendation class to other relevant components within the ontology. This step ensures that the recommendation system comprehensively understands the data and its interconnections.

– Addition of the Recommender Class to the Application Configuration: This step involves adding a recommender class to the application configuration, which is the example of "$Transportation\_mode\_rec$" in Fig. 5. This class serves as an additional recommendation element within the system, enhancing its capability to make more informed and precise recommendations. By integrating this class into the configuration, the system can adapt and extend its recommendations based on new inputs or changes in the application environment.

– Rules-Ontology Connection: This step involves conducting a Rules-Ontology connection. This process links the established rules (which define how decisions are made) with the classes within the ontology. By connecting rules and ontology, the system can utilize predefined logic to generate accurate transportation mode recommendations based on the data provided.

4. RESULTS

4.1 Exporting Fresh Fruits Ontology

The Exporting Fresh Fruits Ontology is developed using the Hozo-ontology editor. The scope of the ontology development is the fresh fruit exporting domain. This ontology contains 12 main classes. The main classes consist of sub-classes, properties/attributes of classes, and sub-classes, as shown in Table 1. The overview of the Exporting Fresh Fruits Ontology is demonstrated in Fig. 6.

Exporting Fresh Fruits Ontology has been developed using a top-down approach. The processes of creating the Exporting Fresh Fruits Ontology consist of 1) Define Scope and Objectives, 2) Identify Stakeholders, 3) Domain Analysis, 4) Conceptualization, 5) Ontology Design, and 6) Formalization.

1) Define Scope and Objectives: Clearly define the scope and objectives of the Exporting Fresh Fruits Ontology. This process involves specifying the domain of interest, which is the exportation of fresh fruits. Determine the goals of the Exporting Fresh Fruits Ontology, such as reducing duplicated information, ensuring regulatory

Table 1: *The classes of Fresh Fruits Exporting Ontology.*

Class	Relation Property	Relation Type	Property	Description
Fresh_fruits	*has*	*a/o*	*A_Fresh_fruits_id*	ID no. of kind of fresh fruits.
	has	*a/o*	*B_Fresh_fruits_name*	Name of fresh fruits
	has	*p/o*	*C_Temperature_storage*	Temperature for exporting storage
	has	*p/o*	*D_Time_storage*	Time for exporting storage
	has	*p/o*	*E_Packaging_exporting*	Type of package of fresh fruits for exporting
	has	*p/o*	*F_Detail_Packaging_exporting*	Instruction of packing fresh fruits for exporting
	has	*p/o*	*G_Certificate_id*	Certificate of origin country
	has	*p/o*	*H_Country_Special_control*	Special control counties for fresh fruits import
Country	*has*	*a/o*	*A_Country_id*	ID no. of countries
	has	*a/o*	*B_Country_name*	Name of countries
	has	*p/o*	*C_Certificate_origin_id*	No. of certificate of origins
	has	*p/o*	*D_Fresh_fruits*	Type of exporting fresh fruits
	has	*p/o*	*E_Transportation_mode_id*	Transportation mode
Certificate_exporting	*has*	*a/o*	*Certificate_exporting_id*	No. of certificate of origins
	has	*a/o*	*Certificate_exporting_name*	Name of certificate of origins country
	has	*a/o*	*Description*	Description of certificate of origins
Export_procedure	*has*	*a/o*	*A_Export_procedure_id*	ID no. of export procedure
	has	*a/o*	*B_Export_procedure_name*	Name of each export procedure
	has	*a/o*	*C_Export_document*	Related document of exporting procedure
	has	*a/o*	*D_Evidence_used*	Related evidence of exporting procedure.
	has	*a/o*	*E_Contact_agency*	Contact of agency who do exporting procedure
Export_laws	*has*	*a/o*	*A_Export_laws_id*	ID no. of exporting laws
	has	*a/o*	*B_Laws_name*	Title of export laws
	has	*a/o*	*C_Type_name*	Type of export laws
	has	*a/o*	*Description*	Description of each export laws
Packaging_fresh_fruits_exporting	*has*	*a/o*	*A_Packaging_fresh_fruits_exporting_id*	ID no. of packaging
	has	*a/o*	*B_Packaging_fresh_fruits_exporting_name*	Type of packaging fresh fruits for exporting
	has	*p/o*	*C_Packaging_fresh_fruits_* exporting	Instruction of packaging for exporting fresh fruits
Temperature_fresh_fruits_storage	*has*	*a/o*	*Temp_fresh_fruits_storage_id*	ID no. of temperatures
	has	*a/o*	*Temp_fresh_fruits_storage*	Phase of temperatures for storage of fresh fruits
	has	*p/o*	*Temp_Type_fresh_fruits*	Temperature for storage based on type of fresh fruits
Time_fresh_fruits_storage	*has*	*a/o*	*Time_fresh_fruits_storage_id*	ID no. of time for storage fresh fruits
	has	*a/o*	*Time_fresh_fruits_storage*	Phase of times for storage of fresh fruits
	has	*p/o*	*Time_Type_fresh_fruits*	Time for storage based on type of fresh fruits
Quantity_exporting	*has*	*a/o*	*Quantity_fresh_fruits_exporting_id*	ID no. of quantities for exporting.
	has	*a/o*	*Quantity_fresh_fruits_export*	Quantity of exporting fresh fruits
Transportation_mode	*has*	*a/o*	*Transportation_mode_id*	ID no. of transportation mode
	has	*a/o*	*Transportation_mode_name*	Transportation mode
Common_carrier	*has*	*a/o*	*A_Common_Carrier_id*	ID no. of common carrier
	has	*a/o*	*B_Common_Carrier_name*	Name of common carrier
	has	*a/o*	*Description*	Description of common carrier
Recommendation_exporting	*has*	*a/o*	*A_Rec_exporting_id*	ID no. of exporting recommendation
	has	*p/o*	*B_Fresh_fruits_rec*	Type of recommendation for exporting fresh fruit
	has	*p/o*	*C_Temp_storage_rec*	Recommendation on temperature for fresh fruits storage
	has	*p/o*	*D_Time_storage_rec*	Recommendation on time storage for fresh fruits
	has	*p/o*	*E_Quantity_exporting_rec*	Recommendation on quantity for exporting fresh fruits
	has	*p/o*	*F_Country_rec*	Recommendation on importer country
	has	*p/o*	*G_Common_carrier*	Recommendation on common carrier
	has	*p/o*	*Suggest_transportation_mode*	Recommendation on mode of transportation
Transportation_mode_rec	*has*	*p/o*	*Transportation_mode_rec*	Recommendation on mode of transportation for exporting fresh fruits with the limitation of existing transportation mode

Noted: *a/o* is "Attribute Of."
p/o is "Part Of."

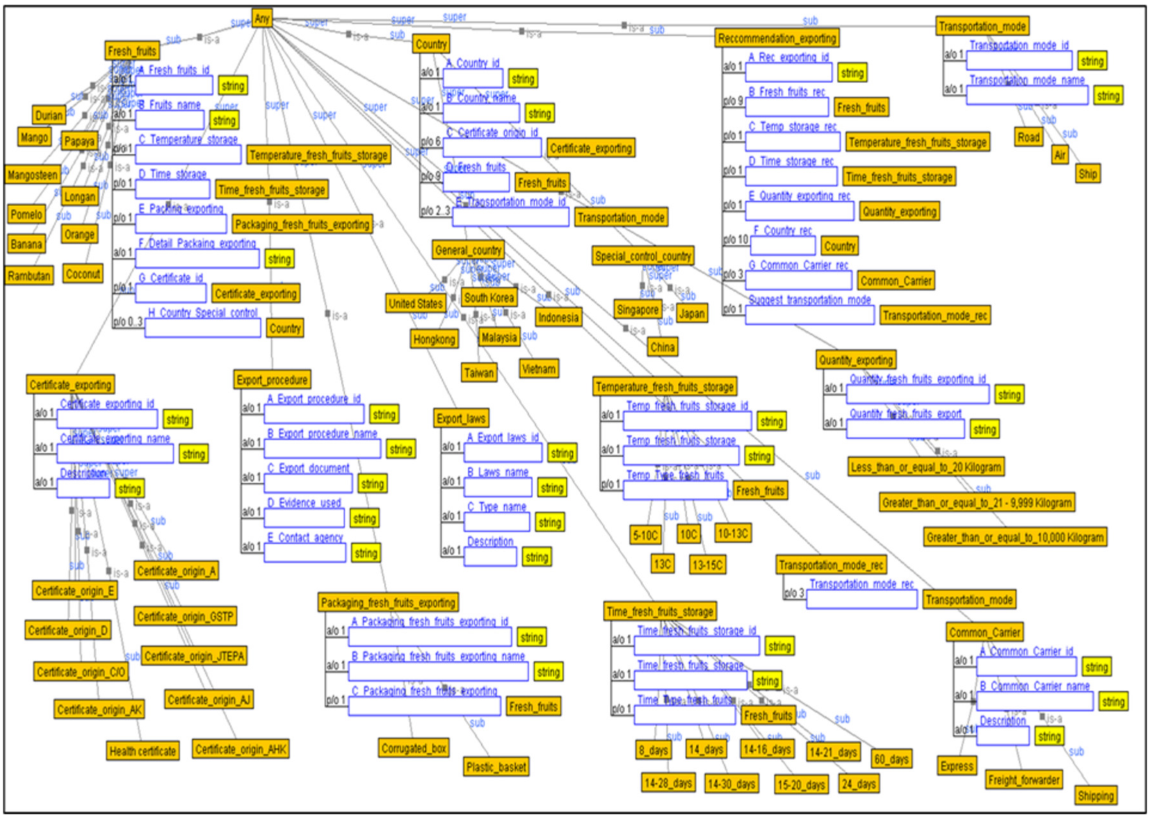

Fig.6: *Exporting the Fresh Fruits Ontology using the Hozo-Ontology Editor.*

compliance, and enhancing market analysis in the fresh fruit export industry.

2) Identify Stakeholders: Identify stakeholders involved in the fresh fruit export process, including exporters, importers, regulatory agencies, agriculturists, distributors, and retailers. The in-depth interview and focus group were used to collect the perspectives and requirements of each stakeholder group to ensure that the ontology adequately represents their needs and concerns.
3) Domain Analysis: Conduct a thorough analysis of the fresh fruit export domain to understand its structure, processes, and critical concepts. Gather domain knowledge from various sources, including domain experts, industry publications, government regulations, trade associations, and academic research. Identify relevant concepts, entities, relationships, and attributes within the domain, such as types of fruits, export regulations, packaging standards, transportation methods, market destinations, and quality assessment criteria.
4) Conceptualization: Based on the domain analysis, conceptualize the ontology by defining its high-level concepts and relationships. Organize the ontology into a hierarchical structure, with top-level concepts representing significant categories within the fresh fruit export domain. Define relationships between concepts using appropriate semantics to capture the interdependencies and associations between different entities.
5) Ontology Design: Design the ontology structure based on the conceptualization, ensuring that it reflects the domain's organization and semantics. Define classes representing different entities in the domain, such as fruit, export processes, regulatory requirements, transportation modes, and market characteristics. Specify properties to describe attributes and relationships between classes, such as "*B_Fresh_fruits_name*," "*Temp_fresh_fruits_storage*," "*B_Laws_name*," etc. Consider using existing ontologies, for example, or standards relevant to the fresh fruit export domain as a basis for ontology design to promote interoperability and reuse of existing knowledge. The Exporting Fresh Fruits Ontology is designed based on the standard of the Department of International Trade Promotion (DITP), Ministry of Commerce, National Bureau of Agricultural Commodity and Food Standards, and Office of Agricultural Economics, Thailand to model export processes, documentation, and regulatory compliance within the ontology is retrieved from their information. Moreover, properties were specif-

ically defined based on the Thai fresh fruit exporting procedure in Fig. 1.

6) Formalization: Choose a formal representation language, such as OWL (Web Ontology Language), to formally specify the ontology's structure, semantics, and constraints. Use the chosen representation language to define classes, properties, individuals, axioms, and logical constraints that comprise the ontology. Ensure the ontology adheres to standard modeling practices and guidelines to maintain consistency, clarity, and interoperability.

In the context of exporting fresh fruit from Thailand, the classification of countries into "General countries" (e.g., the United States, South Korea, Indonesia, etc.) and "Special control countries" (e.g., Singapore, Japan, China) serves a specific purpose in the recommendation management system. Usually, countries are considered instances of a broader class, such as "country." However, in this case, defining individual countries as separate classes instead of instances suggests a deliberate design choice. Defining individual countries as classes instead of instances provides a structured approach to managing different countries' diverse and often complex export requirements. This design enhances the recommendation management system's flexibility, precision, and adaptability, ensuring that each export recommendation aligns with the specific needs and regulations of the target market. For example, an export order of fresh mangoes to Japan could be an instance of the Japan class. In this scenario, the instance would inherit Japan's specific trade rules and recommendations, such as inspection requirements, packaging standards, or logistics advice tailored for exports to Japan.

4.2 Knowledge-Based System of Exporting Fresh Fruit Process

The knowledge-based system for fresh fruit export uses a semantic search system as an interface for showing information. In this study, the Ontology Application Management (OAM) framework has been applied to develop the knowledge-based system. The semantic search system will select the path and conditions for retrieving information. Moreover, this system has an "aggregation function" that groups information by choosing a condition.

4.3 Evaluation of Exporting Fresh Fruits Ontology

Exporting Fresh Fruits Ontology has been evaluated for information retrieval by calculating the F-measure. Three experts on exporting products verify the Exporting Fresh Fruits Ontology. The experts examine keywords for information retrieval from the ontology. The experts discuss the keywords based on the classes through various methods:

- Relevance Check: Experts review the list of extracted keywords to ensure they are relevant to the domain of fresh fruit exporting.
- Completeness Assessment: Experts assess whether the keyword set comprehensively covers all necessary aspects of the domain.
- Contextual Use: Experts evaluate how well the keywords represent the information needed for retrieval in practical scenarios, such as queries related to export processes, regulations, and quality standards.

The evaluation of information retrieval is verified by three values, i.e., precision, recall, and F-measure. Evaluating an ontology for exporting fresh fruits using precision, recall, and F-measure is a common approach for assessing the ontology's effectiveness in accurately representing domain knowledge [16].

Precision: Precision measures the proportion of correctly identified relevant concepts in the ontology compared to all concepts identified by the ontology. In exporting fresh fruits ontology, precision assesses the ontology's ability to accurately capture domain-specific concepts, such as fruit varieties, export regulations, packaging standards, and transportation methods. A high precision score indicates that the ontology contains a high proportion of relevant concepts without including irrelevant or incorrect information. Precision is valuable in ontology evaluation as it emphasizes the ontology's accuracy and correctness in representing domain knowledge.

Recall: Recall measures the proportion of correctly identified relevant concepts in the ontology compared to all pertinent concepts that should have been identified. In exporting fresh fruits ontology, recall assesses the ontology's ability to comprehensively capture all relevant domain concepts without missing any vital information. A high recall score indicates that the ontology effectively covers the breadth and depth of domain knowledge, ensuring that no critical concepts are overlooked. Recall is crucial in ontology evaluation as it highlights the ontology's completeness and comprehensiveness in representing the domain.

F-measure: F-measure is the harmonic mean of precision and recall, providing a balanced assessment of both metrics. It combines precision and recall into a metric that considers the ontology's accuracy and completeness. F-measure is particularly useful in ontology evaluation as it accounts for the trade-off between precision and recall, helping ontology developers find the optimal balance between accuracy and comprehensiveness. A high F-measure score indicates that the ontology balances precision and recall, effectively representing domain knowledge with accuracy and completeness.

These three values are calculated by applying equations (1), (2), and (3) [13, 19, 20].

$$Pricision = \frac{tp}{tp + fp} \quad (1)$$

$$Recall = \frac{tp}{tp + fn} \quad (2)$$

$$F - measure = 2 \times \frac{Precision \times Recall}{Precision + Recall} \quad (3)$$

Where

tp = The number of true positives classified by the ontology.

fn = The number of false negatives classified by the ontology.

fp = The number of false positives classified by the ontology.

From Table 2, the Exporting Fresh Fruits Ontology obtains an average percentage of precision, recall, and F-measure 97.11%, 99.12%, and 97.65%, respectively. The evaluation results show that the Exporting Fresh Fruits Ontology can help improve the correction of searching on a knowledge-based system of exporting fresh fruit process. On the other hand, the system still has some errors in irrelevant results and failure to show relevant results in some concepts such as Fresh fruits, Country, Certificate of exporting, Temperature of fresh fruits exporting, and Time of fresh fruits exporting.

Some errors were observed while evaluating the ontology and the recommendation system, where irrelevant results were shown, and relevant results needed to be included for specific concepts. These issues highlight areas where the system's recommendations or search outputs do not align perfectly with user expectations or intended outcomes.

- Irrelevant Results: Instances where the system suggested concepts, instances, or recommendations that have been not applicable or related to the query or context.
- Missing Relevant Results: Situations where the system failed to display essential or directly relevant concepts that should have been included based on the input or query.

Based on the identified errors, the potential causes of errors may come from the classes' limitations, leading to incomplete ontology coverage. If the ontology does not comprehensively cover all relevant concepts or instances, it may lead to gaps where the system fails to identify or connect relevant information. For example, if a particular fruit variety or export procedure is missing, relevant results may not be shown.

4.4 Evaluation of Knowledge-Based System

The questionnaire is designed to evaluate the knowledge-based system for exporting fresh fruit. It has three aspects: content, searching, and practice. Table 3 presents the results of the evaluation of each element. The sample groups of evaluators are exporters, entrepreneurs, and agriculturists, and the number of evaluators is 35 users.

The evaluation result shows that the content and searching levels are moderately satisfied. For another aspect, the satisfaction level of the practice aspect is moderately satisfied until very satisfied.

5. CONCLUSION

The main contribution of this study is developing a knowledge-based system for exporting fresh fruit.

Table 2: *The results of the information retrieval evaluation.*

Class name	*Output*	tp	fn	fp	Precisions (%)	Recall (%)	F-measure (%)
Fresh_fruits	Type of Fresh fruit	131	4	0	97%	100%	98%
Country	Country of destination	923	2	25	92%	92%	92%
Certificate_exporting	Certificate of origin	10	3	0	93%	100%	95%
Export_procedure	Export procedure	171	0	0	100%	100%	100%
Export_laws	Exporting law and regulation	30	0	0	100%	100%	100%
Packaging_fresh_fruits_exporting	Type of packaging of fresh fruits for exporting	20	0	0	100%	100%	100%
Temperature_fresh_fruits_storage	Temperature of fresh fruits for exporting	20	2	0	88%	100%	92%
Time_fresh_fruits_storage	Time of fresh fruit for exporting	19	1	0	97%	100%	98%
Quantity_exporting	Quantity of exporting	3	0	0	100%	100%	100%
Transportation_mode	Transportation mode	3	0	0	100%	100%	100%
Common_carrier	Common carrier	3	0	0	100%	100%	100%
Recommendation_exporting	Recommendation necessary information for exporting fresh fruit	849	0	0	100%	100%	100%
Transportation_mode_rec	Existing transportation mode	-	-	-	-	-	-
Average (%)					97.11%	99.12	97.65

Table 3: *The result of satisfaction evaluation for the knowledge-based system in the domain of the export process.*

Items	Mean	S.D.
Comprehensive Content		
The contents on the domain of the export process are covered.	4.37	0.48
The contents relate to the current situation.	4.49	0.50
The user interface is easy to use.	3.57	0.68
Searching for information		
The display on the application is proper.	4.26	0.66
Information has met the requirement of users.	4.31	0.55
Implementation		
The knowledge-based system can facilitate the searching information to users	4.46	0.68
The knowledge-based system will be taken for implementation in the export	4.57	0.56
Average	4.22	0.59

Firstly, an ontology for exporting fresh fruits has been constructed as the backbone of the knowledge-based system. The ontology of exporting fresh fruits consists of 12 main classes covering the knowledge of exporting fresh fruits. Secondly, mapping between entities in a relational database schema and exporting fresh fruits ontology. It captures semantic information contained in the structures of the entities based on virtual documents and eliminates incorrect mappings by validating mapping consistency. Finally, an ontology for exporting fresh fruits was experimentally evaluated on several data sets from real-world domains. The results demonstrate that the ontology of exporting fresh fruits performs well in the average value of F-Measure, which is equal to 0.98. Evaluating the knowledge-based system for exporting fresh fruit process shows that the satisfaction score is more than 3.50, which means moderately satisfied. Besides, the results also show that the contextual mappings constructed by the knowledge-based system for exporting fresh fruit are helpful in supporting new entrepreneurs and agriculturists unfamiliar with the exporting procedure.

In addition, evaluating a knowledge-based system for exporting fresh fruit ontology requires a multi-dimensional approach encompassing accuracy, completeness, usability, interoperability, performance, decision support effectiveness, and business impact. By employing appropriate evaluation methods and drawing insights from relevant literature, stakeholders can assess the knowledge-based system's overall quality and effectiveness in supporting fresh fruit export operations. Therefore, the improvement area of a knowledge-based system for exporting fresh fruit ontology must be considered by employing the evaluation results from a multidimensional approach, which is mentioned.

A knowledge-based system's limitations are indeed restrictive and could pose challenges for future adjustments. To ensure the system remains flexible, adaptive, and less prone to obsolescence, it's essential to consider alternative approaches that allow for variability and dynamic updates. The system's limitations would enhance its resilience and maintain its effectiveness in providing accurate and contextually relevant recommendations.

In the future, the knowledge-based system for exporting fresh fruit will be compared with benchmarking criteria. Moreover, some machine learning techniques for mining other interesting and useful semantic mappings will be considered. Finally, a user-friendly interface should be developed to help users explore the needed information easily.

RELATIONSHIP TO THESIS

The research presented in this paper builds upon the findings of the master thesis titled "The Development of Supporting System for Exporting Thai Cargo: A Case Study of Thai Fresh Fruit," which was completed at Naresuan University in 2021. Specifically, the experimental framework and initial data analysis described in Chapters 3 and 4 of the thesis served as the foundation for the current study. While some aspects of the methodology and results overlap with the thesis, this manuscript presents novel insights and expanded analyses not previously included.

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AUTHOR CONTRIBUTIONS

Conceptualization, Thanisorn Tangarommun and Klairung Ponanan; methodology, Thanisorn Tangarommun; generating ontology domain, Thanisorn Tangarommun; validation, Thanisorn Tangarommun and Klairung Ponanan; formal analysis, Nattapon Kumyaito and Klairung Ponanan; investigation, Thanisorn Tangarommun and Nattapon Kumyaito; data curation, Thanisorn Tangarommun; writing—original draft preparation, Thanisorn Tangarommun; writing—review and editing, Thanisorn

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References

[1] Department of International Trade Promotion, "The exporting process of vegetable and fresh fruits; OSEC," 2023. [Online]. Available: https://onestopservice.ditp.go.th/exportlist/26.

[2] R. Mizoguchi, "Part 1: Introduction to ontological engineering," *New generation computing*, vol. 21, pp. 365-384, 2003.

[3] T. Berners-Lee, J. Hendler and O. Lassila, "The semantic web. Scientific American: A new form of Web content that is meaningful to computers will unleash a revolution of new possibilities," *Scientific American*, vol. 284, no. 5, pp. 1-4, 2001.

[4] D. L. McGuinness and F. Van Harmelen, "OWL web ontology language overview; W3C recommendation," 2023. [Online]. Available: https://www.w3.org/TR/2004/REC-owl-features-20040210/$\sharp$s1.

[5] L. W. Lacy, "OWL: Representing information using the web ontology language," in *Ontologies Enablers of the Semantic Web*, Trafford Publishing, 2005, pp. 25-42.

[6] D. L. McGuinness, "Ontologies Come of Age," *Spinning the Semantic Web: Bringing the World Wide Web to Its Full Potential*, MIT Press. pp. 1341-1931, 2005.

[7] A. Takhom, M. Ikeda, B. Suntisrivaraporn and T. Supnithi, "Toward Collaborative LCA Ontology Development: A Scenario-Based Recommender System for Environmental Data Qualification," in *29th International Conference on Information for Environmental Protection (EnviroInfo 2015) Third International Conference on ICT for Sustainability (ICT4S 2015)*, Copenhagen, Denmark, Atlantis Press, pp. 157-164, 2015.

[8] M. Buranarach *et al.*, "A community-driven approach to development of an ontology-based application management framework," *Semantic Technology*, Springer Berlin Heidelberg, Berlin, pp. 306–312, 2013.

[9] A. Onal, S. Otles and I. Seylan, "A Concept Distance Leaning Architecture using Semantic Web based Multi-Agent System," *Logfurum*, vol. 3, no. 1, pp. 1-8, 2007.

[10] B. Marut *et al.*, "OAM: an ontology application management framework for simplifying ontology-based semantic web application development. OAM: an ontology application management framework for simplifying ontology-based semantic web application development," *International Journal of Software Engineering and Knowledge Engineering*, vol. 26, no. 1, pp. 115-145, 2016.

[11] W. Bangkhomned and J. Payakpate, "Applying Ontology Knowledge Representation Technology and Semantic Searching Methods to Support the Production of High Quality Longan Fruit," in *Information Science and Applications: ICISA 2019*, Springer Singapore, pp. 601-612, 2020.

[12] Control Device Division, Enegate Co, ltd. Mizoguchi Laboratory, The Institute of Scientific and Industrial Research, Osaka University. 2011, Hozo Ontology Editor (Distributed Development Version) Operating Manual.

[13] P. Taophan and P. Meesad, "An Ontological Content-Based Filtering for Book Recommendation," *International Journal of the Computer, the Internet and Management*, vol. 25, no. 1, pp. 75-82, 2017.

[14] N. Kaewboonma, T. Supnithi and J. Panawong, "Developing ontology for Thai Zingiberaceae: From taxonomies to ontologies," *2017 14th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON)*, Phuket, Thailand, pp. 596-599, 2017.

[15] P. Visutsak, "Ontology-Based Semantic Retrieval for Durian Pests and Diseases Control System," *International Journal of Machine Leaning and Computing*, vol. 1, no. 11, pp. 92-96, 2021.

[16] N. Rastogi, P. Verma and P. Kumar, "Evaluation of Information Retrieval Performance Metrics using Real Estate Ontology," *2020 Third International Conference on Smart Systems and Inventive Technology (ICSSIT)*, Tirunelveli, India, pp. 102-106, 2020.

[17] P. Visutsak, "Ontology-based semantic retrieval for durian pests and diseases control system," *International Journal of Machine Learning and Computing*, vol. 11, no.1, pp.92-97, 2021.

[18] A. Islam and D. Inkpen, "Semantic Text Similarity Using Corpus-Based Word Similarity and String Similarity," *ACM Transactions on Knowledge Discovery from Data*, vol. 2, no. 2:10, pp. 1-25, 2008.

[19] N. F. Noy and D. L. McGuinness, "Ontology development 101: A guide to creating your first ontology," *Semantic Scholar*, pp. 1-25, 2001.

[20] P. Wiangnak and A. Trongratsameethong, "Automated Knowledge Integration from Heterogeneous Data Sources Using Text Analytics: A Case Study of COVID-19," *ECTI Transactions on Computer and Information Technology (ECTI-CIT)*, vol. 17, no. 4, pp. 533–543, 2023.

Thanisorn Tangarommun is a researcher in the Faculty of Logistics and Digital Supply Chain at Naresuan University, Thailand. He holds a B.Eng. degree in Logistics Engineering from Pibulsongkram Rajabhat University, Thailand, and an M.Eng. in Logistics and Supply Chain from Naresuan University, Thailand. His interests include Semantic Web development based on ontological engineering, as well as logistics and supply chain management.

Klairung Ponanan is a lecturer in the Faculty of Logistics and Digital Supply Chain at Naresuan University, Thailand. She holds a B.Eng. degree in Civil Engineering and an M.Eng. in Civil Engineering (Transportation Engineering) from Naresuan University, Thailand. She studied in the fields of transportation engineering and urban planning. She obtained her doctoral degree from the Graduate School of Engineering at Muroran Institute of Technology, Japan. Her research focuses on urban transportation planning and information systems for supply chain management.

Nattapon Kumyaito is lecturer in Department of Computer Science and Information Technology, Naresuan University, Thailand. He holds a Ph.D. in Information Technology, with expertise in artificial intelligence, machine learning, and optimization algorithms. His research focuses on applying AI techniques to areas like sports training, water resource management, and music generation. He has published widely in international journals and conferences, with contributions in adaptive particle swarm optimization and genetic algorithms for decision-making systems.