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BROTH: The Broad Recommender Ontology for Thai Herbs

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ABSTRACT

With Thailand rapidly embracing digital technology, this paper explores how to bridge the gap between traditional Thai herbal remedies and modern healthcare practices. Thai herbs possess a vast array of medicinal properties, from anti-inflammatory and antimicrobial to antioxidant and pain-relieving. This research introduces the Broad Recommender Ontology for Thai Herbs (BROTH), a comprehensive database designed to encompass various aspects of these herbs. BROTH incorporates botanical data, local Thai names, medicinal uses, recommended plant parts, preparation methods, and even local market availability. Furthermore, a smartphone application utilizing BROTH has been developed as a recommender system. Users can search for herbs in Thai using text or voice recognition. The app then connects them with local vendors selling the desired herbs. This project aims to achieve a dual benefit: improving the health of Thai citizens, particularly the elderly, while simultaneously supporting local herb farmers. The System Usability Score (SUS) administered to 75 users resulted in a score of 83.6, which shows high usability. The BROTH recommender system has the potential to positively impact both public health and local businesses in Thailand.

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Keywords: Thai Herb Ontology, Recommender System, Farming Business, Business-customer Relationship

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1. INTRODUCTION

Thai herbs have been an integral part of traditional medicine in Thailand for centuries, offering a holistic and natural approach to health and well-being [1]. The rich biodiversity of Thailand, combined with ancient knowledge passed down through generations, has contributed to a diverse range of herbs that have immense potential for therapeutic applications [2]. As the people embrace the digital age, it becomes increasingly important to use technology and bridge the gap between traditional remedies and modern healthcare practices [3]. For example, [4] presented an ontology, which mainly expressed knowledge about contraindications of certain herbs. They tested their system with three different scenarios and found it useful and applicable. Ontologies were also proposed to extract the knowledge of older Thai texts on medicine [5] available as palm leaf manuscripts. This ontology consists of 12 classes, including Herb, Test, Preparation, Pharmacy, Method, Effect, Caution, Spell, Symptoms, among others.

The recommendation of Thai herbs for specific ailments has historically faced challenges due to the complexity of traditional knowledge and limited scientific integration. Smartphone applications present a promising solution by offering accessible and user-friendly platforms for consolidating information on Thai herbs, their traditional applications, and emerging scientific evidence. These platforms can integrate data on diseases and symptoms to generate personalized and evidence-based recommendations for Thai herbal use as complementary or alternative therapies. Users benefit from reliable information access, usage tracking, herb-related event notifications, and even connections to local markets for sourcing authentic herbs.

Illustrating this motivation, Kato *et al.* (2010) developed a health advice system using semantic web

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technology in conjunction with Thai herbal ontology, which can give advice on appropriate herbs for the treatment of various symptoms or diseases, and match the users tastes using information from the herbal database. [4] Promkot *et al.* (2019) presented a similar ontology. Their approach was mainly driven by expressing knowledge about contraindications of certain herbs, and they tested their product with three different scenarios to find it useful and applicable. Ontologies were also proposed to extract the knowledge of older Thai texts on medicine [5] (Chamnongsri, 2019).

All of these approaches lack the broader perspective of business connections in the marketing efforts of local farmers. Furthermore, the systems that apply these ontologies do not provide access by speech-to-text. To design and develop applications for knowledge search, recommendation of treatment and health care, and herbal business into marketplaces with Thai herbs on smartphones, we used React Native, which supports both Android and iOS. In this paper, we focus on the application's functionality rather than on its development process.

To empower users with a more intuitive and accessible experience, the project seeks to augment the developed application with voice-based search and recommendation functionalities. This will be achieved by integrating the comprehensive Ontology of Thai Herbs with advanced Voice Recognition and Speech Synthesis technologies. Through natural language voice commands, users can seamlessly navigate the application and acquire personalized herbal information or advice.

Building upon the work of Namahoot, Sivilai, and Brückner (2016), this novel Thai herbal ontology focuses on the symptomatic rehabilitation of common diseases. Designed for a smartphone platform, it caters to the elderly and healthcare professionals, aiming to promote the integration of Thai herbal medicine into broader healthcare markets.

2. RELATED WORKS

To address the challenges in recommending Thai herbs to customers with specific diseases, the use of smartphone applications can offer an accessible and user-friendly solution. These apps can serve as comprehensive digital platforms, consolidating information on Thai herbs, their traditional uses, and emerging scientific evidence. By integrating data on diseases and symptoms, such apps can provide tailored recommendations for Thai herbs, ensuring personalized and evidence-based suggestions for users. Thai herbs have a long history of use as complementary or alternative treatments. Users can access reliable information, track their herb usage, receive notifications for herb-related events, and even connect with local markets to source authentic Thai herbs.

The local markets for Thai herbs in Thailand build a valuable source of traditional remedies [12]. By leveraging smartphone applications, we can bridge the gap between traditional knowledge and modern healthcare, offering customers personalized recommendations for Thai herbs based on their specific benefits [13]. Embracing technology in this way not only ensures the preservation and accessibility of traditional wisdom but also paves the way for innovative approaches to a more holistic healthcare in the digital age.

Furthermore, The application of Thai herbal medicine in treating health issues attracts tourists interested in alternative wellness practices. Herbal Tourism plays an increasing role in some regions of Thailand [14], [15]. Local communities can generate reasonable income from herbal tourism. Besides the medical sector, this kind of tourism has also been stimulated by cosmetic applications of Thai herbs [16]. Herbal tourism is a type of tourism that focuses on the use of herbs for health and wellness. In Thailand, herbal tourism is a growing industry, as the country has a long history of using herbs for medicinal purposes. There are many different types of herbal tourism experiences available in Thailand. Visitors can visit herbal gardens, learn about the medicinal properties of herbs, and even take part in traditional herbal treatments. Some popular destinations for herbal tourism in Thailand include

- Chiang Mai: Chiang Mai is known as the "Rose of the North" and is a popular destination for herbal tourism. There are many herbal gardens and spas in Chiang Mai, as well as opportunities to learn about traditional Thai herbal medicine.
- Phuket: Phuket is a popular tourist destination with a tropical climate. There are several herbal gardens and spas on Phuket, as well as opportunities to learn about traditional Thai herbal medicine.
- Koh Samui: Koh Samui is a popular island destination with a laid-back atmosphere. There are several herbal gardens and spas on Koh Samui, as well as opportunities to learn about traditional Thai herbal medicine.

For many tourists, herbal tourism is an attractive way to experience Thai culture and learn about the country's rich history of herbal medicine. Moreover, when they are looking for a unique and authentic travel experience, herbal tourism in Thailand is a great option [17].

3. ONTOLOGY AND SYSTEM DESIGN

3.1 Dataset

The Herb Ontology should be designed to maximize community use and support functionalities related to herb knowledge, treatment, and business aspects of the developed platform. The herb ontology has been described in OWL, see the following snippets covering Classes, Sub Classes, and Properties.

Classes:
Herb
Distal Class of ThaiHerb
ThaiHerb
Definition as an herb that is used in Thai cuisine for its medicinal properties.
SubClasses of ThaiHerb:
* Galangal
* Kaffir lime leaves
* Lemongrass
* Holy basil
* Makrut lime
* Moringa
* Peppercorns
* Shallots
* Thai chili peppers
* Turmeric
Properties:
hasMedicinalProperty
Domain: ThaiHerb
Range: Property
hasTaste
Domain: ThaiHerb
Range: Taste
hasUseConsistency
Domain: ThaiHerb
Range: UseConsistency
hasUseMenu
Domain: ThaiHerb
Range: UseMenu
hasUsePart
Domain: ThaiHerb
Range: UsePart
hasUseUsage
Domain: ThaiHerb
Range: UseUsage
The hasUsePart property can be used to indicate the part of the herb that is used, such as the leaf, root, stem, flower, seed, or fruit. ThehasUseUsage property can be used to indicate the way in which the herb is used, such as for
treatment, food, or cosmetic purposes. Data:
Galangal
hasMedicinalProperty: Relieves
pain and inflammation
hasTaste: Peppery
hasUseConsistency: Can be used fresh, dried, or powdered.
hasUseMenu: Can be added to soups, stews, and stir-fries.
hasUsePart: Root
hasUseUsage: Treatment and food
Kaffir lime leaves
hasMedicinalProperty: Boosts the immune system and reduces stress.
hasTaste: Citrusy
hasUseConsistency: Can be used fresh or dried.
hasUseMenu: Can be added to soups, stews, and curries.
hasUsePart: Leaf
hasUseUsage: Food
Lemongrass
hasMedicinalProperty: Aids
digestion and relieves muscle pain
hasTaste: Lemony
hasUseConsistency: Can be used
fresh, dried, or powdered.
hasUseMenu: Can be added to soups, stews, and stir-fries.
hasUsePart: Stem
hasUseUsage: Treatment and food
Holy basil
hasMedicinalProperty: Reduces blood pressure and improves circulation
hasTaste: Peppery, minty
hasUseConsistency: Can be used
fresh or dried.
hasUseMenu: Can be added to soups, stews, and stir-fries.
hasUsePart: Leaf
hasUseUsage: Food
Makrut lime
hasMedicinalProperty: Boosts the
immune system and reduces stress
hasTaste: Citrusy
hasUseConsistency: Can be used
fresh or dried.
hasUseMenu: Can be used to add aroma to dishes.
hasUsePart: Fruit
hasUseUsage: Food
Moringa
hasMedicinalProperty: Boosts the immune system and
reduces inflammation
hasTaste: Bitter
hasUseConsistency: Can be used
fresh or dried.
hasUseMenu: Can be added to soups, stews, and stir-fries.
hasUsePart: Leaf
hasUseUsage: Food
Peppercorns
hasMedicinalProperty: Aids
digestion and relieves pain
hasTaste: Spicy
hasUseConsistency: Can be used
fresh or dried.
hasUseMenu: Can be added to soups, stews, and stir-fries.
hasUsePart: Fruit
hasUseUsage: Food
Shallots
hasMedicinalProperty: Boosts the immune system

and
reduces inflammation
hasTaste: Garlicky
hasUseConsistency: Can be used fresh or dried.
hasUseMenu: Can be added to soups, stews, and stir-fries.
hasUsePart: Bulb
hasUseUsage: Food
Thai chili peppers
hasMedicinalProperty: Boosts the immune system and
reduces inflammation
hasTaste: Spicy
hasUseConsistency: Can be used
fresh or dried.
hasUseMenu: Can be added to soups, stews, and stir-fries.
hasUsePart: Fruit
hasUseUsage: Food
Turmeric
hasMedicinalProperty: Reduces
inflammation and relieves pain
hasTaste: Earthy
hasUseConsistency: Can be used
fresh or dried.
hasUseMenu: Can be added to soups, stews, and stir-fries.
hasUsePart: Root
hasUseUsage: Treatment, Food

The herb features are information extracted from the Herb ontology, and they can be used in the BROTH such as follows: Herb name, type, scientific name, family/lineage, common name, local names, local sources suitable environment, suitable season, description, properties / benefits: (common, roots, leaves, flowers, fruits, seeds), method and amount used (how to use), objective (food, cosmetic, treatment), marketplace (b2b, b2c, bbc), picture and location of herb. For example, holy basil 's feature and information can be shown as:

Herb name: holy basil (Queen of Herbs)
Type: red basil; white basil
Scientific name: Ocimum tenuiflorum
Family/lineage: LABIATAE

Common name: Holy basil, Thai basil, Sacred basil (is called ka-prao in Thai)

Local names: Kom Ko (Chiang Mai province) and Hor-gua-su (Mae Hongson province) are called in the North of Thailand, Im Kim Lam and E tu ka, E-tu-Thai in the central and the Northeast of Thailand

Found source: All over, Northeast, North, Central suitable environment: Grows well in all soil types.

Suitable season (all seasons)

Description: square stems with leaves that grow on opposite sides, and the leaves are rounded, slightly cupped, and curve to form a point at the tip. The leaves are generally light green, although some varieties have reddish or purplish leaves.

Properties / benefits: (common,

Roots: The dried roots are brewed or boiled with hot water for drinking. Cure elemental disabilities

Leaves: Expel wind to relieve stomach pain, defecation, cure colic, and relieve nausea, vomiting, and dysentery.

Stem: The whole tree extract reduces intestinal peristalsis, can treat stomach ulcers

Excrete bile, help digest fat, and reduce chest pain.

Flowers: -

Fruits: -

Seeds: Soaking the seeds will swell into a white slime that is then used to mask the eyes when the eyes have powder or dust. That powder or dust will come out, which will not cause our eyes to bruise as well.

Method and amount used (how to use): Used to cook a variety of Thai dishes, which must be selected only for the leaves. Red basil has a more pungent smell than white basil.

Objective: (food, cosmetic, treatment)

Marketplace (b2b, b2c)

Picture and location: nearby

3.2 System design

The Thai herb ontology serves as the foundation for BROTH's functionalities, categorized into three main areas: knowledge retrieval, treatment recommendation, and business-oriented information access.

BROTH is designed as the initial version covering the Phitsanulok Province, see 3.3 Data sources. It will be extended to such provinces and localities in Thailand as Chiang Mai, Phuket, and Koh Samui.

We have based the knowledge base of BROTH on the following seven principles, which cover herbal knowledge, treatment, and business:

1. Use standard and precise information.

2. Use identifiable and unambiguous herb names: Different names may refer to a specific herb or a specific name may refer to different herbs. Most herbs have synonymous or duplicate names, including local names. The scientific name and, therefore, The unique scientific name of each plant of each plant has been used as a nomenclature to prevent confusion.

3. Correct part and condition: 1)which part of herbs must be used, such as root, flower, leaf, bark, stem, fruit, and seed, and 2) the herb characteristic, such as ripeness, maturity, young, rawness of the herb may have the same or different chemical constituents or active substances.

4. Right amount: 1) size and amount, 2) age range, and 3) duration of use. Many herbal medicines are not dangerous, but the amount / size of the overdose can cause harm to the body or the effect of treatment,

especially in young children who are less tolerant than adults and the period of use.

5. Applicable preparation method: 1) how to, such as eat, rub, poultice (mask), soak, 2) how to prepare such as boiled, brewed, baked, stew, preserved and extract etc. The use of herbs correctly according to the principle; for example, some species require fresh plants, juiced, boiled, brew with water, cooked food, dry and bake, eaten fresh or pickled with alcohol, etc. For example, a sore throat can be soothed by ginger. The recommended method is to consume fresh ginger or sliced ginger boiled in water, then sip the resulting tea.

6. Effective disease or symptom treatment: which herb can cure which disease or symptom? Refers to the right herb for the right disease and symptoms, which herb is unfavourable for which disease?

7. Recommend appropriate suppliers: herbs can be matched with the right marketplace, such as B2B, B2C, B2B2C. The future growth of the Thai herbal business depends on sustainable practices. This will allow for production upgrades, leading to increased value and differentiation throughout the industry. Importantly, this includes a focus on fairly distributing the added value to upstream participants, particularly farmer groups. The main things that should be accelerated are: 1) a production system that produces high-volume and high-quality products, such as growing organic herbs, or planting in a plant factory to create opportunities to be used as raw materials for production in advanced industries both in the domestic and export markets, and 2) increasing sales opportunities through creating support markets for manufacturers, such as joining hands with major entrepreneurs in product research and development or making a joint marketing plan to acquire products or distribution channels in order to enter the broader consumer market, etc. BROTH can deal with the best business choice for type of user.

Therefore, the system has been designed to satisfy the aforementioned principles of knowledge, treatment, and business, which are based on the seven principles in the pattern of the Herb ontology and can be integrated with speech recognition and a digital platform for ease of use as shown in Fig. 1.

• Users enter such personal information as gender, age, and topics (treatment, business) for data analytics.

• The system offers three key functionalities: *Treatment Recommendation.* Users can input speech commands indicating a specific symptom or disease. BROTH then recommends appropriate Thai herbs based on its knowledge base.

Herb Knowledge Retrieval. By saying the name of a particular herb or uttering "all herbs," users can retrieve comprehensive data about the identified herb(s) from BROTH's extensive repository.

Business-Oriented Information Retrieval. Leveraging

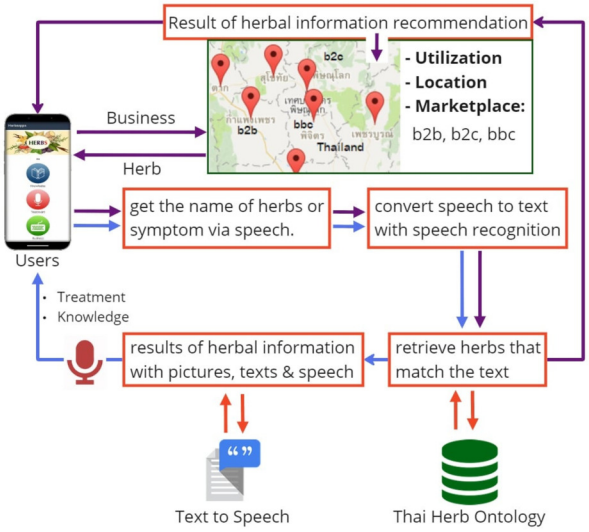

Fig. 1: *Architecture of BROTH.*

both speech and text input, users can query the system for herb information relevant to business purposes (B2B, B2C, B2B2C). This includes details such as cultivation area (in rai, being 1,600 m^2/rai), utilization aspects, and location data with map integration for navigation.

• BROTH employs speech recognition technology to convert user queries into text. This text is then utilized to search and retrieve relevant herb information from the comprehensive Thai herb ontology. The retrieved information encompasses pictures, text descriptions, and even spoken information (potentially for audio playback), providing users with a rich and multifaceted knowledge base on medicinal properties and treatment applications. The system shows results of herbal information recommendations for business functions, which contain herb utilization (foods, cosmetics, and treatment), location with map, and marketplace (B2B, B2C, B2B2C).

The benefits of using Thai herbs for medical treatment:

• much cheaper than using new drugs (modern medicine)

• most herbs are food with healthy side-effects

• no need to buy, can be planted at home

• suitable for most people because they can be served with the appropriate preparation method

• reduce the negative trade balance when ordering drugs from abroad

• make people aware of the value of homegrown plants

• encourage people to help themselves with the use of traditional herbs.

The development of BROTH benefitted greatly from a rapid prototyping process. This iterative approach allowed for early user feedback and continuous improvement of the system's usability and functionality.

A breakdown of the process in three steps:

• Paper Prototyping and User Testing: We started with low-fidelity prototypes using paper mockups. This allowed us to define core functionalities, gather user feedback on user interface design and interaction flow, and refine the system before investing in complex development.

• Digital Prototype and Usability Testing: We moved on to a mid-fidelity digital prototype with basic functionalities like speech recognition and text-based interaction with the herb ontology. This stage focused on testing core user flows, refining the interface, and identifying such usability issues as missing or incorrect herb data.

• High-Fidelity Prototype and Comprehensive Testing: Finally, we developed a feature-rich prototype with functionalities like speech output and integration with the knowledge base. This allowed us to test more complex user experiences and conduct more thorough testing with a larger group of users.

3.3 Data sources

The main data source for Thai herbs used in BROTH is the central database from the Office of Agricultural Economics. According to this database, there are 162 registered herbal growers in Phitsanulok, covering a total area of 1,376.81 rai. The main types of herbs grown are listed in Table 1.

Table 1: *Herbal crop cultivation by farmers in Phitsanulok province.*

No.	Herb Type	No. of Farmers	Area (rai)	Districts
1	Black Pepper	110	987.75	Nakhon Thai, Wang Thong, Noen Maprang, Mueang Phitsanulok, Phrom Phiram, Bang Rakam, Chat Trakan
2	Agarwood	4	74.19	Nakhon Thai, Wang Thong, Bang Rakam
3	Noni	4	67.52	Nakhon Thai, Phrom Phiram, Wang Thong
4	Black Galingale	10	39.38	Chat Trakan, Bang Krathum, Nakhon Thai, Phrom Phiram, Wang Thong
5	Citronella	5	33.83	Wang Thong, Phrom Phiram, Mueang Phitsanulok
6	Cassumunar Ginger	4	33.26	Nakhon Thai, Wang Thong
7	Turmeric	4	30.62	Nakhon Thai, Bang Krathum
8	Roselle	4	25.13	Wang Thong, Nakhon Thai, Mueang Phitsanulok
9	Green Chiretta	1	14.96	Phrom Phiram
10	Betel Leaf	4	11.73	Bang Krathum, Mueang Phitsanulok
11	Bitter Melon	1	7.03	Bang Krathum
12	Asiatic Pennywort	1	3.78	Mueang Phitsanulok
13	Sappan Wood	1	3.00	Nakhon Thai
14	Curcuma Zedoaria	1	3.00	Wang Thong
15	Thunbergia	1	2.82	Bang Krathum
16	Clove	1	2.00	Bang Rakam
17	Long Pepper	1	2.00	Nakhon Thai
18	Butterfly Pea	1	0.75	Mueang Phitsanulok
19	Other Herbs	4	34.08	Chat Trakan, Bang Krathum
	Total	162	1379.81	

The ontology data relating to medicinal properties of the herbs are based on the most reliable sources on Thai herbs available [31-32].

4. RESULTS AND DISCUSSION

This section details the results of the design-and-creation process, followed by a discussion of the strengths and benefits of BROTH as well as its challenges and limitations.

The BROTH platform consists of three main interfaces (Figure 2). Users either click on the button or can say the words according to the main interfaces such as “Treatment”, “Business” and “Knowledge”, then users will be guided to each page for usage (Figures 3, 4, and 5). The platform is designed for ease of use and suitability for all users especially users who have no experience or no background of computer technology. The recommendation is shown after only two clicks or speech inputs by users Fig. 2-5.

Figure 3 shows the interface of the Knowledge page where users just just say the name of the herb to search for related data of specify herb, for example, “ (pronounced as “kra-prao” in Thai, ‘holy basil’) in Fig. 3a, or saying “all herbs” for searching all herbs that exist in the herb ontology. The result of knowledge searching is shown in Fig. 3b for holy basil knowledge and Figure 3c for all herb knowledge, respectively. Figure 3b shows the knowledge of Holy basil as described in the Thai herb ontology, such as type, scientific name, family, other name, found source, description, benefit etc. Figure 3c shows the list of all herbs (i.e., finger root, okra, water mimosa, garlic, Chinese cabbage, and holy basil) in the Thai herb ontology that users can select specific one from Figure 3b for finding further information, and the results are presented in the same format as Fig. 3b.

Figure 4 shows the interface of the Treatment page in which users just type symptom or disease (allowed only one symptom or disease at a time) for treatment recommendation such as ” (pronounced as jep khø in Thai, which means “sore throat” in English) in Fig. 4a-b shows the result of treatment with recommended herbs (ranking in Thai alphabet order such as ก้านพู (clove), กระเทียม(garlic), ขิง (ginger), ขมิ้น(turmeric), etc.), which can cure the symptom of sore throat (correct herb). Users can select herbs by any name, for example, by saying (Ginger) or clicking on the herb name to see more information on how to cure sore throat with ginger. The result of sore throat treatment with ginger is shown in Fig. 4c, as the part of ginger used is rhizome (appropriate part), the method is to eat fresh or slice it to boil with water and sip (appropriate method) and food menus such as fried pork with ginger and products (ginger power) made from ginger are recommended.

Similarly, Figure 5 shows the result of disease treatment for โรคกระเพาะ(pronounced as “rōk kraphó,” ’gastritis’), which users can input via voice (Fig. 5a). The system displayed recommended herbs (such as cabbage, okra, banana, turmeric, and other appro-

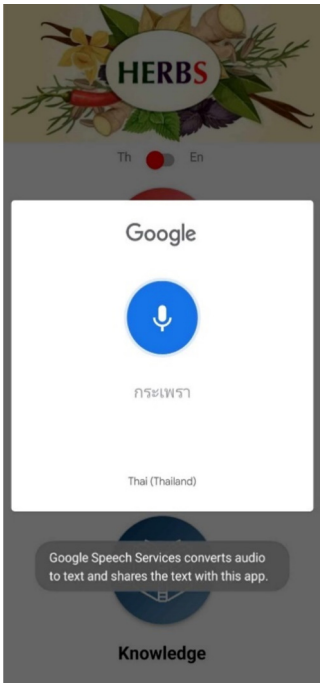

Fig.2: *Main BROTH interface with choice for typing and typing.*

Fig.3 *(b)*

Fig.3 *(a)*

Fig.3 *(c)*

Fig.3: *Interface of the Knowledge page.*

Fig.4 *(a)*

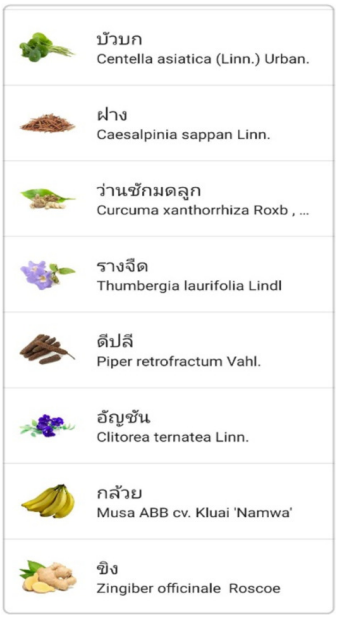

Fig.4 *(b)*

Fig.4 *(c)*

Fig.4: *Interface of treatment page(example: sore throat).*

priate products) that can cure this kind of disease (Fig. 5b). Again, the users can select any herb name by saying " กล้วย " (pronounced as "Kluai" which means "banana") or clicking at this herb name (banana) to see further information how to cure the Gastritis with banana, and the result of Gastritis treatment with banana can be shown in Fig. 5c such as part of banana used (raw banana whole peel), and the method is identified as follows: firstly, "Slice raw banana (whole peel) dry or bake at temperature <50° C and then ground into powder and brew with drinking water". Second, Use 2 tablespoons (correct amount) at the time, mix with a glass of water, drink after dinner.

Figure 6 shows the interface of the business page, on which users say the name of the herb "กระเพรา" (pronounced as "kra-prao" in Thai, "holy basil" in English) in Fig. 6a. The results of the location where

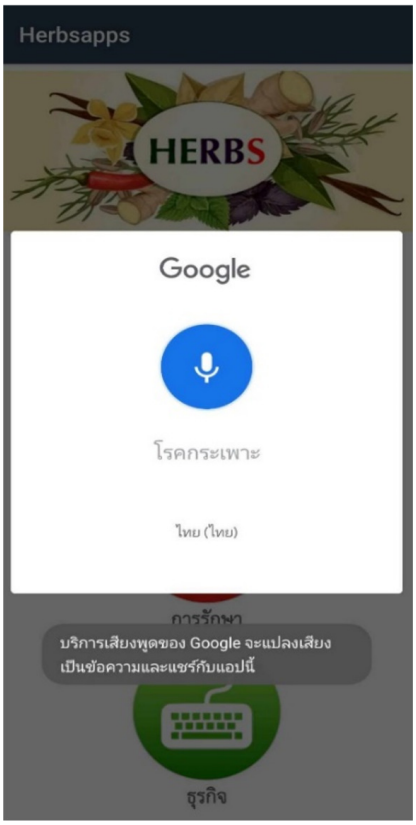

Fig.5 *(a)*

Fig.5 *(b)*

Fig.5 *(c)*

Fig.5: *Interface of treatment page(example: sore throat).*

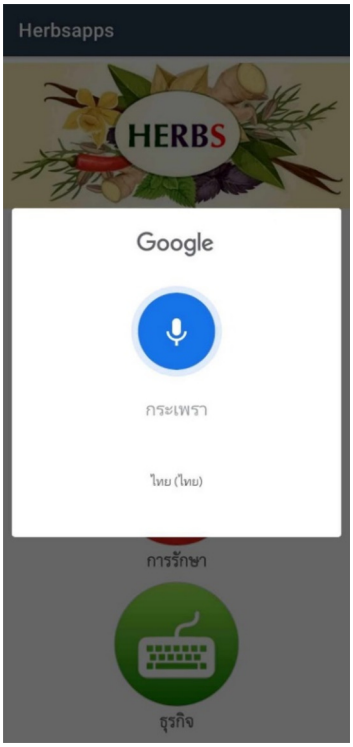

Fig.6 *(a)*

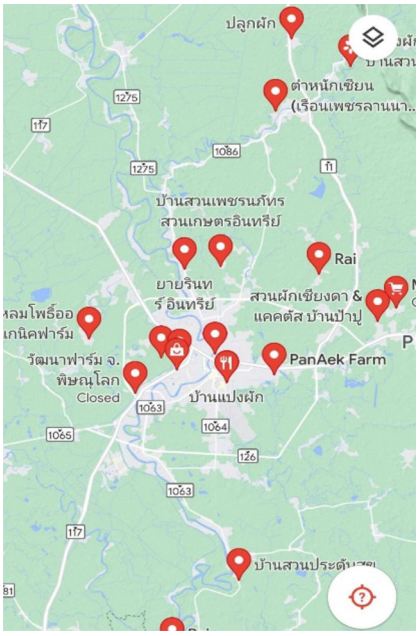

Fig.6 *(b)*

Fig.6: *Interface of the business page for holy basil by speech.*

the holy basil is located are shown in Fig. 6b. Users are allowed to click on the location pin to see more information of the holy basil such as utilization, location (where holy basil is grown and what is the size of the cultivated area, farmland size, how many orders can be provided), and the available marketplace (what kind of business can be managed, such as B2B, B2C, B2B2C). Users can conveniently search for holy basil businesses or marketplaces by entering the province and district shown in Figure 7. The system will then display relevant herbal information. For example, the user fills in the name of the herb as holy basil along with Phitsanulok Province and Bang Rakam District, then BROTH suggests the marketplace, area, utilization (the holy basil can be used for food, cosmetic and treatment), and how to get to the area of holy basil by map (Figure 7).

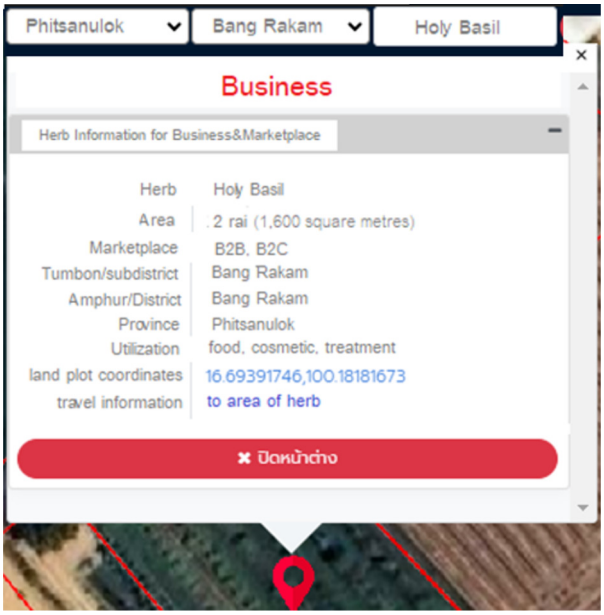

Fig.7: *Interface of business page for holy basil by search.*

BROTH's user-friendly interface is characterized by prioritizing accessibility and personalization [18]. By accepting both voice and text input, the platform embraces inclusivity, removing barriers for users with disabilities, limited literacy, or those unfamiliar with text-based interaction. This is useful particularly for individuals in rural areas or with limited technological experience, populations often marginalized by digital divides. BROTH empowers them to actively participate in the area of herbal knowledge and access personalized recommendations.

Furthermore, BROTH translates basic search functions by understanding individual needs and offering personalized recommendations based on users' specific requests for herbal suggestions. In the future, this personalization may build trust and foster deeper engagement, as users perceive their unique needs being valued and addressed. By harnessing the power of technology to tailor recommendations, BROTH offers a compelling alternative to generic advice, potentially impacting users' health decisions and contributing to improved well-being.

These features solidify BROTH's position as a powerful tool for easing access to herbal knowledge and promoting inclusion within the healthcare landscape. Further research could explore the platform's impact on specific demographics, investigate the potential of personalization, and assess how BROTH's inclusive design can be replicated in other contexts to ensure sound access to health information and resources [19].

The accuracy of information within BROTH's underlying ontology is not merely a technical detail; it is an important piece of the platform's trust and efficacy. Inaccurate or incomplete information within an ontology can lead to unreliable recommendations, potentially harming users' health and well-being [20].

To keep BROTH sustainable, three needs have been considered

- Rigorous Information Sourcing: Employing rigorous information sourcing strategies is crucial. Consulting reputable scientific databases, collaborating with herbal medicine experts, and implementing peer-review processes for information integration can help ensure accuracy and minimize the risk of errors [21].
- Version Control and Updates: Regularly updating the ontology with the latest scientific findings and evidence-based practices is essential. Maintaining version control systems and transparently communicating updates to users fosters trust and demonstrates the platform's commitment to staying current.
- User Feedback and Reporting Mechanisms: Encouraging user feedback and establishing reporting mechanisms for potential inaccuracies allows for continual improvement. Actively engaging with users and incorporating their input helps identify and address errors in a timely manner.

Further amplifying this ethical imperative is BROTH's potential to reach populations in need, including individuals in rural areas with limited access to healthcare professionals. For these users, BROTH may become a valuable source of information about herbal remedies. In such scenarios, inaccurate information carries even greater weight, potentially leading to misguided self-treatment and harming user health. By consistently prioritizing accurate data, BROTH protects user health, fosters trust, and contributes to equitable access to valuable healthcare information.

BROTH, unlike previous works (Table 2), offers user-friendly access via web and mobile apps. It also boasts broader functionality, encompassing herbal treatments, knowledge, and business: users can register and manage their cultivation areas, including displaying location, details, and purchase options on

a map.

We also introduce voice search and text-to-speech features for intuitive herbal information access, catering to users with visual or reading limitations. While image-based search exists [3, 20], its complexity and error susceptibility in diverse/limited datasets makes it less accessible.

The results represent the development and evaluation of an ontology specifically tailored for Thai herbs. They detail the creation of the Broad Recommender Ontology for Thai Herbs (BROTH), which serves as a comprehensive database encompassing various aspects of Thai herbs, such as botanical data, local Thai names, medicinal uses, recommended plant parts, preparation methods, and local market availability. The ontology is designed to facilitate the connection between customers and local farmers, allowing users to access the recommender system via typing and voice recognition to retrieve appropriate information about Thai herbs. The paper also highlights the potential positive impact of the BROTH recommender system on local businesses and the health conditions of the Thai population, especially the elderly.

To evaluate the usability of the system, we applied SUS (System Usability Scale) [33]. The SUS questionnaire comprises ten items.

1. I think that I would like to use this system frequently.
2. I found the system unnecessarily complex.
3. I thought the system was easy to use.
4. I think that I would need the support of a technical person to be able to use this system.
5. I found the various functions in this system were well integrated.
6. I thought there was many inconsistency in this system.
7. I would imagine that most people would learn to use this system very quickly.
8. I found the system very cumbersome to use.
9. I felt very confident using the system.
10. I needed to learn a lot of things before I could get going with this system.

We translated the questionnaire into Thai and presented it to a diverse group of 75 BROTH users with varying levels of digital experience. Using a 5-point Likert scale, they rated each item. The overall score, a high 83.6, suggests a very positive user perception of BROTH's usability. Notably, 17 of these users also participated in the Rapid Prototyping process.

The BROTH system, while aiming to bridge the gap between traditional Thai herbal knowledge and contemporary healthcare, encountered several obstacles. A key challenge was ensuring users trust the system's recommendations. This required a rigorous process of scientific validation, where the purported properties and uses of Thai herbs were meticulously compared against established scientific data. In essence, BROTH had to reconcile the wisdom passed down through generations with the demands of modern scientific methodology. Another major obstacle resided in the maintenance of a comprehensive herbal database. Maintaining the most up-to-date information on the properties, applications, and potential adverse effects of each herb presented a constant challenge.

Beyond the data aspect, fostering user adoption of the BROTH system demanded addressing accessibility concerns. Designing a user-friendly smartphone application, particularly for elderly users, required careful consideration. Additionally, promoting the platform's value proposition to the general population presented a problem that needed to be overcome.

5. CONCLUSION AND FURTHER WORK

This paper has presented an ontology serving a recommender system for Thai herbs that aims to connect customers and farmers locally. Customers access the recommender system via typing and voice and retrieve appropriate information about Thai herbs: local names (mainly used as input by customers/users), botanical data, medical properties, local availability, and local vendors. The user interface of the recommender system has been designed in the Thai language to cater for local availability by the customers and vendors. It can be expected that the BROTH recommender system has a positive impact on local businesses as well as on the health conditions of the Thai population, especially the elderly.

The main contributions of this paper include the introduction of the Broad Recommender Ontology for Thai Herbs (BROTH), which serves as a comprehensive database encompassing various aspects of Thai herbs, such as botanical data, local Thai names, medicinal uses, recommended plant parts, preparation methods, and local market availability. Additionally, the paper details the development of a smartphone application utilizing BROTH as a recommender system, allowing users to search for herbs in Thai using text or voice recognition and connecting them with local vendors selling the desired herbs. The paper also discusses the potential positive impact of the BROTH recommender system on local businesses and the health conditions of the Thai population, especially the elderly.

The system can be further improved by adding a video function presenting preparation methods for Thai herbs to gain maximum benefits [28]. Additionally, it can be helpful to have the opportunity to take photos of herbs and identify the names and properties of herbs and their benefits [20], [29]. The utilization should support the location where to find food, cosmetic, and treatment product. [30].

Table 2: *The comparison with recent research works .*

Title	Voice Recognition		Map	Business	Treatment	Knowledge	Ontology Design	Platform	
	Speech to Text	Text to Speech						Web App.	Mobile App.
The Personalized Traditional Medicine Recommendation System Using Ontology and Rule Inference Approach [4]	×	×	×	×	✓	×	✓	✓	×
Ontology Development for Thai Herbal Medicine Recorded in Ancient Documents [5]	×	×	×	×	✓	✓	✓	×	×
New product development co creation process: a Thai case of micro community enterprises of non-food herbal products and r&d government organizations [6]	×	×	×	✓	×	×	×	×	×
Approaches and styles of tourism management of the Thai Herb Community to promote tourism in the Herbal City of Saraburi Province [7]	×	×	×	✓	×	✓	×	×	×
A Mobile App and an API for Essential and Useful Thai Herbs Search [22]	×	×	×	×	×	✓	×	✓	✓
Web-based and Mobile Oriented Herbal Information System in Nigeria [23]	×	×	×	×	×	✓	×	✓	×
Recognition System of Herbal Medicine on Mobile Terminal Based on Android Platform [24]	×	×	×	×	×	✓	×	×	✓
A Database System for the Diversity of Medicinal Herbs used as Traditional Medicinal Formulas of the Cha-UatThai Traditional Medicine Club, Cha-Uat District, Nakhon Si Thammarat Province [25]	×	×	×	×	×	✓	×	×	✓
Evaluation of Indonesian traditional herbal medicine ontology quality [19]	×	×	×	×	✓	✓	✓	×	×
Toward a knowledge-based system for African traditional herbal medicine: A design science research approach [26]	×	×	×	×	✓	✓	✓	×	×
Semantic Knowledge Representation of Plants Used in Traditional Medicine in Somalia [27]	×	×	×	×	✓	✓	✓	×	×
Doctor Herb, The Herbal Augmented Reality Application [28]	×	×	×	×	✓	✓	×	×	✓
Thai Herbs Application [29]	✓	×	×	×	✓	✓	×	✓	✓
BROTH: The Broad Recommender Ontology for Thai Herbs	✓	✓	✓	✓	✓	✓	✓	✓	✓

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AUTHOR CONTRIBUTIONS

Conceptualization, CS.N and K.N.; methodology, , CS.N; software, CS.N. and P.M.; validation, CS.N., and K.N.; formal analysis, CS.N.; investigation, CS.N. and K.N.; data curation, K.N, W.P. and C.W.; writing original draft preparation, CS.N, K.N, and M.B.; writing review and editing, CS.N, K.N, and M.B.; visualization, P.M. and CS.N.; supervision, K.N. and CS.N.; funding acquisition, K.N., CS.N.,W.P and C.W.. All authors have read and agreed to the published version of the manuscript.

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