ChatGPT

Knowledge Graph Model for Symbolic Herb Reasoning

Background and Existing Ontologies

Knowledge graphs (KGs) offer a structured way to encode domain knowledge as triples (head–relation–tail) connecting entities via semantic relationships [1]. In the herbal domain, most knowledge graph efforts so far have focused on medicinal uses – linking herbs to diseases, symptoms, and chemical compounds for treatment purposes [2] [3]. For example, Wang *et al.* (2019) constructed a TCM knowledge graph with herbs, symptoms, and formulas, even using a knowledge graph embedding topic model to recommend herbal treatments [3]. Another effort by Somé *et al.* built a West African traditional medicine KG with *143* plants and *108* multi-herb recipes for treating *110* ailments [4] – highlighting that representing **blends** (herbal combinations) is a recognized need in medical KGs. Ontologies like Alkhatib & Briman's Herbal Medicine Ontology align traditional herbal knowledge with modern biomedical ontologies (symptom and disease hierarchies), drawing herb definitions from MeSH taxonomy for interoperability [5]. These projects demonstrate the value of integrating botanical data (taxonomy, plant parts) with usage knowledge, though their emphasis is largely on pharmacological efficacy and safety.

In contrast, the **symbolic and cultural dimensions** of herbal knowledge have received less attention in KG form. Ethnobotanical and folkloric uses of herbs – e.g. for rituals, spiritual well-being, or cultural symbolism – are rich with relationships that go beyond biomedical efficacy. Herbs often carry deep symbolic attributes in various traditions; for instance, in Chinese intangible heritage the Qingyang sachet practice uses aromatic herbs to ward off harm and invite blessings [6]. Such cultural artifacts encode meaning (e.g. herbs in sachets representing blessings or protection) and link to lineage: frogs embroidered on sachets symbolize fertility and prosperity, while paired dragon-phoenix motifs signify auspicious marital harmony [7]. Capturing this **symbolic ontology** of herbs requires modeling cultural context and mythic attributions in addition to botanical facts. Some knowledge frameworks in cultural heritage have begun to model these aspects – e.g. an ontology for Qingyang sachet embroidery included classes for materials (herbs), craft processes, and cultural symbolism [6] [7]. This informs our approach to represent not only the plant's scientific identity but also its **cultural lineage** (which traditions use it), **preparation methods** in rituals, and **symbolic attributes** (qualities or intentions it represents). Modern graph database technology (such as Neo4j) has been used to implement similar ontologies in practice [8], enabling visualization of complex relationships. We will leverage these lessons to design a hybrid ontology that bridges botanical data with symbolic knowledge, while optionally linking out to external databases (e.g. Wikidata or plant taxonomies) for standard references [9]. The goal is a self-contained **symbolic herbal knowledge graph** that supports interactive filtering, blend exploration, and provenance tracking of ritual use.

Proposed Graph Schema for Symbolic Herbal Ontology

Our knowledge graph schema (ontology) for symbolic herb reasoning defines several key **entity types (nodes)** and **relationship types (edges)** to cover herbs, their meanings, cultural contexts, and usage. The core graph is a self-sufficient ontology of symbolic herbal knowledge, while allowing optional links to

external data (e.g. Wikidata QIDs or taxonomic IDs) for each herb node as reference points [5]. The principal node types and their roles are:

- **Herb** – A plant or herbal substance used in ritual or symbolic contexts. Each Herb node represents a specific species or common variety (e.g. **"White Sage"**, **"Rosemary"**). It can have properties like scientific name and an external identifier (to Wikidata or a plant database) for reference, but those links are not hard dependencies. Herbs are central entities connected to their attributes and usage.
- **Symbolic Attribute** – An abstract quality or intention symbolically associated with herbs. Examples include **"Purification"**, **"Protection"**, **"Love"**, **"Prosperity"**, **"Remembrance"**, etc. These nodes allow filtering and reasoning based on the desired symbolic effect or meaning. Many herbs have one or multiple symbolic attributes (e.g. rosemary symbolizes remembrance, sage signifies purification).
- **Cultural Tradition** – A cultural or folkloric context in which herbal knowledge is embedded. This could be a tradition or lineage such as **"Traditional Chinese Medicine"**, **"Ayurveda"**, **"Native American ritual"**, **"Western ceremonial magic"**, **"Ancient Greek lore"**, etc. It provides lineage/provenance for practices (who uses the herb in that way). Herbs may be linked to one or several traditions indicating where that symbolic use is recorded.
- **Preparation Method** – A mode of preparation or application for the herb in rituals. Examples: **"Incense/Burning"**, **"Tea infusion"**, **"Essential Oil"**, **"Satchet/Pouch"**, **"Bath"**, **"Tincture"**. This captures *how* the herb is used to manifest its effect (burned as incense for purification, brewed as tea for calming, etc.). An Herb can have multiple preparation edges if it's used in different forms.
- **Blend (Formula)** – A composite node representing a named mixture or common combination of herbs used together for a particular symbolic purpose. For example, **"Four Thieves Blend"** or **"Love Attraction Sachet Mix"** could be Blend nodes. Blends contain ingredient herbs as part of their structure. By treating blends as first-class entities, the graph can capture known synergistic recipes (e.g. a cleansing incense blend that combines white sage *and* cedar). This supports **blend exploration**, allowing queries like "find blends that include rosemary" or "suggest a blend for protection". (In many cases, blends might also have a tradition and a symbolic intention associated.)
- **Ritual Event (Log)** – A contextual node representing a recorded instance of herb usage (a specific ritual or user log entry). This is used to encode **provenance** and outcomes of herbal use in practice – essentially the "ritual log". A Ritual Event node might record when and by whom a certain combination of herbs was used, for what intention, and with what result. It links to the herbs or blend used, the intended symbolic attribute, the tradition or setting, and possibly an outcome or user feedback (successful, needs adjustment, etc.). These event nodes provide a factual basis that grounds the symbolic associations in real practice, and they enable iterative learning (the system can learn confidence from repeated successful events).

With these nodes, we define the following key **relationships** (edges) in the ontology (domain → range notation):

- **Herb –hasSymbolicMeaning→ Symbolic Attribute:** Links an herb to a concept it symbolizes or the intention it supports. (E.g. *Rosemary –hasSymbolicMeaning→ Remembrance*). An herb can have multiple symbolic meanings, and conversely many herbs might share an attribute (e.g. both sage and cedar *haveSymbolicMeaning→ Purification*).
- **Herb –usedIn→ Cultural Tradition:** Indicates that the herb is traditionally used in a given culture or system, particularly for symbolic or ritual purposes. For example, *White Sage –usedIn→ Indigenous North American (Lakota)* or *Lotus –usedIn→ Ayurveda*. This relation provides cultural lineage; it can also

be qualified with notes (via attributes or reified nodes) such as historical period or specific community if needed.

- **Herb –preparedAs→ Preparation Method:** Specifies a common preparation for using the herb symbolically. For instance, *Mugwort –preparedAs→ Incense/Burning*, *Lavender –preparedAs→ Essential Oil*. Multiple edges here denote the versatility of use forms.
- **Blend –hasIngredient→ Herb:** Connects a blend node to each Herb that is part of its recipe. For example, a *"Peaceful Home Incense" –hasIngredient→ Lavender*, and also –hasIngredient→ Sage, etc. This allows the graph to represent internal structure of multi-herb formulas. (In a property graph implementation, the Blend node might also carry an attribute for its formula name or ratio, but structurally we capture just the membership via edges).
- **Blend –hasSymbolicPurpose→ Symbolic Attribute:** Links a blend to the main intent it is designed for (if the blend has a specific named purpose). For instance, *Love Attraction Sachet Mix –hasSymbolicPurpose→ Love*. This is analogous to herb→meaning, but at the blend level (especially if a blend is curated to amplify a particular effect).
- **Blend –usedIn→ Cultural Tradition:** (Optional) If a blend is known in or originates from a particular tradition, we can link it similarly to indicate provenance (e.g. a specific potion formula from European folk magic).
- **Ritual Event –uses→ Herb/Blend:** Connects a ritual log node to the herbs or blend that were used in that event. If a blend node exists for that combination, the event might just link to the blend; otherwise it can link individually to each Herb used. For example, *RitualEvent#123 –uses→ Sage*, –uses→ Cedar.
- **Ritual Event –hadIntent→ Symbolic Attribute:** Denotes the goal or intention of that ritual (e.g. purification, healing, luck). This captures what symbolic outcome was sought.
- **Ritual Event –outcome→ Outcome** (where *Outcome* might be a simple value or a node like **Success**, **Failure**, or a textual note). This relationship logs the result or feedback from that event (e.g. success, or maybe a qualitative rating). It helps in learning which herb or blend applications are consistently effective.
- **Herb –contraindicatedWith→ Herb:** (Optional) A relationship type to denote *conflicts or negative interactions* in a symbolic or practical sense. In non-medical terms this could mean two herbs should not be used together (perhaps due to clashing energies or smoke combinations). This can be informed by traditional taboos or practical experience. We include this relation type for completeness in supporting blend reasoning (to rule out conflicting combinations). For example, if tradition says *"Don't mix herb A with herb B in the same ritual"*, we would encode *A –contraindicatedWith→ B*.

Additionally, each entity or relationship in the KG can carry **literal attributes** for further detail (e.g. a Herb node might have a `scientific_name` or `plant_family`; a Ritual Event could have a `date` or `practitioner` attribute, etc.). We avoid hard-coding too many literal attributes in the core schema, focusing instead on the semantic link structure that enables reasoning. External identifiers can be attached as well: e.g. a Herb node may have a *sameAs* link or attribute to a Wikidata item or a plant database entry, ensuring we can reference detailed botanical info when needed [9]. By not requiring these links, the ontology remains **self-contained**, but they serve as bridges to rich data (Wikidata has multilingual names, taxonomic hierarchy, etc., improving global accessibility of the knowledge [10]).

Below is a set of **example triples** (subject–predicate–object statements) instantiating this schema. These illustrate how the knowledge graph might be populated with real data about herbs, symbolic meanings, blends, and usage logs. We provide 20 sample triples grouped by category:

1. **White Sage** – **hasSymbolicMeaning** → *Purification* (White sage is widely regarded as a purifying herb in cleansing rituals)
2. **White Sage** – **usedIn** → *Indigenous North American Tradition* (It is used in Native American smudging ceremonies)
3. **White Sage** – **preparedAs** → *Incense* (Typically burned as incense or smudge sticks)
4. **Rosemary** – **hasSymbolicMeaning** → *Remembrance* (Rosemary symbolizes memory and remembrance in European folklore)
5. **Rosemary** – **usedIn** → *Ancient Greek Ritual* (Ancient Greeks used rosemary sprigs in funerals for remembrance)
6. **Lavender** – **hasSymbolicMeaning** → *Tranquility* (Lavender is associated with calm and peace)
7. **Lavender** – **preparedAs** → *Essential Oil* (Commonly extracted as oil for its calming fragrance)
8. **Lavender** – **usedIn** → *Aromatherapy Practice* (Widely used in modern aromatherapy traditions)
9. **Mugwort** – **hasSymbolicMeaning** → *Protection* (Mugwort is seen as a protective herb, e.g. hung above doorways)
10. **Mugwort** – **usedIn** → *European Folklore* (It appears in European folk magic for protection and prophecy)
11. **Holy Basil (Tulsi)** – **hasSymbolicMeaning** → *Sacredness* (Tulsi is revered as a sacred plant)
12. **Holy Basil (Tulsi)** – **usedIn** → *Ayurveda* (Used in Ayurvedic tradition both medicinally and spiritually)
13. **Holy Basil (Tulsi)** – **preparedAs** → *Tea* (Often prepared as a herbal tea/offering)
14. **Protection Incense Blend** – **hasIngredient** → *White Sage* (A blend for protection contains white sage)
15. **Protection Incense Blend** – **hasIngredient** → *Cedar* (The blend also contains cedar wood)
16. **Protection Incense Blend** – **hasSymbolicPurpose** → *Protection* (The intended purpose of this blend is protection)
17. **Protection Incense Blend** – **usedIn** → *Modern Paganism* (Such blends are used in contemporary Pagan/Wiccan practice)
18. **RitualEvent_001** – **uses** → *White Sage* (Log entry: white sage was used in a specific ritual event)
19. **RitualEvent_001** – **hadIntent** → *Purification* (The intent of that ritual was spiritual purification of a space)
20. **RitualEvent_001** – **outcome** → *Success* (Outcome recorded: the space was perceived as cleansed afterwards)

(The above triples are illustrative; in a real graph, RitualEvent_001 would also have a date/time and could link to a specific user or ceremony entry. Likewise, herbs like White Sage might carry a link to their Wikidata ID Q131122 for reference, and "Modern Paganism" could link out to an external concept if needed.)

This schema supports **interactive filtering** and visual exploration. Each facet (herb, tradition, symbolic attribute, etc.) can be represented as a "ring" or category in a UI, and selecting a value (a "petal") filters the graph accordingly – for example, picking the *Purification* attribute highlights all herbs and blends connected to purification, which can then be further filtered by a tradition ring (showing only those used in say, Ayurveda). The graph structure is well-suited to visualization: using tools like Neo4j Bloom or similar, users could see herbs clustered by symbolism or navigate from a blend to its ingredients dynamically. In the background, the same schema enables semantic queries (e.g. SPARQL or Cypher queries) to retrieve

answers like “find all cleansing herbs used in East Asian traditions” or “what blends for love are recorded in the log with successful outcomes”.

Reasoning Strategies and Hybrid Inference

To deliver non-medical guidance with this knowledge graph, we propose a **hybrid reasoning approach** that combines rule-based symbolic reasoning with lightweight vector embeddings. The system will use explicit rules to capture the logical relationships (especially for mapping user intentions to herbs/rituals in a transparent way), and **knowledge graph embeddings** to handle similarity, analogy, and discovery of new combinations. We also incorporate a confidence-scoring mechanism grounded in provenance (citations or user logs) to ensure guidance is given with appropriate uncertainty for folk knowledge. Below, we outline the reasoning strategies:

Rule-Based Symbolic Reasoning

Rule-based reasoning applies deterministic if-then logic on the graph’s relationships, leveraging the ontology’s semantic structure. These rules are crafted to reflect expert knowledge and ritual heuristics. For example:

- **Rule 1: Attribute Matching** – *If* a user requests an herb for a specific intention or symbolic attribute X (e.g. **“purification”**), *then* retrieve all Herb nodes H such that **H –hasSymbolicMeaning→ X**. (Optionally filter by a user’s cultural context if provided, e.g. prefer herbs also linked to that user’s tradition). This rule directly uses the `hasSymbolicMeaning` relation to find candidates that fulfill the desired goal.
- **Rule 2: Tradition Filter** – *If* the user or scenario specifies a cultural framework Y (e.g. **“Celtic lore”**), *then* constrain any recommendations to herbs or blends that **–usedIn→ Y**. This ensures the guidance stays within a familiar or relevant tradition lineage when required. It can be combined with Rule 1 as needed (first find all herbs for X, then filter those that are used in Y).
- **Rule 3: Blend Suggestion and Synergy** – *If* a user’s goal involves multiple attributes or a broad intention that could benefit from combination, *then* suggest a Blend that covers those aspects, or construct one by combining herbs for each aspect. For example, if someone desires a ritual for both **protection** *and* **prosperity**, the system can find an herb for protection (say, *mugwort*) and one for prosperity (say, *basil*), and recommend using them together. Before suggesting a new blend, the system will check for any known **contraindications**: e.g. if herb A and herb B have a **contraindicatedWith** relationship (or belong to clashing traditions), the rule will avoid that pairing or flag a caution. Similarly, if a pre-built Blend node exists that matches the multi-faceted intent, that blend is suggested. This rule emulates the way an expert might combine herbs to cover multiple symbolic needs, while respecting do-not-mix rules from the knowledge base.
- **Rule 4: Ritual Log Feedback Loop** – *If* a particular herb or blend has many positive outcomes recorded in Ritual Event logs for a given purpose, *then* prioritize that item in recommendations for that purpose. Conversely, if an item has consistently poor or mixed outcomes in logs, de-prioritize or add a caution. This rule uses the **ritual log provenance**: essentially aggregating the `outcome` of past events. For instance, if *“Protection Incense Blend”* was used 10 times with success reported each time, the system can boost its confidence when recommending it for protection. This introduces a feedback mechanism where the graph “learns” from usage.

These rules are encoded as pseudo-logic or query templates operating on the KG. They ensure the system's suggestions are **transparent** (traceable to specific triples) and adhere to domain constraints. Prior work has shown that such rule-based systems can effectively suggest herbal remedies and even detect conflicts [11] – for example, an expert system by Alkhatib *et al.* used inference rules to propose new herbal blends and identify conflicting herb pairs, improving the safety of recommendations [11]. In our non-medical context, the rules focus on symbolic efficacy and cultural coherence instead of pharmacology, but the principle is similar: encode expert knowledge (e.g. "sage and sweetgrass complement each other for cleansing") as logical implications in the graph. By chaining these rules, the system can handle complex queries (e.g. "I want a night-time protection ritual in the Celtic tradition") by breaking them into sub-tasks: find protection herbs, filter to Celtic ones (e.g. *rowan* or * juniper*), then maybe suggest a preparation (burn as incense at night) – each step justified by a graph link.

Embedding-Based Similarity and Blend Discovery

While rules cover explicit knowledge, we also employ **knowledge graph embeddings** to capture implicit patterns and support discovery. A KG embedding maps entities (and possibly relations) to vectors in a latent space, such that similar or related entities end up close together. By training embeddings on our graph (or a combination of our graph and external text corpora about herbs), the system can recognize non-obvious similarities – for example, two herbs from different cultures that share a pattern of symbolic uses might end up near each other in the embedding space even if they don't share a direct link. This enables two main capabilities:

- **Herb Similarity & Substitution:** Given a particular herb, we can find other herbs with a similar symbolic "profile" by measuring cosine similarity between embedding vectors. For instance, if *White Sage* is not available, the system might suggest *Cedar* or *Palo Santo* as alternatives because their embeddings are close (they all may appear in purification rituals in the graph). This is informed by the graph's structure but generalizes beyond exact matches. Research in KG and recommender systems has shown that embedding-based similarity can reveal interchangeable or analogous items [12]. In our case, this helps maintain flexibility – users can discover new herbs with comparable virtues or find regionally available substitutes for an intention.
- **Blend Recommendation via Vector Composition:** We can leverage embeddings to propose new blends or enhancements. One simple approach: take the vector for a target symbolic attribute (or a combination of attribute vectors) and find herbs whose vectors are close to that point. Another approach is to use vector arithmetic: e.g. vector(*Protection*) + vector(*Prosperity*) might be compared against herb vectors to find herbs or existing blends that cover both (this is analogous to finding words that match combined concepts in word embedding models). More directly, we can detect clusters of herbs that frequently co-occur in rituals (their embeddings might form a cluster or have a certain relationship). Embedding methods have been applied in TCM KGs to find related herbs and improve recommendation accuracy [3]. By training on a graph that includes blend membership relations, the embedding can learn representations of herbs that capture co-usage contexts. This could yield suggestions like "Herb A and Herb B are often used together, and Herb C is similar to B, so consider adding Herb C." The **"similarity calculation"** afforded by KG embeddings provides a quantitative way to explore blend possibilities [12] that are not explicitly in the data. It's a creative aid: for instance, if we have many purification herbs, embedding clusters might highlight one that is aromatically complementary to another. We keep the embedding models lightweight (e.g. TransE or Node2Vec on the graph) to ensure interpretability and speed, given the domain KG is not enormous.

The **hybrid mode** means the system can generate suggestions through two channels: one strictly rule-based (exact matches, logically guaranteed to fit criteria), and one via similarity (suggestive, exploratory). We will combine these by, say, first using rules to get a baseline result set, then expanding or re-ranking results with the embedding scores. For example, if a user asks for "calming herbs used in Ayurveda", Rule 1+2 might return *Holy Basil* and *Brahmi*. The embedding component could then suggest *Ashwagandha* because it's not explicitly tagged "calming" but appears in similar contexts in the vector space (maybe due to its stress-relief reputation). We present these additional suggestions with a slightly lower confidence, as a way to broaden the user's exploration.

Confidence Scoring and Provenance

Since this system provides **non-medical guidance** (where outcomes can be subjective and knowledge is drawn from folklore and personal experience), it's crucial to communicate uncertainty and source of information for each recommendation. We implement a confidence scoring mechanism that takes into account **evidence count, consistency, and context fit** for any given suggestion. Key factors in the confidence score include:

- **Multi-source Backing:** If a certain herb-symbolic link is documented across *many* independent sources or traditions, we assign higher confidence. For example, if *lavender* → *tranquility* appears in European aromatherapy, Traditional Chinese herb lore, and modern witchcraft literature, it's likely a well-established association. Conversely, a very obscure claim (only one source or a single user's log) gets a lower base score. This approach is analogous to Wikidata's practice of attaching multiple references to a statement to bolster its reliability [13] – our KG can store references or count of sources for each triple, and the reasoning engine uses that metadata.
- **User Context and Log History:** The confidence can be adjusted based on relevance to the user's context. For instance, if our ritual log nodes show that *mugwort for protection* had consistently positive outcomes in similar contexts to the user's query (e.g. home cleansing rituals), confidence is higher. If the user's own past interactions (if tracked) showed a dislike or allergy to a certain herb's smoke, the system would lower confidence for that suggestion. Essentially, the **ritual log provenance** is folded into confidence: each event outcome acts as a tiny vote for or against the efficacy of a herb/blend in that scenario.
- **Conflict or Controversy:** If there is a known conflict in the data (say one tradition praises an herb for an intent, but another regards that herb as counterproductive for the same intent), the system will either avoid that suggestion or present it with a cautionary note and medium/low confidence. The score thus encodes not just "how much" evidence, but also consistency of evidence.
- **Default Levels:** As a baseline, widely used general-purpose herbs start with higher confidence than very niche or experimental ones. E.g. sage for purification (common, high confidence) vs. some rare herb with a lore of purification (uncommon, propose it but with caveats).

The confidence score is presented alongside each recommendation (e.g. 4 out of 5 stars, or a textual qualifier like "Highly recommended" vs "Possible option"). This guides the user in making informed choices and aligns with the non-medical ethos: we are not guaranteeing results, just sharing knowledge with an indication of how *strongly* the knowledge is supported. All recommendations will be traceable to their **provenance** in the graph. For example, the UI could allow the user to click on a suggestion and see something like: "Lavender is suggested for tranquility **because** it has been used for calming in 3 different traditions and 5 logged rituals showed positive outcomes" – and even list those traditions or events. Under the hood, this trace is possible because the KG stores those links (heritage and log usage) as first-class data.

Finally, we note that maintaining up-to-date references (scholarly or community sources) for each assertion can further bolster confidence. In our design, each triple (especially Herb→SymbolicAttribute) could carry reference tags pointing to ethnographic texts or databases (similar to how Wikidata attaches citations to statements) [13]. This not only supports confidence scoring but also satisfies scholarly rigor and transparency. Users can be given access to these citations if they desire more detail or verification.

In summary, our knowledge graph model uses a **hybrid reasoning** approach: a symbolic rule engine to enforce explicit knowledge and ensure culturally valid combinations, and an embedding-based component to surface subtler connections and analogies. The graph schema itself is rich enough to support both (the rules operate on its discrete relations, the embeddings on its learned representation). By logging each ritual use and integrating feedback, the system can **learn and refine** its guidance over time, all while keeping the user informed of *why* a suggestion is made and how confident we are in it. This approach provides a balanced, intelligent guidance system for symbolic herb usage – one that is rooted in structured knowledge but enhanced with adaptive, data-driven insight.

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- **(Additional relevant data sources)**: World Flora Online (global plant taxonomy database), **Wikidata** (structured data on plants, common names in multiple languages), and **Ethnoherbs Project** (EU initiative integrating traditional herbal knowledge with scientific data). These can serve as external reference links to enrich the symbolic herb graph without being hard dependencies.

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