

Analysis of Entity-Oriented Knowledge Panel Recommendation Patterns

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Abstract

To systematically understand the information recommendation paradigm of entity-based knowledge panels and their working principles, this study investigates them by leveraging the fundamental concepts of knowledge graphs and entity search technologies. First, the data sources of knowledge panels are analyzed. Next, the design and planning of knowledge modules within knowledge panels are analyzed. Finally, the workflow of knowledge panels is analyzed and discussed. Through the research, it is found that to achieve the goal of recommending relevant domain knowledge in knowledge panels, this involves not only user demand patterns and the design and rules of knowledge modules, but also the construction of conceptual databases and various entity-related factors.

Full Text

Analysis of Knowledge Panel Recommendation Mode for Entity

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Abstract: To systematically understand the entity-based knowledge panel as an information recommendation mode and its operating principles, this paper examines its workings through the foundational concepts of knowledge graph and entity search technologies. First, we analyze the data sources of knowledge panels. Next, we examine the design and planning of knowledge modules within knowledge panels. Finally, we analyze and discuss the workflow of knowledge panels. Our research reveals that recommending relevant domain knowledge in knowledge panels involves not only user demand patterns and knowledge module design principles, but also the construction of concept databases and various entity-related factors.

Keywords: Knowledge Panel; Knowledge Graph; Entity Search

1 Introduction

With the development of the Semantic Web, the Internet is transitioning from a Document Web—comprising only web pages and hyperlinks between them—to a Data Web that contains various entities and rich relationships between them. Against this backdrop, major search engine companies are building knowledge graphs (such as Google’ s Knowledge Graph) based on the Data Web to improve search quality and better satisfy users’ deeper latent information needs from an entity search (semantic search) perspective. The content displayed in knowledge panels represents the results returned after search engines perform entity searches on knowledge graphs [1]. More specifically, this content comprises structured summary information most relevant to a particular entity, such as information about President Obama’ s children, spouse, birthday, education, and other related entities. In this context, President Obama is treated as an entity, while education and birthday are treated as attributes of that entity. Entities may be those identified from user queries, entities recognized in Web documents [2], or topics treated as entities [3].

Essentially, the content in knowledge panels is a knowledge graph representation specific to a particular entity and represents a concrete manifestation of entity search. Compared with traditional keyword-based search processes, entity search can more effectively and directly identify the most relevant structured summary information for an entity from a knowledge graph because its focus is not on “keyword” -level information but on “entity” -level information within knowledge graphs. This structured summary information can not only be used to dynamically and intelligently recommend information resources to users but can also be “intelligently” displayed to users without requiring additional query operations. Furthermore, knowledge panels save users considerable valuable time while providing precise information resources.

Superficially, the content displayed in knowledge panels may not seem revolutionary, as users could obtain roughly the same information by visiting President Obama’ s Wikipedia page. However, at a deeper level, the mechanism for displaying content in knowledge panels represents a significant engineering transformation for search engine companies, as it appears capable of thinking like a human to excavate the most relevant data [4]. In light of this, this paper provides an in-depth understanding of the knowledge panel information recommendation mode by analyzing its implementation mechanism—how search engines use knowledge graph and entity search technologies to identify entities (concepts) involved in queries and their attributes, and display corresponding knowledge panels based on entity importance. This analysis offers practical references for designing and developing similar knowledge panel recommendation modes in the future.

[Figure 1: see original paper]

2 Related Research

“OneBox” technology served as the prototype for knowledge panel technology, with its initial simple applications displaying information such as weather (e.g., entering “weather location”), word definitions (e.g., entering “define: XXX” or “what is XXX”), music (e.g., entering a band name), and books (e.g., entering a book title) [5]. As information volumes grew exponentially, this information display technology could not adequately satisfy the broad intentions behind user searches because it failed to effectively incorporate users’ real-time behavioral data. To better integrate this behavioral data and maximize satisfaction of user information needs, Google published a patent in 2007 that addressed this issue in detail [6]. The study pointed out that to flexibly display relevant information in a single knowledge panel, search engines need to know how and when to display results, which involves not only numerous user behavioral data but also underlying information resource databases. User-related behavioral data includes: user’ s country, language used, Cookie information that can identify the user, language used in the query, time the query was sent, historical access log data, terms in the query, and terms in documents or objects in the information resource database. Information resource databases include: image repositories, web page repositories, news repositories, and product repositories. Based on this information, the study proposed methods for modeling behavioral data to predict and decide whether to search a specific information resource database and display extracted results.

Although the aforementioned research effectively satisfied user information needs by incorporating behavioral data, the granularity of displayed content remained insufficiently refined. For instance, displayed content consisted of relatively “coarse” aggregated results of documents or objects lacking semantic relationships, and it failed to adequately consider other information contained in query statements, such as entities and their relationships. Additionally, it is worth noting that the design of backend information resource databases did not effectively organize and store knowledge and its relationships in a classified manner, thus failing to help users clarify knowledge systems—an important objective.

With the emergence of knowledge graph technology [7] and entity search technology [8, 9], knowledge panel technology focusing on entities gradually attracted industry attention [1, 10]. These studies pointed out that to display rich semantically relevant information in knowledge panels, three aspects require planning: first, mining entities referenced in user queries; second, identifying content items related to those entities and providing a series of knowledge modules for displaying information about the entities; and third, integrating knowledge panels themselves into existing search result pages or other pop-up windows. Although these studies profoundly revealed the dynamic changing patterns of knowledge domains—(1) knowledge panel content is the most relevant data for an entity,

not documents or objects; (2) this data is the most relevant information obtained by performing searches on that entity in the knowledge graph; and (3) both implementations require dynamic sorting by relevance and importance—these studies still had limitations, such as failing to profoundly elaborate on the implementation mechanism or working principles of knowledge panel technology by effectively combining knowledge graph and entity search technologies, since the working mechanism of knowledge panels is based on these two technologies.

In another study, the authors designed a peripheral knowledge panel called “Side-Point” embedded with implicit search technology [11]. In practical applications, this knowledge panel significantly reduced users’ information discovery costs and satisfied two types of user information needs: active needs (where users attempt to satisfy their information needs through active Web searches) and latent needs (where information needs are often identified and satisfied simultaneously during browsing that users had not originally anticipated). Therefore, the authors argued that under per-unit-time user attention costs, obtaining valuable information is closely related to the information environment users employ, such as using knowledge panels.

3 Current Status and Significance of Knowledge Panel Technology

3.1 Application Status

Leveraging knowledge graph and entity search technologies, search engine companies are initiating a new transformation in the search domain: focusing less on keyword matching and more on concept matching and understanding entities, providing users with richer knowledge related to entities in knowledge panels rather than just links [12]. Due to their characteristic of providing summary information, major search engine companies are increasingly intensifying research on knowledge panel technology applications to provide users with diverse innovative services. To understand these deployed applications, the author collected and organized several important applications implemented based on knowledge panel technology:

- Answering comparison questions and displaying compared items. For example, if users want to compare the nutritional value of olive oil and butter, knowledge panels can display detailed comparison charts [13].
- Helping users quickly find legitimate sources for their favorite movies, music, and automotive services. Google’s newly launched “Listen Now” module displays music lists related to a musical artist, providing not only links to free versions but also links to other services such as Spotify, Rhapsody, Beats Music, and Google Play. Beyond music, Google is also testing displays of “books,” “social networks,” “movies,” and “automobiles” in knowledge panels, involving information on sales and rental prices [14, 15].
- Helping users find free, subject-classified online course resources, and helping users obtain information about books available for online purchase,

borrowable from local libraries, or fully accessible online [16].

- Displaying complete reviews from different users for a particular entity (such as a product or political figure). These review information sources come from different websites containing different reviews for the same entity [17].
- Displaying school evaluations, rankings, and academic indicators for schools ranging from elementary to high school to higher education, providing ranking details (such as national, state-level, and STEM education rankings), nearby schools in the region, and comparison information [18].
- Displaying corresponding content in pop-up windows. When users hover their cursor over an entity on a page, related information is automatically and intelligently displayed in a pop-up knowledge panel window [2].
- Displaying content related to food and medicine, providing extremely detailed browsable classification information or suggestions [19].

Analysis of these operational services reveals that knowledge panels are being used to display increasingly useful information to users. As knowledge graphs become more comprehensive, detailed, and complete, search engines become “smarter,” enabling knowledge panels to display more precise information and ultimately giving rise to more innovative service modes.

3.2 Significance

By automatically driving an information discovery session in the background and displaying discovered information to users, knowledge panel technology not only provides information that users never thought of but need to search online to obtain, but also satisfies the goal of providing users with latent information needs. In other words, the integrative and intelligent nature of knowledge panel technology means it has very important significance for future applications of many innovative service modes. The author summarizes six major significance aspects:

- (1) **Providing Relevant Data:** Knowledge panel technology provides only important data directly related to a specific entity. It uses relevance to deeply “understand” user behavior and thereby performs subsequent searches to display specific content, sorting this related content by importance. This application only analyzes, searches, and provides answers among things directly related to the entity (or user), achieving a transformation from “searching for information” to “understanding searches.” This fundamentally differs from traditional search, which provides information intermediary stations—traditional search can provide rich search results but cannot directly answer related questions.
- (2) **Reducing Access Frequency:** Knowledge panel technology reduces the number of visits users must make to pages to obtain relevant factual information. It not only avoids distracting users but also “practices” the search philosophy that “the future of search is no search.” This application

intelligently matches information for users based on its mastered data—you don't need to search, let alone click to the second or third page. Furthermore, this application will make everyone's information portal increasingly personalized, precise, and centralized.

- (3) **Reducing Time Overhead:** Knowledge panel technology reduces the time overhead users must spend to satisfy their information needs. It fundamentally reduces the time-consuming retrieval operations traditionally required—when searching for results on the Internet, regardless of how result lists are presented and organized, users still need to select themselves. As data in knowledge graphs becomes increasingly complete and entity search engines become “smarter,” this application will proactively push information to users by combining contextual information, thereby reducing users' search time and potentially giving rise to new “matching + pushing” modes.
- (4) **Improving User Information Recommendation Experience:** Knowledge panel technology collects and organizes information related to entities and displays it to users in a unified format. This application not only conveniently helps users understand concise and clear structured summary information but also helps users understand knowledge systems in detail from multiple perspectives, making recommended information more aligned with user needs.
- (5) **Assisting Navigation:** Knowledge panel technology provides links to other related topics, allowing users to easily select these links as follow-up queries for the current entity in a “seamless and natural” way, thereby achieving a certain degree of resource mining. This application assists user navigation during browsing by displaying information combinations containing links that satisfy latent needs, potentially giving rise to diverse business service modes.
- (6) **Providing New Content:** Knowledge panel technology no longer limits itself to organizing, displaying, and sorting information in traditional ways. This application can provide information that is literally unrelated but semantically relevant based on understanding user search intentions, and may even provide information that users never thought of searching for online.

4 Implementation Mechanism of Knowledge Panel Technology

4.1 Data Sources

Knowledge panel technology is an intelligent knowledge service that achieves specific goal-oriented information discovery and recognition on task-oriented knowledge bases. Although the display process of knowledge panels concerns how search engines decide which queries to display corresponding knowledge panels

for, the integrated information requires utilizing multiple separate data sources containing structured data organized by entity, in the form of entity-attribute-value and entity-relationship-entity. Taking Google's Knowledge Graph released in 2012 as an example, it is an entity (concept)-based knowledge base. According to incomplete statistics, to date it contains 500 million entities and 3.5 billion facts [7]. With knowledge graph and entity search technologies as backend support, content displayed in knowledge panels is not simple text accumulation but point-by-point answers. Moreover, this implementation process is not a simple information retrieval process but more of a data verification process (through relationships between entities). This partially solves the problem of precise information pushing.

Figure 1 shows a knowledge panel. When a user enters the query "Barack Obama" in the Google search engine, a knowledge panel automatically appears in the upper right corner of the results page. The displayed content is the most relevant summary information for the "Barack Obama" entity returned by the search engine. As can be seen, the displayed information has characteristics of clear organization, simplicity, and strong relevance. Obviously, this information comes from many separate data sources. Essentially, content in knowledge panels consists of two types of related information: entity attribute information and information about other entities related to the entity. In Figure 1, attribute information includes basic information such as birth date, children, entity image, and marriage, as well as non-basic information such as social information. This non-basic information is what simultaneously has associations with other entities and constitutes an important component of rich knowledge panels. Information about related other entities is displayed in the list under "People also search for," provided as links for users to click and perform entity searches again.

[Figure 1: see original paper]

4.2 Knowledge Module Design and Planning

Given that information in knowledge panels may come from multiple data sources such as images, videos, audio, news articles, products, and reviews, different content organization forms are needed to standardize how these information sources are displayed. This content organization form is the knowledge module, which is also a prerequisite for knowledge panels to "intelligently" display content [20]. In view of this, the author analyzes the relationship between knowledge modules and entity categories, the manifestation of knowledge modules in knowledge graphs, and the relevance between knowledge modules, starting from various entities or concepts existing in the real world and combining knowledge graph and entity search technologies.

(1) Relationship Between Knowledge Modules and Entity Categories:

As is well known, different industries and domains contain different knowledge modules (corresponding to entity categories in knowledge graphs). Under knowl-

edge modules are different knowledge points (corresponding to entities in knowledge graphs), and under each knowledge point are different content items (corresponding to attributes in knowledge graphs). Their representation in knowledge graphs can be shown in Figure 2. For each entity in the figure, besides basic attributes associated with the entity, there are numerous entity categories associated with the entity. It is these entity categories that enrich the semantic association information of entities because entity search technology can perform searches on these associated entity categories [21]. To display these entity categories and their related information in knowledge panels, different knowledge modules need to be pre-designed to match corresponding entity categories in knowledge graphs. These modules may include “person,” “place,” “location,” “movie,” “product,” “image,” and “book.” Of course, in practical applications, corresponding knowledge modules will be refined and designed according to actual business needs.

Additionally, it should be considered that for a knowledge module, there may be multiple associated sub-modules. For these refined sub-modules, corresponding specific knowledge modules also need to be established. For example, for a “person” knowledge module, there may be an “actor” knowledge module, a “singer” knowledge module, and another “political figure” knowledge module. Similarly, the design of these sub-modules is still based on actual business requirements.

(2) Manifestation of Knowledge Modules in Knowledge Graphs: Figure 2 [Figure 2: see original paper] shows a subgraph of the entity, entity category, and relationship network, which is a vivid description of information contained in knowledge graphs, mainly consisting of nodes and edges. The entity network may contain three types of nodes: - **Entity:** As mentioned earlier, an entity can be anything. Entities in Figure 2 include E1, E2, and E3. - **Semantic Class (Entity Category, Knowledge Module):** A type of entity or a collection of entities, such as “country,” “city,” “school,” “person,” and “political figure.” C1, C2, C3, and C4 in Figure 2 are semantic classes. - **Text:** Usually serving as names and descriptions of entities and semantic classes, or attribute values, such as T1~T5 in Figure 2.

Additionally, the types of edges between nodes in this network are divided into three categories: - **Entity-Semantic Class:** From an entity pointing to its semantic class. This type of edge is marked in Figure 2. - **Subclass (Entity Category, Knowledge Module)-Superclass (Entity Category, Knowledge Module):** From a semantic class pointing to its parent class, identified as “superclass” in Figure 1. It is worth noting that many such associations may exist in practical applications, and the associations are complex. - **Attribute:** From an entity pointing to its attribute value. Different attribute types correspond to different types of edges. For example, “birthplace,” “wife,” and “birth” in Figure 2 are three different attributes. All entities and semantic classes have a special attribute “name” that points to text-type nodes, representing the name or natural language expression of the entity or semantic class (such as Chinese name, English name, etc.).

[Figure 2: see original paper]

(3) Relevance Between Knowledge Modules: As can be seen from Figure 2, an entity is associated not only with multiple attributes but also with multiple entity categories. The process of displaying information related to that entity in knowledge panels is the process of selecting the most relevant and valuable content items connected to the entity in the network graph shown in Figure 2 according to relevance. The entire selection process is accomplished through entity search technology [22]. In addition to existing relevance between entities and between entity categories in the network graph, entity search technology also needs to leverage other important relevance information related to entities to match important content items in knowledge graphs, such as context, novelty, importance, user's current geographic location, access logs, and recent user session information. Regardless of the type of relevance, they all represent the degree of relevance to the entity through a certain weight value. Content items with larger weights are more likely to be selected as candidates [23]. Consequently, the searched content may be more accurate and better aligned with user search needs.

4.3 Workflow Analysis and Discussion

The core idea of knowledge panels is to display the most relevant structured summary information for a specific entity rather than a category of documents to better satisfy user information needs. Essentially, this display process is the process of entity search algorithms understanding user intent, performing searches in knowledge graphs, and providing the most direct results. This involves two core retrieval subtasks: first, using relevance to find corresponding entities in knowledge graphs; second, based on the previous step, using entity categories and entity relationships to find related entities [24]. To achieve a systematic understanding of the knowledge panel content display process, or to gain a more systematic understanding of its working principles, the author summarizes a workflow consisting of ten components and elaborates on it in detail.

The workflow shown in Figure 3 [Figure 3: see original paper] begins with an entity and, after a series of complex internal operations, finally displays a knowledge panel for users. As can be seen from the entity network subgraph in Figure 2, for a particular entity, besides specific basic attributes connected to it, there are other entities also connected to it, which are similarly understood as attributes of that entity. To describe this more reasonably, each attribute of an entity is referred to as a content item. According to the display order of content in knowledge panels, the author provides a detailed analysis of the function provided by each component in the workflow.

[Figure 3: see original paper]

(1) Entity: The content displayed in knowledge panels is associated with user query statements, specifically with entities in query statements. However, the

representation of entities in query statements may not be standardized, requiring various processing to form a standardized entity, such as using context information from the query statement to disambiguate the entity. After standardized processing, the system obtains information related to entity categories, relationships, and context associated with the entity.

(2) Identifying Standard Content Items for Entities: For each entity, its standard content items include basic factual information related to the entity such as title, typical image, and description information. This information is the basic attribute information shown in Figure 2. Considering that an entity may have dozens or even more attributes, the system needs to assign a dynamically generated ranking score to each standard content item based on the entity's context and other information. This score is used to represent the degree of relevance and popularity to the entity, ensuring that standard content items with higher scores are likely to be selected as candidate content items.

(3) Identifying Additional Content Items for Entities: Additional content items for entities are other entities or information identified as being associated with the current entity. These identified other entities or information may also number in the dozens or more. Therefore, the system needs to assign a dynamically generated ranking score to each additional content item based on the entity's context and other information. This score is used to represent the degree of relevance and popularity to the current entity. For example, if one additional content item has a higher ranking score than another, it may be considered more relevant to the current entity. Additionally, additional content items with higher ranking scores may be selected as candidate content items for the entity.

(4) Identifying Content Categories for Each Content Item: Determine the content category for each identified content item. The same word (entity) can have completely different meanings in different contexts. To enable computers to understand the meaning of the word, the system needs to fully utilize the entity's context and other information. In knowledge graphs, an entity is associated with multiple entity categories. Therefore, the process of determining content categories is the process of fully utilizing the entity's context and other information to calculate the similarity between content items and each content category. If the calculated result value is larger, it indicates that the content item has a high degree of association with the content category, thus determining it can be a candidate content category. Common methods that can be used include: set-based, content-based, lexical-level category label similarity-based, and hierarchical structure distance measurement-based approaches. Additionally, content categories can be used to classify content items directly associated with the same or similar entity categories. Finally, content categories may also represent a content type. For example, a content category for image content can be used to identify content items of image files.

(5) Identifying Preferred Module Types for Content Categories: Assign a preferred module type to each content item or content item category. For

example, the system may designate an “image” module as the preferred module type for content items classified in the “movie” category. In this example, content items identified as “actors” in the “movie” category will typically be presented in the form of images in the “image” module. The selection of preferred module types is based on representations of content categories suitable for presenting information about content items. It is these preferred module types that enrich the content displayed in knowledge panels, because when displaying relevant information about an entity, one may only want to display corresponding images, tables, or comparable content rather than other less relevant information.

(6) Selecting Knowledge Modules to be Provided in Knowledge Panels Based on Preferred Module Types, Ranking Scores of Identified Content Items, and Panel Constraints of Knowledge Panels: The system selects knowledge modules based at least in part on the ranking scores of identified content items and the categories of identified content. Simultaneously, it also “considers” factors such as the limited display space of knowledge panels to decide which knowledge modules to display.

(7) Assigning Identified Content Items to Selected Knowledge Modules: Assign each identified content item or portion of identified content items to selected knowledge modules. The assignment process is based on the content category of content items. For example, designate a knowledge module for each content category, then assign portions of identified content items to each content category. If a knowledge module has a limited number of placeholders for content items—for instance, an image module only allows a row of five images—the system may assign content items with the highest ranking scores to the knowledge module. Additionally, content with lower ranking scores may be excluded from the knowledge module or may be included in the knowledge module as a response to additional user requests (such as requests that take context information into account).

(8) Assigning Selected Knowledge Modules to Positions in Knowledge Panels: The system assigns knowledge modules to corresponding positions in knowledge panels based on the ranking scores of identified content items or based on display constraints of knowledge panels. Display constraints specify an order for each knowledge module type, thereby allowing knowledge modules to be assigned to their respective positions in knowledge panels according to this specified order. For example, constraints may specify that image modules be displayed at the bottom of knowledge panels. If multiple knowledge modules are selected—for instance, two or more image modules—multiple knowledge modules may be assigned to corresponding positions in knowledge panels based on the ranking scores of identified content items assigned to the knowledge modules.

In implementation, the system can periodically use offline processing to select knowledge modules and content items for entities. Alternatively, this operation can be performed during user query time. By selecting knowledge modules and content items during query time, knowledge panels can present the most current content items that are more temporally relevant, such as content items related

to upcoming events.

(9) Populating Knowledge Panels with Selected Knowledge Modules and Identified Content Items: First, populate knowledge panel templates with standard content items. Second, populate the knowledge modules with identified and assigned content.

(10) Providing Knowledge Panels: Knowledge panels can be displayed in an appropriate position on the page or presented as pop-up windows when interacting with users, thereby serving as structured information recommendation boxes for certain entities. The collected and organized information is displayed to users in a unified format to concisely help users understand the main information about entities (keywords), thereby shortening the time users spend finding information. Additionally, knowledge panels can be displayed on multiple devices such as smartphones and tablets.

5 Conclusion

As a novel information recommendation mode, knowledge panels are gradually gaining industry attention. Because knowledge panels possess the characteristic of allowing users to automatically obtain information without actively searching for it, they can effectively satisfy user information needs and represent the future of computing and search. This paper conducted in-depth analysis and research on the implementation mechanism of knowledge panel technology and its related content, particularly providing detailed analysis of data sources, knowledge module design and planning, and workflow. From this research, we understand that conditionally displaying much entity-related information in knowledge panels is a significant challenge because it requires not only fully utilizing well-organized structured data and relationships (knowledge graphs) but also a completely new search technology (entity search).

The analysis and research indicate that to use knowledge panels as a new information recommendation mode for recommending relevant domain knowledge, first, we must fully mine user demand patterns and pre-plan and design relevant content points to be displayed. Second, existing knowledge must be reorganized into an updatable entity database in structures such as “entity-attribute-value” and “entity-relationship-entity.” Finally, different knowledge modules must be pre-designed for different types of entities, entity categories, and relationships to adapt to different display needs. Additionally, various current relevance factors of users must be considered in specific implementations, such as designing this information into a uniformly schedulable model. Overall, whether content in knowledge panels can effectively satisfy user needs is mainly determined by a comprehensive decision-making process based on multiple relevancies. In future research, the author will study entity search technology to better satisfy users’ knowledge acquisition needs or better meet users’ new demands for search services. Of course, to achieve comprehensive and efficient information recommendation services, the only way is to create an open ecosystem.

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