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Knowledge Graphs: An Information Retrieval Perspective

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ABSTRACT

In this survey, we provide an overview of the literature on knowledge graphs (KGs) in the context of information retrieval (IR). Modern IR systems can benefit from information available in KGs in multiple ways, independent of whether the KGs are publicly available or proprietary ones. We provide an overview of the components required when building IR systems that leverage KGs and use a task-oriented organization of the material that we discuss. As an understanding of the intersection of IR and KGs is beneficial to many researchers and practitioners, we consider prior work from two complementary angles: leveraging KGs for information retrieval and enriching KGs using IR techniques. We start by discussing how KGs can be employed to support IR tasks, including document and entity retrieval. We then proceed by describing how IR—and language technology in general—can be utilized for the construction and completion of KGs. This includes tasks such as entity recognition, typing, and relation extraction. We discuss common issues that appear across the tasks that we consider and identify future directions for addressing them. We also provide pointers to datasets and other resources that should be useful for both newcomers and experienced researchers in the area.

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Introduction

1.1 Motivation

A *knowledge graph* (KG) is a repository of entities as well as their relationships and attributes that is represented as a graph. In modern approaches to information access, KGs are ubiquitous (Dalton and Dietz, 2013). Specifically, in information retrieval (IR) KGs are instrumental in enabling semantic search.

There are two hallmarks of semantic search in an IR context: (1) going beyond "ten blue links" in order to return relevant results of any kind (such as direct answers, actionable entities, or relationships) and (2) understanding queries and documents, and improving the matching between them with relevant relationships. Ideally, a search engine is able to directly answer a user's information need—or at least generate possible interpretations of the information need that is expressed through the query. To achieve this goal, various entity-oriented components that solve specific problems at different stages in the information retrieval pipeline are required, including identifying entities in the query, identifying entities in documents, and methods that leverage entity and relationship information to help identify relevant items to retrieve.

Despite the fact that IR and KGs are increasingly intertwined in the context of modern web and domain-specific search engines, there is no broad treatment in the literature of KGs from an IR perspective, and vice versa. We aim to fill this gap through this survey by providing a task-oriented overview of research in this area.

1.2 Aims

The aim of this survey is to bridge two important components of modern information access: IR and KGs. We summarize research work, group related approaches, and discuss challenges shared across tasks at the interface of IR and KGs. Our contributions in this survey can be summarized as follows: (1) we present an extensive overview of tasks related to KGs from an IR perspective; (2) we provide a thorough review for each task; and (3) we present discussions on common issues that are shared among the tasks.

1.3 Methodology

To meet the aim articulated above and to be able to present the methods described in this survey in a systematic manner, we first identify different sets of tasks related to IR and KGs and group individual tasks that are closely related. The main organizational principle that we use in the survey is to group tasks in two directions: *knowledge graphs for information retrieval* and *information retrieval for knowledge graphs*.

For each task, we trace back its origin, the original motivation, setup, and define the task in a formal fashion. We then identify seminal work or influential approaches as they have been introduced over time. We group approaches based on characteristics that are natural for each task. We also identify related work based on these groupings. We put more emphasis on recent developments concerning the task, how the methods differ from early approaches, and the interesting additional problems that arise over time in the context of the task.

Having examined each task one-by-one, we then proceed to identify the key challenges that we encounter frequently across tasks. We focus on challenging aspects that will be beneficial for future research.

1.4 Scope

We consider over 300 publications published prior to 2020 and spanning the fields of information retrieval, knowledge representation, machine learning, and natural language processing. Due to the broad nature of the survey, we put more emphasis on recent advances involving new tasks and approaches. Thus, some tasks and approaches will be covered in greater detail than others.

In the survey, our view of IR is an inclusive one and that incorporates natural language processing and language technology techniques. We also consider tasks that have an origin in those fields, such as entity recognition, relation extraction, and knowledge base (KB) completion.

Some of the tasks that we consider cover a broad area. For broad tasks—that may well deserve a survey of their own—we only cover key publications and present the task in a high-level fashion. This includes tasks such as entity recognition, entity linking, and relation extraction. We present an overview of tasks, but refer the reader to existing surveys (if they exist) for details. For emerging, specific tasks we provide more details in addition to a literature review. We present their setup and contrast different approaches with more depth and detail.

Recent interest in the area of semantic search has not only given rise to hundreds of publications but also to attempts to synthesize the material. By now there is a growing number of tutorials in the area, which we enumerate in Appendix B.6. While we believe that ours is the first survey to focus on the interaction between IR and KGs, there is a recent survey on semantic search by Bast *et al.* (2016) that partially overlaps with ours. The most significant differences are that we discuss recent developments on how KGs are being leveraged for IR, we provide a broader coverage of knowledge graph construction and completion, and finally, we present several applications that involve a combination of the individual tasks and components in our survey.

1.5 Structure

The rest of this survey is organized as follows. In Section 2 we describe the background: definitions of fundamental concepts and notation that we use throughout the survey. In Section 3 we introduce core entity-related tasks on which we build in the remainder of the survey: entity linking and named entity recognition and classification. The heart of the survey consists of Sections 4 and 5. Section 4 describes how KGs are being leveraged to improve IR tasks. In Section 5 we turn the table and detail how IR and, more generally, language technology is being used for the construction and completion of KGs. Section 6 is meant to provide detailed motivation for the survey by offering treatments of end-to-end tasks at the interface of IR and KGs. We conclude the survey in Section 7 with a look back, with a discussion of the key issues that we identified in the course of the survey, and with potential research directions in at the interface of IR and KGs.

Acronyms used and useful resources used in this survey are listed in appendices to this survey, Appendix A and B, respectively.

As to possible reading orders of the material in the survey, we recommend the following. Readers who are relatively new to the area should simply read all sections in their natural order: 1, 2, . . . , 7. Readers who are already familiar with the area can move ahead to the core of the survey in Section 4. Alternatively, they can freshen up on notation and terminology in Section 2, catch up on the background material on entity linking and entity recognition and classification in Section 3, sample from Section 6, and then continue with the remaining material. See Figure 1.1.

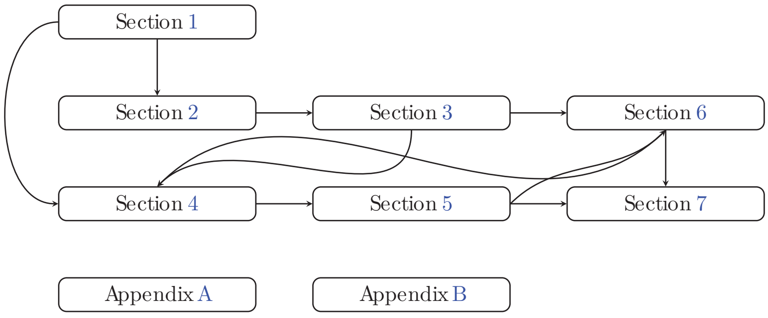

Figure 1.1: Possible reading orders.

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