We present a web-based tool Sangrahaka for annotating entities and relationships from text corpora towards construction of a knowledge graph and subsequent querying using templatized natural language questions. The application is language and corpus agnostic, but can be tuned for specific needs of a language or a corpus. The application is freely available for download and installation. Besides having a user-friendly interface, it is fast, supports customization, and is fault tolerant on both client and server side. It outperforms other annotation tools in an objective evaluation metric. The framework has been successfully used in two annotation tasks. The code is available from https://github.com/hrishikeshrt/sangrahaka.

Semantic tasks are high-level tasks dealing with the meaning of linguistic units and are considered among the most difficult tasks in NLP for any language. Question Answering (QA) is an example of a semantic task that deals with answering a question asked in a natural language. The task requires a machine to ‘understand’ the language, i.e., identify the intent of the question, and then search for relevant information in the available text. This often encompasses other NLP tasks such as parts-of-speech tagging, named entity recognition, co-reference resolution, and dependency parsing [21].

Making use of knowledge bases is a common approach for the QA task [19, 22, 30, 32]. Construction of knowledge graphs (KGs) from free-form text, however, can be very challenging, even for English. The situation for other languages, whose state-of-the-art in NLP is not as advanced in English, is worse. As an example, consider the epic Mahabharata in Sanskrit. The state-of-the-art in Sanskrit NLP is, unfortunately, not advanced enough to identify the entities in the text and their inter-relationships. Thus, human annotation is currently the only way of constructing a KG from it.

Even a literal sentence-to-sentence translation of Mahabharata in English, which probably boasts of the best state-of-the-art in NLP, is not good enough. Consider, for example, the following sentence from (an English translation of) “The Mahabharata” [15]:

Ugrasrava, the son of Lomaharshana, surnamed Sauti, well-versed in the Puranas, bending with humility, one day approached the great sages of rigid vows, sitting at their ease, who had attended the twelve years’ sacrifice of Saunaka, surnamed Kulapati, in the forest of Naimisha.

The above sentence contains numerous entities, e.g., Ugrasrava, Lomaharshana, as well as multiple relationships, e.g., Ugrasrava is-son-of Lomaharshana. One of the required tasks in building a KG for Mahabharata is to extract these entities and relationships.

Even a state-of-the-art tool such as spaCy [20] makes numerous mistakes in identifying the entities; it misses out on Ugrasrava and identifies types wrongly of several entities, e.g., Lomaharshana is identified as an Organization instead of a Person, and Saunaka as a Location instead of a Person. Consequently, relationships identified are also erroneous. This highlights the difficulty of the task for machines and substantiates the need for human annotation.

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1Mahabharata is one of the two epics in India (the other being Ramayana) and is probably the largest book in any literature, containing nearly 1,00,000 sentences. It was originally composed in Sanskrit.

2This is not a criticism of spaCy; rather, this highlights the hardness of semantic tasks such as entity recognition.
2 BACKGROUND

There are numerous text annotation tools available including WebAnno [35], FLAT [28], BRAT [26], GATE Teamware [14], and doccano [23], for handling a variety of text annotation tasks including classification, labeling and sequence-to-sequence annotations.

Ideally, an annotation tool should support multiple features and facilities such as friendly user-interface, simple setup and annotation, fairly fast response time, distributed framework, web-based deployment, customizability, access management, crash tolerance, etc. In addition, for the purpose of knowledge-graph focused annotation, it is important to have capabilities for multi-label annotations and support for annotating relationships.

While WebAnno is extremely feature rich, it compromises on simplicity. Further, its performance deteriorates severely as the number of lines displayed on the screen increases. GATE also has the issue of complex installation procedure and dependencies. FLAT has a non-intuitive interface and non-standard data format. Development of BRAT has been stagnant, with the latest version being published as far back as 2012. The tool doccano, while simple to setup and use, does not support relationship annotation. Thus, unfortunately, none of these tools supports all the desired features of an annotation framework for the purpose of knowledge-graph annotation. Further, none of the above frameworks provide an integration with a graph database, a querying interface, or server and client side crash tolerance.

Thus, to satisfy the need of an annotation tool devoid of these pitfalls, we present Sangrahaka. It allows users to annotate and query through a single platform. The application is language and corpus agnostic, but can be customized for specific needs of a language or a corpus. Table 1 provides a high-level feature comparison of these annotation tools including Sangrahaka.

A recently conducted extensive survey [24] evaluates 78 annotation tools and provides an in-depth comparison of 15 tools. It also proposes a scoring mechanism by considering 26 criteria covering publication, technical, function and data related aspects. We evaluate Sangrahaka and other tools using a the same scoring mechanism, albeit with a modified set of criteria. The details are in § 4.

3 ARCHITECTURE

Sangrahaka is a language and corpus agnostic tool. Salient features of the tool include an interface for annotation of entities and relationships, and an interface for querying using templatized natural language questions. The results are obtained by querying a graph database and are depicted in both graphical and tabular formats. The tool is also equipped with an administrators’ interface for managing user access levels, uploading corpora and ontology creation. There are utility scripts for language-specific or corpus-specific needs. The tool can be deployed on the Web for distributed annotation by multiple annotators. No programming knowledge is expected from an annotator.

The primary tools and technologies used are Python 3.8 [29], Flask 1.1.2 [16, 25], Neo4j Community Server 4.2.1 [31], SQLite 3.35.4 [18] for the backend and HTML5, JavaScript, Bootstrap 4.6 [4], and vis.js [13] for the frontend.

3.1 Workflow

Figure 1 shows the architecture and workflow of the system.

The tool is presented as a web-based full-stack application. To deploy it, one first configures the application and starts the server. A user can then register and login to access the interface. The tool uses a role based access system. Roles are Admin, Cursor, Annotator, and Querier. Permissions are tied to roles. Table 2 enlists the roles and the permissions associated with them. A user can have more than one role. Every registered member has permission to access user control panel and view corpus.

An administrator creates a corpus by uploading the text. She also creates a relevant ontology for the corpus and grants annotator access to relevant users. The ontology specifies the type of entities and relationships allowed. An annotator signs in and opens the corpus viewer interface to navigate through lines in the corpus. For every line, an annotator then marks the relevant entities and can make a decision of whether to keep or discard a specific annotation. This is useful to resolve conflicting annotations. An administrator may customize the graph generation mechanism based on the semantic task and semantics of the ontology. She then imports the generated graph into an independently running graph database server. A querier can then access the querying interface and use templatized natural language questions to generate graph database queries. Results are presented both in graphical as well as tabular formats and can be downloaded as well.

3.2 Backend

The backend is written in Python, using Flask, a microwebframework. Pluggable components of the backend are a relational database and a Neo4j graph database server.

Web Framework: The web framework manages routing, templating, user-session management, connections to databases, and other backend tasks. A Web Server Gateway Interface (WSGI) HTTP server runs the Flask application. We use Gunicorn [6] running behind an NGINX [9] reverse proxy for this purpose. However any WSGI server, including the Flash’s in-built server, can be used.

Data: Data related to user accounts, roles as well as corpus text, ontology, entity annotations and relationship annotations are stored in a relational database. This choice is made due to the need of
cross-references (in database parlance, joins) across user, corpus and annotation related information. Any relational database compatible with SQLAlchemy [11] can be used. We have used SQLite. An administrator uploads various chapters in a corpus as JSON files using a pre-defined format. Each JSON object contains text of the line and optional extra information such as word segmentation, verse id, linguistic information etc. The structure of JSON file corresponding to a chapter is explained in Appendix A of [27]. This information is then organized in a hierarchical structure with 4 levels: Corpus, Chapter, Verse and Line. Additionally, there is an Analysis table that stores the linguistic information for each line. The system is equipped to deal with morphologically rich languages. Lemmas (i.e., word roots) are stored in a separate table and referenced in entity and relationship annotations. Every entity annotation consists of a lemma, an entity type, a line number and user-id of the annotator. Every relationship annotation consists of a source (lemma), a target (lemma), a relationship type, an optional detail text, a line number and user-id of the annotator.

Knowledge Graph: A knowledge graph is constructed using the entity and relationship annotations. Neo4j is used as the graph database server to store and query the KG. Connection to it is made using the Bolt protocol [3]. Hence, the graph database can exist independently on a separate system. Cypher query language [5] is used to query the graph database and produce results.

Natural Language Query Templates: Templates for natural language questions are added by an administrator. A query template has two essential components, a natural language question with placeholder variables and a Cypher equivalent of the query with references to the same placeholder variables. Placeholder variables represent values where user input is expected. Query templates are provided in a JSON file whose structure is explained in Appendix A of [27]. The natural language query template, combined with user input, forms a valid natural language question, and the same replacement in Cypher query template forms a valid Cypher query.

Configuration: The application contains several configurable components. The entire configuration setting is stored in a settings file. Table 3 explains some important configuration options.

Utility Scripts: Utility Python scripts are provided for tasks that need to be performed in the background. The primary among these is a graph generation script to generate JSONL [8] formatted data suitable for direct import in the Neo4j Graph Database. Sample scripts are also provided for generation of corpus file and query template file. These can be easily customized to suit corpus specific or application specific needs.

### 3.3 Frontend

The frontend is in form of a web application. HTML5 webpages are generated using Jinja template engine [7], styled using Bootstrap 4.6 and made interactive using JavaScript. The web-based user interface has several components that are accessible to users based on their roles. The user interface is shown in Figure 2.

**Corpus Viewer Interface:** The corpus viewer interface consists of a row-wise display of lines in a corpus. For such languages such as Sanskrit, German, Finnish, Russian, etc. that exhibit a large number of compound words, the corpus viewer can display the word-split output added by the administrator. Further, an administrator may run other language specific tools to obtain any kind of semantic and syntactic information about the components of the sentence as a list of key-value pairs. The corpus viewer displays this information in a tabular format whenever a line is selected.

**Annotator Interface:** The annotator interface is interlinked with the corpus viewer interface. It contains two views, one for entity annotation and the other for relation annotation. Adaptive autocomplete suggestions are offered based on previously added lemmas and lemmas present in the line being annotated.

**Query Interface:** The query interface makes use of pre-defined natural language query templates and combines them with user input to form Cypher queries. A user may directly edit the Cypher query as well if she so desires. These are communicated to the graph database using Bolt protocol and results are fetched. Result of a Cypher query is a subgraph of the knowledge graph and is presented in an interactive interface that allows users to zoom-in to specific areas of the graph, rearrange nodes and save the snapshot of the graph as an image. Results are also displayed in a tabular manner and can be exported in various file formats including CSV, JSON, text, etc.

**Admin Interface:** The administrator frontend allows an administrator to perform tasks such as change users’ access levels, create...

### Table 3: Main configuration options

| Option            | Explanation                        |
|-------------------|------------------------------------|
| Admin user        | Username, Password and E-mail of owner |
| Roles             | Configuration of Roles and Permissions |
| SQL config        | SQLAlchemy compatible Database URI  |
| Neo4j config      | Server URL and Credentials          |

![Figure 1: Architecture and Workflow](image-url)
corpus, upload chapters in a corpus, and create ontology. Adding a new corpus requires two steps: corpus creation and chapter upload. The corpus creation step refers to creating a new entry in the Corpus table along with a description. Once a corpus has been added, chapters associated with the corpus can be uploaded.

**Ontology Creation**: The ontology creation interface allows an administrator to add or remove node types and relation types. If an entity or relation type is being used in an annotation, removal of the same is prevented.

**Curation**: Curation is performed through the annotation interface. A curator can see annotations by all annotators and can choose to keep or remove them as well as add new annotations.

### 3.4 Fault Tolerance

Corpus viewer and annotation interface act as a single-page application [10] and make use of AJAX [2] calls to communicate with the server. Entity and Relation annotation processes have two steps, ‘Prepare’ and ‘Confirm’. Once an entity or a relation is prepared, it is stored in a browser based localStorage [17] that persists across browser sessions and is, thus, preserved even if the browser crashes. Once a user clicks ‘Confirm’, an attempt to contact the server is made. If the attempt is successful and the data is inserted in the database successfully, the server returns success and the data associated with that annotation is cleared from the local storage. If the server returns failure, the data persists. Thus, a server crash does not affect the user’s unconfirmed annotations. Further, if a page is already loaded in the browser and the server crashes, a user can still continue to annotate. The unconfirmed entities and relations are color coded and can be easily located later to confirm once the server is restored. Thus, the application is fault-tolerant on both client and server side. This is an important feature that distinguishes Sangrahaka from other tools.

### 4 EVALUATION

The tool has been used for two distinct annotation tasks: (1) a chapter from a medical text (Ayurveda) corpus in Sanskrit (BPN) [1], and (2) full text of the epic Ramayana in English (VR) [12]. Table 4 presents details of these tasks.

As a subjective evaluation of the tool, the annotators from both the tasks, were asked to rate the tool on a scale of 5. We received an overall rating of 4.5 from 10 annotators.

As an objective evaluation, we followed the methodology used in [24]. We dropped parameters linked to publication and citations and those that were not met by any tool. Instead, we added 4 new criteria, namely (1) support for querying, (2) server side and (3) client side crash tolerance and (4) distributed annotation support. We re-evaluated the three highest-scoring tools (WebAnno, BRAT, and FLAT) from [24] as well as Sangrahaka using the modified set of 25 criteria. Sangrahaka outperformed other tools with a score of 0.82 compared to FLAT (0.78), WebAnno (0.74) and BRAT (0.70). Further details about the evaluation can be found in Appendix B of [27].

### 5 CONCLUSIONS AND FUTURE WORK

In this paper, we have proposed a web-based tool Sangrahaka for annotation and querying of knowledge graphs.

In future, we plan to streamline the process of running utility scripts and third-party NLP tools directly through the frontend. We also aim to explore ways of resolving conflicting annotations automatically. Further, we will release more user-friendly installation options such as Docker, VM, etc.
A DATA EXAMPLES

The tool primarily uses JSON data format for various purposes such as corpus input and query template definitions.

A.1 Corpus Format

The outermost structure is a list containing objects corresponding to lines. The keys of a line object include text (line text), split (optional text with word segmentation), verse (optional verse id in case of poetry), analysis (optional linguistic information as a list of key-value pairs, corresponding to tokens in the sentence).

Following is an example of a corpus file containing a single sentence.

```
[{
  "verse": 1,
  "text": "To sainted Nárad, prince of those",
  "split": "",
  "analysis": {
    "source": "spacy",
    "text": "",
    "tokens": [
      {
        "Word": "Nárad",
        "Lemma": "Nárad",
        "Tag": "NNP",
        "POS": "PROPN"
      },
      {
        "Word": "prince",
        "Lemma": "prince",
        "Tag": "NN",
        "POS": "NOUN"
      }
    ]
  }
}],
```

A.2 Query Template

The outermost structure is a list, containing query objects. Each query object corresponds to a single query template and has the keys gid, groups, texts, cypher, input and output where gid is used to group similar queries together in the frontend, and groups and texts are objects that contain language names as keys, and names of groups and query texts in those languages as values. If a query expects user input, those are specified as {0} in the query text. The value of key input is a list of objects containing information to populate frontend user-input elements. Every object should have a unique id for the element and a type of the input element. The valid types are entity, entity_type, relation and relation_detail.
Following is an example of a query template file containing a single query,

```json
[
  {
    "gid": "1",
    "cypher": "MATCH (p1)-[r:IS_FATHER_OF]->(p2)
                 WHERE p2.lemma =~ "{0}" RETURN *",
    "input": [
      {
        "id": "p",
        "type": "entity"
      }
    ],
    "output": [
      "p1", "r", "p2"],
    "texts": {
      "english": "Who is the father of {0}?",
    },
    "groups": {
      "english": "Kinship",
    }
  },
]
```

### B. Evaluation

Due to the nature of semantic annotation, where an annotator usually has to spend more time on mentally processing the text to decide the entities and relationships than the actual mechanical process of annotating the text, and the fact that annotations are done over several sessions of various lengths over an extended period of time, time taken for annotation is not an adequate metric of evaluation.

#### B.1 Subjective Evaluation

As a subjective evaluation, a survey was conducted among the annotators from two annotation tasks. They were asked to rate the tool on a scale of 5 in several metrics. The survey also asked them to describe their experience with Sangrahaka. A total of 10 annotators participated in the survey.

Table 5 shows the ratings given by the users. Figure 3 shows a word-cloud representation of the testimonials provided by the users.

#### B.2 Objective Evaluation

Neves et al. [24] used 26 criteria classified in four categories, viz., publication, technical, data and functional. We considered four additional criteria A1, A2, A3 and A4. Criteria from publication category (P1, P2 and P3) have not been considered. Further, the criteria which were not satisfied by any of the tools in the comparison (F2 and F6), have also been omitted for the score calculation purpose.

Table 6 lists the 25 criteria that we have used for evaluation of the annotation tools.
| ID | Description                              | Weight | WebAnno | doccano | FLAT  | BRAT | Sangrahaka |
|----|------------------------------------------|--------|---------|---------|-------|------|------------|
| P1 | Year of the last publication             | 0      | 1       | 0       | 0     | 1    | 1          |
| P2 | Citations on Google Scholar              | 0      | 1       | 0       | 0     | 1    | 0          |
| P3 | Citations for Corpus Development         | 0      | 1       | 0       | 0     | 1    | 0          |
| T1 | Date of the last version                 | 1      | 1       | 1       | 1     | 0.5  | 1          |
| T2 | Availability of the source code          | 1      | 1       | 1       | 1     | 1    | 1          |
| T3 | Online availability for use              | 1      | 0       | 0       | 1     | 0    | 0          |
| T4 | Easiness of Installation                 | 1      | 0       | 1       | 1     | 0.5  | 1          |
| T5 | Quality of the documentation             | 1      | 1       | 1       | 1     | 1    | 0.5        |
| T6 | Type of license                          | 1      | 1       | 1       | 1     | 1    | 1          |
| T7 | Free of charge                           | 1      | 1       | 1       | 1     | 1    | 1          |
| D1 | Format of the schema                     | 1      | 1       | 1       | 1     | 0.5  | 1          |
| D2 | Input format for documents               | 1      | 1       | 0.5     | 1     | 1    | 1          |
| D3 | Output format for annotations            | 1      | 1       | 1       | 0.5   | 1    | 0          |
| F1 | Allowance of multi-label annotations     | 1      | 1       | 0       | 1     | 1    | 1          |
| F2 | Allowance of document level annotations  | 0      | 0       | 0       | 0     | 0    | 0          |
| F3 | Support for annotation of relationships  | 1      | 1       | 0       | 0     | 1    | 1          |
| F4 | Support for ontologies and terminologies | 1      | 1       | 0       | 1     | 1    | 1          |
| F5 | Support for pre-annotations             | 1      | 0.5     | 0       | 0.5   | 0    | 0          |
| F6 | Integration with PubMed                  | 0      | 0       | 0       | 0     | 0    | 0          |
| F7 | Suitability for full texts               | 1      | 0.5     | 0.5     | 1     | 1    | 1          |
| F8 | Allowance for saving documents partially | 1      | 1       | 1       | 1     | 1    | 1          |
| F9 | Ability to highlight parts of the text   | 1      | 1       | 1       | 1     | 1    | 1          |
| F10| Support for users and teams              | 1      | 0.5     | 0.5     | 1     | 0.5  | 0.5        |
| F11| Support for inter-annotator agreement    | 1      | 1       | 0.5     | 0     | 0.5  | 0.5        |
| F12| Data privacy                             | 1      | 1       | 1       | 1     | 1    | 1          |
| F13| Support for various languages            | 1      | 1       | 1       | 1     | 1    | 1          |
| A1 | Support for querying                     | 1      | 0       | 0       | 0     | 0    | 1          |
| A2 | Server side crash tolerance              | 1      | 0       | 0       | 0     | 0    | 1          |
| A3 | Client side crash tolerance              | 1      | 0       | 0       | 0     | 0    | 1          |
| A4 | Web-based/distributed annotation         | 1      | 1       | 1       | 1     | 1    | 1          |

**Total** 25  18.5  15.0  19.5  17.5  20.5

**Score** 0.74  0.60  0.78  0.70  **0.82**

Table 6: Criteria for evaluation of annotation tools