USING DYNAMIC KNOWLEDGE GRAPH FOR FAKE NEWS EARLY DETECTION

by

Albertus Andito

Candidate Number 198910

INTERIM REPORT

Bachelor of Computer Science

UNIVERSITY OF SUSSEX

2020

Table of Contents

List of Figures iii

1 Introduction 1

1.1 Problem Area 1
1.2 Aim and Objectives 3
1.2.1 Primary Objectives 3
1.2.2 Extension Objective 5
1.3 Motivation 5
1.4 Project Relevance 5

2 Professional and Ethical Considerations 7

2.1. BCS Code of Conduct 7
2.2. Ethical Issues 8

3 Background and Related Works 9

3.1 Knowledge Graphs 9
3.2 Dynamic Knowledge Graph 10
3.3 Automatic Fact-checking 10
3.4 Knowledge Stream 11
3.5 Knowledge Graph Embedding for Fake News Detection 12

4 Requirements Analysis 14

4.1 Target Users 14
4.2 High-level Design 14
4.3 Functional Requirements 16
4.3.1 Knowledge Graph Updater (KGU) 16
4.3.2 Fact-checker 16
4.3.3 User Interface (UI) 16
4.4 Non-Functional Requirements 17
4.5 Evaluation 17

5 Project Plan 19

References 22

Appendix A: Meeting Log 24

Appendix B: Proposal Document 27

Appendix C: Ethical Compliance Form 30

List of Figures

Fig 1. Example of a knowledge graph 3
Fig 2. Streams of knowledge example 12
Fig 3. Simple TransE illustration 13
Fig 4. High-level system design 15
Fig 5. Gantt chart of the project plan 21

1 Introduction

Fake news has been considered as a serious problem that is affecting society in the last few years, especially after the 2016 United States presidential election result was heavily influenced by fake news, where it was estimated that the average American saw one or more news stories from fake news websites before the election [1]. Many approaches to identify and tackle fake news have been devised, including manual fact-checking, which is done by websites such as Snopes[1] and Fullfact[2], and automatic fake news detectors, such as ones that are proposed by [2], [3], and [4].

The existing automatic fake news detection methods generally work well for news that have been published way in the past. However, news articles are often about recent events, including events that are still happening. Thus, some knowledge and facts could become invalid in just a short period of time. A fake news detection system should be able to cope with such timeliness of news, where information or facts dynamically change over time. With that, fake news can be recognised early and immediately after the ground truth is updated.

This project is focusing on overcoming that timeliness characteristic of news by developing a fake news detection system that uses dynamic knowledge graph to store the ground truth.

1.1 Problem Area

Preventing and mitigating the spread of fake news at an early stage is crucial because people are more likely to trust fake news when it has become widespread [5]. Fake news early detection aims to help achieve that, although it comes with some challenges.

[1] https://www.snopes.com
[2] https://fullfact.org/

As mentioned above, the timeliness of news means that the ground truth information changes over time, even potentially in just a short period of time. This rapid change of information usually happens for breaking news. For example, in 2012, former Egyptian president Hosni Mubarak was reported to be "clinically dead", before it was then clarified that he was in a critical condition[3]. Although the example might be an edge case, all other news also brings new information that requires the ground truth to be updated.

Current automatic fake news detection solutions do not incorporate this timeliness aspect of news. Some techniques, including ones in [6] and [7], rely on how the fake news propagates on social networks, which is too late for detecting fake news at an early stage as no social context information is available yet at that time [8]. Other techniques, such as the one in [8], detect fake news based on the writing style that is used in the article. However, as deceptive writing style keeps evolving, such methods may not be accurate in the future and not applicable for all news topics [9].

Therefore, a fake news early detection system should primarily depend only on the news content itself, which can be done with knowledge-based fake news detection methods. In a knowledge-based fake news detection, information is stored in a knowledge graph as a set of SPO (Subject, Predicate, Object) triples. For instance, the information from the sentence "Sanjeev Bhaskar is the chancellor of the University of Sussex" can be represented as `(SanjeevBhaskar, Chancellor, UniversityOfSussex)` triple in the knowledge graph. Thus, the knowledge graph is a graph structure that represents facts as SPO triples, where the entities (subjects and objects) are represented as nodes and the relationships (predicates) are represented as edges [5]. To check whether a news article is valid or not, the information from the article is compared with the knowledge graph using fact-checking techniques, such as knowledge graph embedding TransE [10] as used in [11] and Knowledge Stream [12].

[3] https://edition.cnn.com/2012/06/19/world/meast/egypt-mubarak/index.html

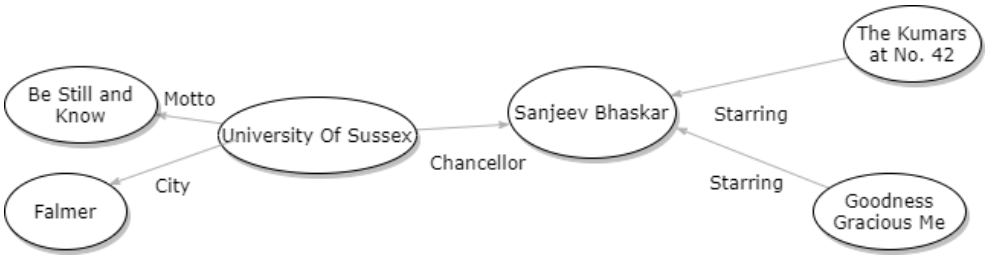


Fig 1. Example of a knowledge graph

The problem arises when the knowledge graph does not contain the latest information, which could result in the fact-checking being incorrect when verifying a recent article. To overcome this problem, the system should be able to: gather new trusted articles; extract the triples from the articles; and add or remove triples to and from the knowledge graph, which will make the knowledge graph dynamic. With this, the fact-checking method will use an up-to-date knowledge graph every time it verifies an article.

1.2 Aim and Objectives

The aim of this project is to develop a fake news detection system where the ground truth is stored in a dynamic knowledge graph and updated in real-time, in an attempt to recognise fake news at an early stage. To achieve that aim, several objectives for this project are explained below.

1.2.1 Primary Objectives

1) Carry out an evaluation on existing knowledge-based fake news detection systems. Some papers around knowledge-based fake news detection have been published, including [2] and [12]. Although they do not incorporate the timeliness aspect of news and do not make use of dynamic knowledge graph, the general steps or framework should be similar. Therefore, they can serve as a baseline for this project.

2) Identify existing knowledge graphs that are relevant and can be extended for news data.

   It is possible to build a knowledge graph of news information from the ground up. However, open knowledge graphs that are actively maintained, such as DBpedia[4], Wikidata[5], or YAGO[6], can be utilised for this project. This should reduce the amount of work that needs to be done in this project.

3) Implement an article extractor that extracts SPO triples from articles and added them to the knowledge graph, while also removing outdated triples.

   This objective relates to the first part of the system, where the system should keep the knowledge graph updated.

4) Develop and implement at least two algorithms to compare the to-be-verified facts with the knowledge graph.

   As mentioned above, there exist algorithms and techniques that are used to verify information with the knowledge graph. This project should use and modify them as necessary so that they are more appropriate for dynamic knowledge graph.

5) Develop an interface for users to submit articles and check their truthfulness, and to update the knowledge graph.

   Another part of this system is the interface that should be able to run in 2 modes. The first mode is where the user can submit a claim or an article and expects the system to verify whether it is a correct statement or not. The other mode is where the user can update the knowledge graph manually so that the system incorporates user feedback.

6) Evaluate the different methods used to automatically verify the news articles.

[4] https://wiki.dbpedia.org/
[5] https://www.wikidata.org/
[6] https://yago-knowledge.org/

The news verification methods should be evaluated, either by running the system with a gold standard dataset, user evaluation, or both.

1.2.2 Extension Objective

Deploy the fake news detection system to a cloud server where it can run all the time. To make the system works in real-time, it needs to receive news articles all the time and immediately update the knowledge graph. If this objective is achieved, the system should be able to cope with all news, including ones that are very recent.

1.3 Motivation

The motivation of this project came from the fact that there has not been much research that utilises dynamic knowledge graph for fake news detection. Current research also mainly only uses traditional sources such as Wikipedia as the main knowledge base, rather than also incorporating checked news content, which could provide better domain knowledge [5]. Therefore, this project could have a novel contribution to the fake news detection research field.

In addition to that, as fake news remains a huge problem in our society, a system that could detect fake news in real-time, such as one proposed in this project, will be beneficial for a lot of parts of the society, including ones that tend to be easily deceived by misinformation.

1.4 Project Relevance

This project is relevant to my degree course, BSc Computer Science (with an industrial placement year) for several reasons. It focuses on research in the field of Natural Language Processing, which I have learnt from the Natural Language Engineering module and will study further in the Advanced Natural Language Engineering module next term. Being able to construct a computer-based system is one of the course learning outcomes. Thus, the Software Engineering module and my industrial placement year experience will also prove to be useful for the development part of this project.

The rest of this report is structured as follows: professional and ethical considerations are justified in section 2; related works and background research are explained in section 3; requirements analysis is detailed in section 4; and the project plan is shown in section 5.

2 Professional and Ethical Considerations

2.1. BCS Code of Conduct

This project will be undertaken with the BCS Code of Conduct[7] in mind. The relevant points are explained in this subsection. *With regards to public interest, you shall:*

1.1 – have due regard for public health, privacy, security, and wellbeing of others and the environment. The system will use articles only from trusted news sites, which should not have any distressing content. If any disturbing contents are found, I shall bring this issue to my supervisor.

1.2 – have due regard for the legitimate rights of third parties. All tools and libraries used in this project will be free to use, if not open-sourced. Articles from news sites are allowed to be used in this project as this is a non-commercial project.

With regards to professional competence and integrity, you shall:

2.1 – only undertake to do work or provide a service that is within your professional competence. I have taken university modules that are related to this project, such as Natural Language Engineering and Software Engineering. That should mean I am competent enough to do this project.

2.5 – respect and value alternative viewpoints and seek, accept and offer honest criticisms of work. Feedback from my supervisor and user evaluation will be accepted and considered for the project's improvement.

2.7 – reject and will not make any offer of bribery or unethical inducement. No incentives will be given to the users evaluating this project.

[7] https://www.bcs.org/membership/become-a-member/bcs-code-of-conduct/

2.2. Ethical Issues

My supervisor and I have reviewed the university's Research Ethics Guidance and we believe that this project does not require ethical review. The data used in this project will come from news articles from trusted news sites, which means that they are unlikely to be distressing. However, if such content is found to be used, I will immediately contact my supervisor to mitigate the issue. The data used will not contain any personal information as they are publicly available on the internet and will not come from websites such as Twitter that mainly use user-driven content.

However, as this project will possibly undergo user evaluation, in which the users will be testing the system, an ethical compliance form is required to be completed. We believe that this project meets the 12 criteria listed in the form. Some of the criteria are justified below.

1. *Participants were not exposed to any risks greater than those encountered in their normal working life.* The system will not have any dangerous elements, as it will only consists of fake news detection and knowledge graph updating.
2. *The study materials were paper-based, or comprised software running on standard hardware.* Participants will test the system running on a standard laptop.
5. *No information about the evaluation or materials was intentionally withheld from the participants.* Participants will be able to see the information in the knowledge graph that is being used, if they choose to do so.
8. *Neither I nor my supervisor are in a position of authority or influence over any of the participants.* Participants will be free to express any opinions on the system without any influence.
12. *All the data collected from the participants is stored securely, and in an anonymous form.* All responses will be stored securely on my laptop and all information will be anonymised.

A signed copy of the form is included as an appendix.

3 Background and Related Works

3.1 Knowledge Graphs

As briefly mentioned, a knowledge graph is a collection of facts in the form of SPO triples. In this project, the knowledge graph will be used as the ground truth for the fact-checking process. Although it is possible to build a knowledge graph from scratch by extracting facts only from news articles, the gathered knowledge will likely to be incomplete. Instead, a pre-existing knowledge graph can be used as the background knowledge graph, that can later be extended with the information from news articles.

There are several open knowledge graphs that are popular in the research community, including DBpedia, Wikidata, and YAGO. DBpedia is a static knowledge graph that extracts knowledge from Wikipedia and is currently being updated monthly with over 21 billion triples published [13]. Furthermore, DBpedia has developed DBpedia Live system where it keeps DBpedia in synchronisation with Wikipedia with a delay of at most a few minutes [14]. Even though this dynamic DBpedia Live service was shut down in May 2018, it was revived in May 2019[8]. Similarly, YAGO is a knowledge graph that extracts information from Wikipedia combined with synsets from WordNet. It is known to be a high-quality knowledge graph as it has a manually verified accuracy of 95% [15]. Wikidata is a crowdsourced knowledge graph that allows users to extend and modify the knowledge [16].

In [17], an in-depth comparison between the three knowledge graphs can be seen based on their accessibility, timeliness, and completeness. All provide data dumps that can be downloaded. The data set can be accessed using SPARQL from either the public endpoints or local endpoints if hosted locally. In terms of timeliness, Wikidata has the most updated information because of its crowdsourcing nature. DBpedia Live, which is continuously updated, can compete with Wikidata for this criterion. However, none of the three are

[8] https://blog.dbpedia.org/2019/08/01/dbpedia-live-restart-getting-things-done/

considered to have complete entities and relations, as combining the three will provide a more comprehensive data.

3.2 Dynamic Knowledge Graph

Constructing a dynamic knowledge graph automatically is still seen as an expensive technical challenge. NOUS is a framework for building dynamic knowledge graphs by combining an existing curated knowledge graph, such as YAGO or DBpedia, with extracted knowledge from unstructured text [18]. In NOUS, data comes continuously in a streaming fashion. Named entity extraction, co-reference resolution, and relationship extraction using OpenIE [19] are performed every time the input data arrives for triple extraction

The entities in the extracted triples need to be matched to entities that are in the curated knowledge graph. A distant supervision-based approach was used to learn a rule-based model for every predicate and map them from the extracted triples to the target knowledge graph. If the entities or relations are not found, a new node or relation is created into the custom knowledge graph.

3.3 Automatic Fact-checking

In their survey, Zafarani and Zhou [5] have explained what one needs to do to perform an automatic fact-checking process for knowledge-based fake news detection. The process can be split into fact extraction and fact-checking stages. In the former stage, the knowledge graph is constructed by extracting knowledge from the sources as raw facts, which then needs to be cleaned-up by tackling some issues. The redundancy issue can be solved with entity resolution [20], invalidity can be addressed by allowing facts to have start and end dates, conflicting knowledge can be resolved by Multi-Criteria Decision-Making [21], unreliability can be tackled by not using low-credibility websites as the sources, and incompleteness can be solved by performing link prediction between entities to infer new facts from existing facts.

In the fact-checking stage, a to-be-verified `(Subject, Predicate, Object)` triple is compared with the true facts contained in the knowledge graph. The entities in `Subject` and `Predicate` need to be located on the knowledge graph. If the entities matched, the triple is considered to be true if the edge connecting the entity nodes is labelled as `Predicate`. Otherwise, the triple can be considered as false, or a knowledge inference can be done for the triple. Knowledge inference involves computing the probability of an edge labelled as `Predicate` connecting `Subject` and `Object` nodes to exists in the knowledge graph, which can be done with link prediction techniques.

Formally, the fact-checking problem can be defined with the following formulae,

$$\mathcal{F} : (s_i, p_i, o_i) \xrightarrow{G_{KB}} A_i$$

$$A = I\ (A_1, A_2, \dots, A_n)$$

where $\mathcal{F}$ is a function that assigns the authenticity or truthfulness value to the (s_i, p_i, o_i) triples from the to-be-verified article by comparing them with the triples in the knowledge graph G_{KB}. A_i is 1 if the triple is true and 0 otherwise. The to-be-verified article is considered to be true when A is 1 and 0 otherwise, which is calculated by using an aggregating function I (weighted or arithmetic average) to aggregate all A_i's.

3.4 Knowledge Stream

[12] proposed a novel unsupervised method for fact-checking which treats knowledge graph as a flow network, named Knowledge Stream. A "stream" is a collection of paths that connect the Subject and Object entities. Figure 3 shows the best paths computed by Knowledge Stream for `(David and Goliath (book), author, Malcolm Gladwell)` triple. Here, knowledge is seen as an abstract commodity that needs to be transferred from the Subject to the Object entity across the network. Each edge in the network has a capacity to carry knowledge and a cost of usage. The capacity is calculated as the product of the cosine similarity between the edge label and the predicate of the triple, and a specificity degree of the entity.

Meanwhile, the cost is also set as the specificity degree of the entity. With this method, fact-checking is viewed as the problem of finding the optimal paths that move the maximum flow of knowledge with the minimum cost. After the paths in the stream are found, the truth score of the triple is calculated as the sum of the net flow across all paths in the stream.

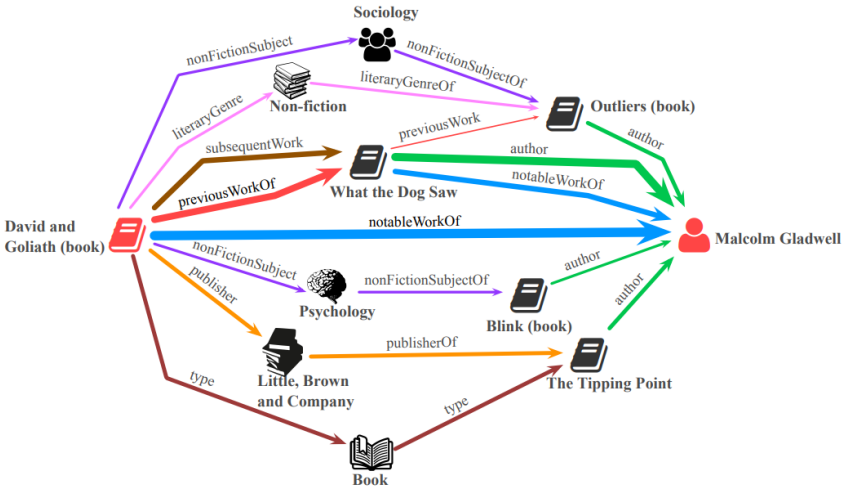


Fig 2. Streams of knowledge example

An experiment shows that Knowledge Stream often outperforms other existing fact-checking methods, such as PredPath [22], Knowledge Linker [23], and PRA [24], when it is run against real-world datasets. Another advantage of this method is that Knowledge Stream is a purely supervised algorithm, unlike PredPath and PRA that require supervision.

3.5 Knowledge Graph Embedding for Fake News Detection

Another way of performing knowledge inference or link prediction in fake news detection is by using knowledge graph embedding, which was explored in [2] and [11]. The purpose of knowledge graph embedding is to generate a vector representation of the entities and relations from the knowledge graph which can be easily manipulated without changing the existing structure of the knowledge graph [25]. A well-known knowledge graph embedding model is TransE, which interprets the relationship as a translation vector so that it connects the embedded entities with low error [10].

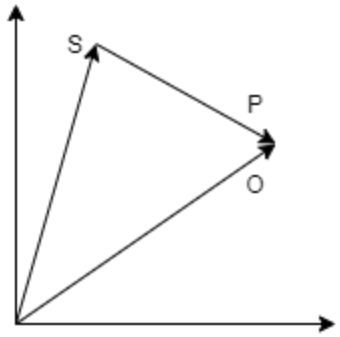


Fig 3. Simple TransE illustration

In the context of knowledge inference, given a triple (S, P, O), the embedding of O entity should be close to the embedding of S entity for the fact to be regarded as true. In other words, if the fact is true, $S + P \approx O$. Otherwise, $S + P$ should be far away from O if the fact is wrong. In [2], TransE model that represent triples as vector is trained using a knowledge graph, and a news item that consists of many triples is classified by calculating the error of each triple using the following formula,

$$f_b(triple_i) = \|s_i + p_i - t_i\|_2^2.$$

Either the average or the max of the errors from the triples of the news item determines whether the news is considered to be true or false. Specifically, when the error is large, the news is said to be false, and true otherwise. [2] has also developed a novel model, B-TransE, that uses two TransE models in which each is trained with fake news and true news, respectively. It performs better than the single TransE model.

[11] has compared the performance between TransE and the Knowledge Stream method discussed above in detecting fake news. It was concluded that when only real news articles are used as the background knowledge graph, TransE outperforms Knowledge Stream, although the latter performs better when using open knowledge graphs.

4 Requirements Analysis

4.1 Target Users

The target users of this fake news detection system would be the members of the public who want to check the validity of the news that they have received. The user might be a novice with technology, which means the interface of the system should be easy to follow. A more sophisticated user might want to have more control over the system. They can do this by providing feedback to the system on facts that they believe should be updated.

An example of a fact-checking tool that is currently accessible for public use is the Google Fact Check Explorer[9]. Using that tool, users can search for fact check results about a topic or person. However, the fact-checking process is not done by the tool. It compiles the fact-checking results from several manual fact-checking websites. An automated fact-checking system that is open for the public has yet to be seen.

4.2 High-level Design

A large part of this project is dedicated to developing the fake news detection system, which consists of two main parts. The first part is a component that keeps the knowledge graph updated, which is done by keeping a mirror of the chosen open knowledge graph and extend it with the triples extracted from the news articles. Therefore, this component must also be able to collect news articles periodically and extract the triples from them. This first component will be called the Knowledge Graph Updater. I acknowledge that automatically adding and removing new information to the knowledge graph will be a non-trivial problem. It will have some challenges, for instance, resolving conflicting information with many-to-many relationships and dealing with synonymy. However, to mitigate the issues, this component will benefit from the user feedback submitted through the user interface, which will help deciding whether a fact should be updated or not.

[9] https://toolbox.google.com/factcheck/explorer

The second part is a component that does the actual fact-checking. When a to-be-verified article is submitted, the component will extract the triples from the article and run the fact-checking algorithms on them. Whichever algorithms are used, this component will query or use the knowledge graph in some way to calculate the truthfulness of a to-be-verified news article. This component will be called the Fact-checker.

To make this system usable, an interface is needed for the users to interact with. The first part of the interface relates to the Fact-checker. Users will be able to submit a news article and receive a truthfulness score for the article. The second part of the interface is used for submitting feedback to the system on whether a fact in the knowledge graph should be updated or not, which relates to the Knowledge Graph Updater.

Figure 4 summarises how the components in the system interact with each other.

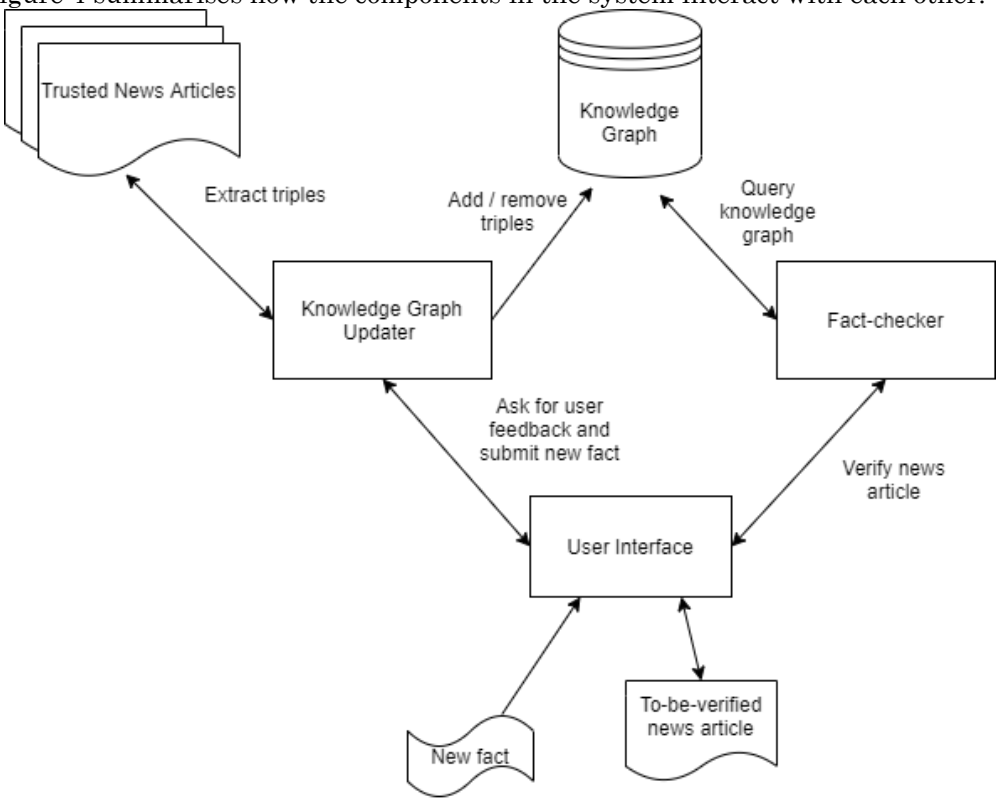


Fig 4. High-level system design

More detailed system requirements are described in the following functional and non-functional requirements subsections.

4.3 Functional Requirements

4.3.1 Knowledge Graph Updater (KGU)

1. The KGU should mirror or update the knowledge graph if the existing open knowledge graph used is updated.
2. The KGU should scrape news articles from trusted news websites periodically, at least every 1 hour if the system is running all the time.
3. The KGU shall extract SPO triples from the trusted news articles and from the user feedback.
4. The KGU shall add the extracted triples to the knowledge graph if the triples do not exist yet in the knowledge graph.
5. The KGU shall modify or remove triples from the knowledge graph if they are conflicting with the extracted triples.

4.3.2 Fact-checker

1. The fact-checker shall extract SPO triples from the to-be-verified news articles.
2. The fact-checker shall perform fact-checking algorithms on the to-be-verified triples.
3. Depending on the fact-checking algorithm, the fact-checker should be able to query the knowledge graph as needed.
4. The fact-checker shall return the calculated truthfulness score for the triples based on the fact-checking algorithms.

4.3.3 User Interface (UI)

1. In the fact-checking mode, the UI shall accept a news article in the form of sentences as input.

2. In the fact-checking mode, the UI should be able to accept a news article link as input.
3. In the fact-checking mode, the UI shall send the user input to the Fact-checker component.
4. In the fact-checking mode, the UI shall display the truthfulness score of an article received from the Fact-checker.
5. In the knowledge graph update mode, the UI shall accept a sentence as input.
6. In the knowledge graph update mode, the UI shall send the input to the KGU component.
7. In the knowledge graph update mode, the UI should return some form of feedback to the user stating that the knowledge graph has been updated, possibly by showing the related entities.

4.4 Non-Functional Requirements

1. The system shall be easy to use, at least in the fact-checking mode.
2. The system shall return the outputs to the user in real-time.
3. The system should be able to update the knowledge graph continuously in real-time.
4. The KGU and Fact-checker shall be written in Python as it offers plenty Natural Language Processing libraries.
5. The UI shall be a web interface written in HTML, CSS, and JavaScript.

4.5 Evaluation

There are several ways in which the system could be evaluated. The first approach would be to evaluate the different fact-checking algorithms used in the system, in relation to the dynamic knowledge graph usage. This is related to the Fact-checker's Functional Requirement 2 and 4. Labelled datasets that are available from the internet can be used for

the evaluation. It is also worth mentioning that the system is unlikely to have high accuracy for all types of entities and relations. Hence, it will be useful to constrain the relationships in the datasets for evaluation purposes.

In terms of usability, which is related to Non-Functional Requirement 1, user evaluation can be done for the system. Users will be asked to submit news articles and decide which algorithm they prefer. They will also see if the outputs from the system are helpful or not. A similar evaluation will also be done for the knowledge graph updater. As discussed in section 2, this user evaluation will be in compliance with the "Research Ethics Guidance".

5 Project Plan

Figure 5 shows the project plan as a Gantt chart. The project is currently on track, as I have finished the tasks that are required until this interim report is done. Those tasks include:

a. Initial background and related work research, which have been done extensively, although it is likely that this is a continuous process that will still be done during the development process.

b. Project proposal, which has been sent to and discussed with my supervisor.

c. Datasets research, where I have found several potential datasets to be used for evaluation.

d. Knowledge graph research, where I have compared several open knowledge graphs to be used as the background knowledge graph.

e. Requirements analysis for the system

f. High-level design of the system

g. This interim report

Remaining tasks that I will complete for this project:

h. Knowledge graph construction framework, where I will mirror an existing open knowledge graph as a background knowledge graph for this project.

i. Implement SPO triple extractor for sentences.

j. Implement news article scraper from trusted news sites.

k. Implement Knowledge Graph Updater which will add or remove triples to the knowledge graph. This is dependent on task h, i, and j.

l. Develop and implement multiple fact-checking algorithms, which is dependent on task h.

m. Implement Fact-checker component, which depends on task l.

n. Create the User Interface. For this to be fully functional, it depends on the completion of task k and m.

o. Evaluate fact-checking algorithms, which is dependent on task l.

p. User evaluation, which is dependent on task n.

q. Poster creation.

r. Draft report, which will be written as the project goes on.

s. Final report based on the supervisor's feedback on the draft report.

The number of hours per week that I will dedicate to this project is listed below:

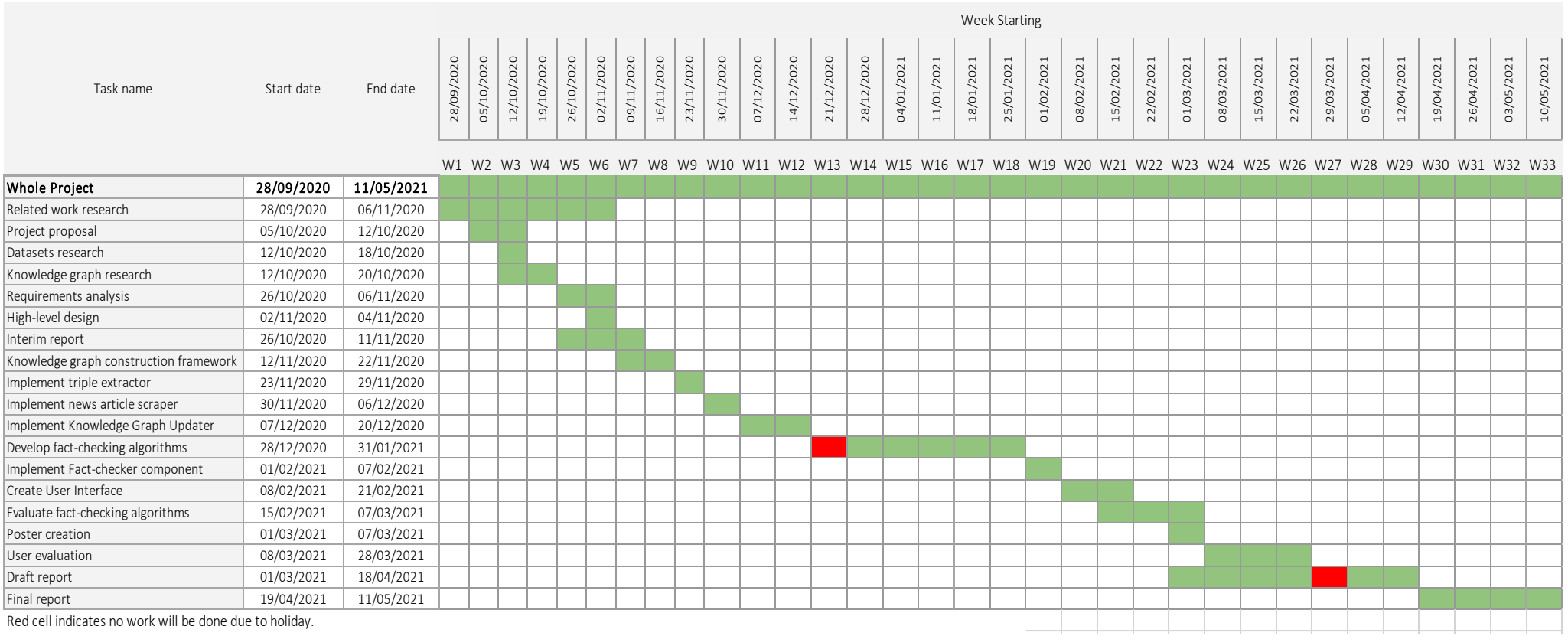
a. Autumn semester (– 11 December 2020): 10 hours

b. Spring semester: 20 hours

c. Holidays:

- 14 December 2020 – 20 December 2020: 20 hours
- 21 December 2020 – 27 December 2020: 0 hour
- 28 December 2020 – 3 January 2021: 20 hours
- 18 January 2021 – 24 January 2021 (intersemester week): 20 hours
- 29 March 2021 – 04 April 2021: 0 hour
- 05 April 2021 – 18 April 2021: 20 hours

d. Exam period (4 January 2021 – 17 January 2021): 5 hours



Task name	Start date	End date
Whole Project	**28/09/2020**	**11/05/2021**
Related work research	28/09/2020	06/11/2020
Project proposal	05/10/2020	12/10/2020
Datasets research	12/10/2020	18/10/2020
Knowledge graph research	12/10/2020	20/10/2020
Requirements analysis	26/10/2020	06/11/2020
High-level design	02/11/2020	04/11/2020
Interim report	26/10/2020	11/11/2020
Knowledge graph construction framework	12/11/2020	22/11/2020
Implement triple extractor	23/11/2020	29/11/2020
Implement news article scraper	30/11/2020	06/12/2020
Implement Knowledge Graph Updater	07/12/2020	20/12/2020
Develop fact-checking algorithms	28/12/2020	31/01/2021
Implement Fact-checker component	01/02/2021	07/02/2021
Create User Interface	08/02/2021	21/02/2021
Evaluate fact-checking algorithms	15/02/2021	07/03/2021
Poster creation	01/03/2021	07/03/2021
User evaluation	08/03/2021	28/03/2021
Draft report	01/03/2021	18/04/2021
Final report	19/04/2021	11/05/2021

Red cell indicates no work will be done due to holiday.

Fig 5. Gantt chart of the project plan

(Word count: 4782)

References

[1] H. Allcott and M. Gentzkow, "Social Media and Fake News in the 2016 Election," *J. Econ. Perspect.*, vol. 31, no. 2, pp. 211–236, May 2017, doi: 10.1257/jep.31.2.211.

[2] J. Z. Pan, S. Pavlova, C. Li, N. Li, Y. Li, and J. Liu, "Content Based Fake News Detection Using Knowledge Graphs," in *The Semantic Web – ISWC 2018*, vol. 11136, D. Vrandečić, K. Bontcheva, M. C. Suárez-Figueroa, V. Presutti, I. Celino, M. Sabou, L.-A. Kaffee, and E. Simperl, Eds. Cham: Springer International Publishing, 2018, pp. 669–683.

[3] M. D. Ibrishimova and K. F. Li, "A Machine Learning Approach to Fake News Detection Using Knowledge Verification and Natural Language Processing," in *Advances in Intelligent Networking and Collaborative Systems*, Cham, 2020, pp. 223–234, doi: 10.1007/978-3-030-29035-1_22.

[4] B. A. Asaad and M. Erascu, "A Tool for Fake News Detection," in *2018 20th International Symposium on Symbolic and Numeric Algorithms for Scientific Computing (SYNASC)*, Sep. 2018, pp. 379–386, doi: 10.1109/SYNASC.2018.00064.

[5] X. Zhou and R. Zafarani, "A Survey of Fake News: Fundamental Theories, Detection Methods, and Opportunities," *ACM Comput. Surv.*, vol. 53, no. 5, pp. 1–40, Sep. 2020, doi: 10.1145/3395046.

[6] C. Castillo, M. Mendoza, and B. Poblete, "Information credibility on twitter," in *Proceedings of the 20th international conference on World wide web - WWW '11*, Hyderabad, India, 2011, p. 675, doi: 10.1145/1963405.1963500.

[7] X. Zhou and R. Zafarani, "Network-based Fake News Detection: A Pattern-driven Approach," *ACM SIGKDD Explor. Newsl.*, vol. 21, no. 2, pp. 48–60, Nov. 2019, doi: 10.1145/3373464.3373473.

[8] X. Zhou, A. Jain, V. V. Phoha, and R. Zafarani, "Fake News Early Detection: An Interdisciplinary Study," *ArXiv190411679 Cs*, Sep. 2020, Accessed: Oct. 30, 2020. [Online]. Available: http://arxiv.org/abs/1904.11679.

[9] S. Castelo *et al.*, "A Topic-Agnostic Approach for Identifying Fake News Pages," *Companion Proc. 2019 World Wide Web Conf.*, pp. 975–980, May 2019, doi: 10.1145/3308560.3316739.

[10] A. Bordes, N. Usunier, A. Garcia-Duran, J. Weston, and O. Yakhnenko, "Translating Embeddings for Modeling Multi-relational Data," in *Advances in Neural Information Processing Systems 26*, C. J. C. Burges, L. Bottou, M. Welling, Z. Ghahramani, and K. Q. Weinberger, Eds. Curran Associates, Inc., 2013, pp. 2787–2795.

[11] S. S. Pavlova, "Using Knowledge Graphs for Fake News Detection," University of Aberdeen, Aberdeen, UK, 2018.

[12] P. Shiralkar, A. Flammini, F. Menczer, and G. L. Ciampaglia, "Finding Streams in Knowledge Graphs to Support Fact Checking," in *2017 IEEE International Conference on Data Mining (ICDM)*, Nov. 2017, pp. 859–864, doi: 10.1109/ICDM.2017.105.

[13] M. Hofer, S. Hellmann, M. Dojchinovski, and J. Frey, "The New DBpedia Release Cycle: Increasing Agility and Efficiency in Knowledge Extraction Workflows," in *Semantic Systems. In the Era of Knowledge Graphs*, vol. 12378, E. Blomqvist, P. Groth, V. de Boer, T. Pellegrini, M. Alam, T. Käfer, P. Kieseberg, S. Kirrane, A. Meroño-Peñuela, and H. J. Pandit, Eds. Cham: Springer International Publishing, 2020, pp. 1–18.

[14] J. Lehmann *et al.*, "DBpedia – A large-scale, multilingual knowledge base extracted from Wikipedia," *Semantic Web*, vol. 6, no. 2, pp. 167–195, 2015, doi: 10.3233/SW-140134.

[15] T. Pellissier Tanon, G. Weikum, and F. Suchanek, "YAGO 4: A Reason-able Knowledge Base," in *The Semantic Web*, Cham, 2020, pp. 583–596, doi: 10.1007/978-3-030-49461-2_34.

[16] D. Vrandečić and M. Krötzsch, "Wikidata: a free collaborative knowledgebase," *Commun. ACM*, vol. 57, no. 10, pp. 78–85, Sep. 2014, doi: 10.1145/2629489.
[17] S. G. Pillai, L.-K. Soon, and S.-C. Haw, "Comparing DBpedia, Wikidata, and YAGO for Web Information Retrieval," in *Intelligent and Interactive Computing*, Singapore, 2019, pp. 525–535, doi: 10.1007/978-981-13-6031-2_40.
[18] S. Choudhury *et al.*, "NOUS: Construction and Querying of Dynamic Knowledge Graphs," in *2017 IEEE 33rd International Conference on Data Engineering (ICDE)*, Apr. 2017, pp. 1563–1565, doi: 10.1109/ICDE.2017.228.
[19] O. Etzioni, M. Banko, S. Soderland, and D. S. Weld, "Open information extraction from the web," *Commun. ACM*, vol. 51, no. 12, pp. 68–74, Dec. 2008, doi: 10.1145/1409360.1409378.
[20] L. Getoor and A. Machanavajjhala, "Entity resolution: theory, practice & open challenges," *Proc. VLDB Endow.*, vol. 5, no. 12, pp. 2018–2019, Aug. 2012, doi: 10.14778/2367502.2367564.
[21] M. Viviani and G. Pasi, "A Multi-criteria Decision Making Approach for the Assessment of Information Credibility in Social Media," in *Fuzzy Logic and Soft Computing Applications*, Cham, 2017, pp. 197–207, doi: 10.1007/978-3-319-52962-2_17.
[22] B. Shi and T. Weninger, "Discriminative predicate path mining for fact checking in knowledge graphs," *Knowl.-Based Syst.*, vol. 104, no. C, pp. 123–133, Jul. 2016, doi: 10.1016/j.knosys.2016.04.015.
[23] G. L. Ciampaglia, P. Shiralkar, L. M. Rocha, J. Bollen, F. Menczer, and A. Flammini, "Computational Fact Checking from Knowledge Networks," *PLOS ONE*, vol. 10, no. 6, p. e0128193, Jun. 2015, doi: 10.1371/journal.pone.0128193.
[24] N. Lao and W. W. Cohen, "Relational retrieval using a combination of path-constrained random walks," *Mach. Learn.*, vol. 81, no. 1, pp. 53–67, Oct. 2010, doi: 10.1007/s10994-010-5205-8.
[25] Q. Wang, Z. Mao, B. Wang, and L. Guo, "Knowledge Graph Embedding: A Survey of Approaches and Applications," *IEEE Trans. Knowl. Data Eng.*, vol. 29, no. 12, pp. 2724–2743, Dec. 2017, doi: 10.1109/TKDE.2017.2754499.

Appendix A: Meeting Log

Meeting 18/08/2020

- Short initial discussion via e-mail where I proposed the idea of the project.
- Suggestions around the interface and how to make the project more feasible were given.

Meeting 05/10/2020

- Discussed initial ideas and overview of the project.
- Gone through the structure of the interim report.
- Discussed an idea where the interface could have 2 modes: fake news checking mode and admin mode where the user can give feedback on whether the fact in the knowledge graph should be updated or not.
- Discussed how the system should be evaluated. It could be by evaluating different methods for identifying facts that I will develop, where one is simple and the other is difficult. The evaluation could be done by asking end-users which method they prefer.
- If human evaluation is needed, I would need to submit an ethical compliance form.
- Talked about how to make the project more feasible, by possibly constraining the relationships that the system is looking for.
- Considered expanding existing knowledge graphs and finding possible news article sources

Meeting 12/10/2020

- Discussed the project proposal draft that I sent.
- Extended Objective 2: "conduct user testing to evaluate the interface" deemed to be unnecessary as it is somehow a part of Primary Objective 6. Thus, Extended Objective 2 will be removed.

- Initially, Extended Objective 1: "deploy system to cloud server" was also seen as unnecessary. I made a point that if it is a full system, then it needs to be able to run all the time. But it is not a requirement, hence it is an extended objective.
- Discussed how to get the news data, either scrape from news websites or find available datasets.
- Supervisor suggested that I investigate the relationships in existing knowledge graphs and pick some common relationships that also appear in (Covid-19) news.

Meeting 21/10/2020

- Supervisor suggested to reimplement the Aberdeen Uni student's dissertation and use it as a baseline for my project.
- Discussed DBpedia and DBpedia Live.
- Talked about entity relationships that can be considered, such as "person"-said-"statement"-at-"date"-at-"place". I should also maybe start with relationships between named entities.
- Supervisor suggested that maybe different newspapers paraphrased statements that made them misleading, which could also be investigated for future works.
- For "A said B" relationships, I should focus on whether it is true that "A said B" or not, but not focusing on whether B itself is correct or not. Then, I could expand on investigating if a paraphrased statement means the same thing as the original statement.
- Discussed two different families of fact-checking algorithms, which are knowledge graph embedding and network flow, and the possibility to compare both.
- Supervisor suggested me to understand the TransE embedding model.
- I was reminded of what the interim report should consist of.

Meeting 26/10/2020

- Explained and discussed the TransE knowledge graph embedding model.

Meeting 2/11/2020

- Discussed details of specific sections needed to be included in the interim report.

Meeting 9/11/2020

- Discussed the feedback for the interim report draft.
- Most of the errors are grammatical or typographical.
- I need to put more on the ethical issues section.
- Clarified the system design, with regards to the Knowledge Graph Updater's interaction with the User Interface and news articles.
- Discussed a bit more on TransE and how it deals with relationships synonymy.

Appendix B: Proposal Document

Project Proposal

Using Dynamic Knowledge Graph for Fake News Early Detection

by Albertus Andito

Candidate number: 198910

Supervisor: Julie Weeds

Project Background

News are often about recent events, including events that are still happening. Thus, some knowledge and facts could become invalid in just a short period of time. A fake news detection system should be able to cope with such timeliness of news, where information or facts dynamically change over time. With that, fake news can be recognised early and immediately after the ground truth is updated.

Therefore, this project will involve creating a prototype of a fake news early detection system, which automatically keeps the ground truth updated in real-time inside a knowledge graph. The ground truth will be extracted from trustworthy news articles in the form of SPO (Subject, Predicate, Object) triples.

Another component of this project will be a web application that serves as the interface for the user to check whether a certain statement or news is correct or not, by querying the knowledge graph. The interface could also have a mechanism that allows the user to check whether the ground truth should be updated when the facts are believed to be out-of-date.

The scope of this project should be limited to make it more feasible, such as by limiting the number of predicates or entity types, or perhaps limiting the domain.

Aim

- Develop a fake news detection system where the ground truth is stored in a dynamic knowledge graph and updated in real-time, in attempt to recognise fake news at an early stage.

Primary Objectives

1. Research and evaluate existing knowledge-based fake news detection systems.

2. Identify existing knowledge graphs that are relevant and can be extended for news data.
3. Implement an article extractor which extracts SPO triples from articles and added them to knowledge graph, while also removing outdated triples.
4. Develop and implement at least two algorithms to compare the to-be-verified facts with the knowledge graph.
5. Develop an interface for users to submit articles and check their truthfulness, and to update the knowledge graph.
6. Evaluate the different methods used to automatically verify the news articles.

Extension Objectives

1. Deploy the fake news detection system to a cloud server where it can run all the time.

Relevance

This project is relevant to my degree course, BSc Computer Science (with an industrial placement year) for several reasons. It focuses on research in the field of Natural Language Processing, which I have learnt from the Natural Language Engineering module and will study further in the Advanced Natural Language Engineering module next term. Being able to construct a computer-based system is one of the course learning outcomes. Thus, the Software Engineering module and my industrial placement year experience will also prove to be useful for the development part of this project.

Resources required

- Access to news articles. For testing and development purposes, the number of articles needed is limited. However, to fully achieve Extension Objective 1, unlimited access to news articles might be necessary.
- Cloud resource for running the server to achieve Extension Objective 1.

Bibliography

[1] M. D. Ibrishimova and K. F. Li, “A Machine Learning Approach to Fake News Detection Using Knowledge Verification and Natural Language Processing,” in *Advances in Intelligent Networking and Collaborative Systems*, Cham, 2020, pp. 223–234, doi: 10.1007/978-3-030-29035-1_22.

[2] X. Zhou and R. Zafarani, “A Survey of Fake News: Fundamental Theories, Detection Methods, and Opportunities,” *ACM Comput. Surv.*, vol. 53, no. 5, pp. 1–40, Sep. 2020, doi: 10.1145/3395046.

[3] J. Z. Pan, S. Pavlova, C. Li, N. Li, Y. Li, and J. Liu, “Content Based Fake News Detection Using Knowledge Graphs,” in *The Semantic Web – ISWC 2018*, vol. 11136, D. Vrandečić, K. Bontcheva, M. C. Suárez-Figueroa, V. Presutti, I. Celino, M. Sabou, L.-A. Kaffee, and E. Simperl, Eds. Cham: Springer International Publishing, 2018, pp. 669–683.

[4] P. Lara-Navarra, H. Falciani, E. A. Sánchez-Pérez, and A. Ferrer-Sapena, “Information Management in Healthcare and Environment: Towards an Automatic System for Fake News Detection,” *International Journal of Environmental Research and Public Health*, vol. 17, no. 3, Art. no. 3, Jan. 2020, doi: 10.3390/ijerph17031066.

[5] S. Choudhury *et al.*, “NOUS: Construction and Querying of Dynamic Knowledge Graphs,” in *2017 IEEE 33rd International Conference on Data Engineering (ICDE)*, Apr. 2017, pp. 1563–1565, doi: 10.1109/ICDE.2017.228.

[6] S. S. Pavlova, “Using Knowledge Graphs for Fake News Detection,” University of Aberdeen, Aberdeen, UK, 2018.

Interim log

Meeting #1 (18-08-2020):
Short initial discussion via e-mail where I proposed the idea of the project. Suggestions around the interface and how to make the project more feasible were given.

Meeting #2 (05-10-2020):
First meeting since the term started. Discussed about the scope of the project, considerations on expanding existing knowledge graphs, how to evaluate the project, and possible news articles sources.

Appendix C: Ethical Compliance Form

Ethical Compliance Form for UG and PGT Projects*
School of Engineering and Informatics
University of Sussex

This form should be used in conjunction with the document entitled "Research Ethics Guidance for UG and PGT Projects".

Prior to conducting your project, you and your supervisor will have discussed the ethical implications of your research. If it was determined that your proposed project would comply with **all** of the points in this form, then both you and your supervisor should complete and sign the form on page 3, and submit the signed copy with your final project report/dissertation.

If this is not the case, you should refer back to the "Research Ethics Guidance for UG and PGT Projects" document for further guidance.

---

1. Participants were not exposed to any risks greater than those encountered in their normal working life.
   Investigators have a responsibility to protect participants from physical, mental and emotional harm during the investigation. The risk of harm must be no greater than in ordinary life. Areas of potential risk that require ethical approval include, but are not limited to, investigations that require participant mobility (e.g. walking, running, use of public transport), unusual or repetitive activity or movement, physical hazards or discomfort, emotional distress, use of sensory deprivation (e.g. ear plugs or blindfolds), sensitive topics (e.g. sexual activity, drug use, political behaviour, ethnicity) or those which might induce discomfort, stress or anxiety (e.g. violent video games), bright or flashing lights, loud or disorienting noises, smell, taste, vibration, or force feedback.

2. The study materials were paper-based, or comprised software running on standard hardware.
   Participants should not be exposed to any risks associated with the use of non-standard equipment: anything other than pen-and-paper, standard PCs, mobile phones, and tablet computers is considered non-standard.

3. All participants explicitly stated that they agreed to take part, and that their data could be used in the project.
   Participants cannot take part in the study without their knowledge or consent (i.e. no covert observation). Covert observation, deception or withholding information are deemed to be high risk and require ethical approval through the relevant C-REC.

---

*This checklist was originally developed by Professor Steven Brewster at the University of Glasgow, and modified by Dr Judith Good for use at the University of Sussex with his permission.

If the results of the evaluation are likely to be used beyond the term of the project (for example, the software is to be deployed, the data is to be published or there are future secondary uses of the data), then it will be necessary to obtain signed consent from each participant. Otherwise, verbal consent is sufficient, and should be explicitly requested in the introductory script (see Appendix 1).

4. No incentives were offered to the participants.
   The payment of participants must not be used to induce them to risk harm beyond that which they risk without payment in their normal lifestyle. People volunteering to participate in research may be compensated financially e.g. for reasonable travel expenses. Payments made to individuals must not be so large as to induce individuals to risk harm beyond that which they would usually undertake.

5. No information about the evaluation or materials was intentionally withheld from the participants.
   Withholding information from participants or misleading them is unacceptable without justifiable reasons for doing so. Any projects requiring deception (for example, only telling participants of the true purpose of the study afterwards so as not to influence their behaviour) are deemed high risk and require approval from the relevant C-REC.

6. No participant was under the age of 18.
   Any studies involving children or young people are deemed to be high risk and require ethical approval through the relevant C-REC.

7. No participant had a disability or impairment that may have limited their understanding or communication or capacity to consent.
   Projects involving participants with disabilities are deemed to be high risk and require ethical approval from the relevant C-REC.

8. Neither I nor my supervisor are in a position of authority or influence over any of the participants.
   A position of authority or influence over any participant must not be allowed to pressurise participants to take part in, or remain in, any study.

9. All participants were informed that they could withdraw at any time.
   All participants have the right to withdraw at any time during the investigation. They should be told this in the introductory script (see Appendix 1).

10. All participants have been informed of my contact details, and the contact details of my supervisor.
    All participants must be able to contact the investigator and/or the supervisor after the investigation. They should be given contact details for both student and supervisor as part of the debriefing.

11. The evaluation was described in detail with all of the participants at the beginning of the session, and participants were fully debriefed at the end of the session. All participants were given the opportunity to ask questions at both the beginning and end of the session.

    Participants must be provided with sufficient information prior to starting the session, and in the debriefing, to enable them to understand the nature of the investigation.

12. All the data collected from the participants is stored securely, and in an anonymous form.

    All participant data (hard-copy and soft-copy) should be stored securely (i.e. locked filing cabinets for hard copy, password protected computer for electronic data), and in an anonymised form.

Project title: Using Dynamic Knowledge Graph for Fake News Early Detection

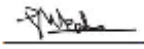
Student's Name: Albertus Andito

Student's Registration Number: 21802720

Student's Signature: 

Date: 10 November 2020

Supervisor's Name: Julie Weeds

Supervisor's Signature: 

Date: 10 November 2020