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CSE402: CHATBOT and BINDING THEORY
Final Report

(Bachelor of Science Thesis)

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ABSTRACT

CHATBOT

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The goal of this project is to model Turkish at phonological, morphological, syntactic and semantic levels by using language theories and to develop a chatbot based on these models by creating an ontology. The chatbot we developed is related to the transportation of Aydın province. By choosing four numbers from the municipal buses, a chatbot is created that can answer any questions you may have about the routes, stops, hours and passenger fares of the buses with these numbers. The another goal of this project is finding the antecedent of reflexive and reciprocal pronouns using the c-command relationship.

KEYWORDS: Chatbot, Natural Language Processing, Morphological Analysis, Syntactic Analysis, Semantic Analysis, Phonological, Binding Theory, C-Command, Antecedent, Anaphors, Indexing, Co-indexing, Co-reference

ÖZET

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Bu projenin amacı, dil kuramlarını kullanarak Türkçeyi sesbilimsel, biçimbilimsel, sözdizimsel ve anlambilimsel düzeyde modellemek ve bir ontoloji oluşturarak bu modellere dayalı bir sohbet robotu geliştirmektir. Geliştirdiğimiz sohbet robotu Aydın ilinin ulaşımı ile ilgilidir. Belediye otobüslerinden dört numara seçilerek bu numaralara sahip otobüslerin güzergahları, durakları, saatleri ve yolcu ücretleri ile ilgili aklınıza gelebilecek her türlü soruyu cevaplayabilecek bir chatbot oluşturmaktır. Bu projenin bir diğer amacı ise, c-komut ilişkisini kullanarak dönüşlü ve karşılıklı zamirlerin öncülünü bulmaktır.

ANAHTAR KELİMELER: Sohbet Robotu, Doğal Dil İşleme, Morfolojik Çözümleme, Sözdizimsel Çözümleme, Anlamsal Çözümleme, Fonolojik, Bağlanma Teorisi, C-Komutu, Öncül, Anafor, İndeksleme, Eş İndeksleme, Eş Referans

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LIST OF ACRONYMS/ABBREVIATIONS

NLP Natural Language Processing

NLU Natural Language Understanding

NLG Natural Language Generation

JSON Javascript Object Notation

NP Noun Phrase

VP Verb Phrase

DET Determiner

PP Prepositional Phrase

1. INTRODUCTION

The chatbots developed so far are at a level that will give results with keywords. Our primary goal is to further improve the chatbots available today. The processes we will do for this are to model Turkish at the phonological, morphological, syntactic and semantic levels by using language theories and to develop a chatbot based on these models by creating an ontology. The goal of this project is to model Turkish at phonological, morphological, syntactic and semantic levels by using language theories and to develop a chatbot based on these models by creating an ontology.

The purposes of binding theory are distinguishing several types of noun phrases. Chomsky's binding theory contains three conditions, which govern the distribution of reflexive and reciprocal pronouns (principle A), ordinary pronouns (principle B), and full noun phrases (principle C), respectively. Chomsky 1981 derives the grammaticality pattern on the basis of the structural relation of c-command, in principle A. Our goal here is to write a program that finds the antecedent of reflexive and reciprocal pronouns using the c-command relationship.

2. BACKGROUND KNOWLEDGE

In order to description the project we want to develop, we must first introduction in by describing the chatbot.

2.1. CHATBOT

Chatbot is artificial intelligence software that users communicate with a person in digital environment as if they are messaging and use it for purposes such as getting information about a subject.

2.1.1. THE HISTORY OF CHATBOT

In 1951, Alan Turing's "Can machines think?" his work, titled, is seen as the first reference to chatbot. In chronological order, the developed chatbots are as follows:

Eliza - 1966

The first chatbot is ELIZA, which was developed by Joseph Weizenbaum in 1966. ELIZA was conceived as a psychologist. However, since natural language processing and machine learning technologies were not developed enough, at that time, it could only respond with word matching method.

Parry - 1972

Parry was more serious tech than Eliza and was helpful in communicating with a patient diagnosed with paranoid schizophrenia.

Jabberwacky - 1988

It is an artificial intelligence that interacts with humans using a voice-operated system.

Dr. Sbaitso - 1992

Speech synthesis program created for MS-DOS and designed to create a digitized sound by interacting with users.

A.L.I.C.E - 1996

ALICE was developed by Richard Wallace in 1995. Unlike Eliza, the ALICE chatbot was able to use NLP technology, allowing for a more sophisticated conversation.

Smarterchild - 2001

Smarterchild is a chatbot with fast data access and features such as personalized conversations.

IBM Watson - 2006

Watson, developed by IBM, is a chatbot that can use NLP technology and use data to obtain information.

Siri - 2010

Siri was developed by Apple in 2010. Since its development, Siri has been operating in Apple products as an assistant that answers user questions and web service requests.

Google Now - 2012

Developed by Google to answer questions. As a mobile app, Google Now can activate requests by transferring them to a group of web services.

Alexa - 2015

It was developed by Amazon as a bot that can issue voice commands using the NLP algorithm.

Cortona - 2015

Cortana, developed by Microsoft in 2015, acts as a personal assistant. It recognizes NLP commands, uses Bing to answer user questions, and also sets reminders.

Facebook Messenger - 2016

He created a platform with bots that he interacted with Facebook users using the chat interface.

Tay - 2016

It was developed to imitate the speech and habits of an American teenage girl. However, it was shut down after a period of 16 hours due to a few complications with its learning abilities.

2.2. TYPES OF CHATBOT

2.2.1. Menu/Button Based Chatbots

These Chatbots aim to find the right result by going deeper with a question at each stage in order to reach the desired answer. Although this type of Chatbot is largely sufficient in general support features, it may be insufficient in more extensive situations.

2.2.2. Keyword Recognition Based Chatbots

Keyword Recognition Based Chatbots, which is a type of chatbot that tries to suggest directions by following the user's spelling, tries to give approximate correct answers partially with the support of artificial intelligence. However, this type of Chatbot may be insufficient in frequently asked similar questions or when keywords are entered too much.

2.2.3. Contextual Chatbots

Contextual Chatbots are known to be the most advanced of their kind. Using machine learning and artificial intelligence, these Chatbots serve for specific users with the ability to remember, learn, and improve over time from previous conversations.

2.3. NATURAL LANGUAGE PROCESSING (NLP)

Natural Language Processing (NLP) is a field of study that enables computers to analyze and understand parts of natural language. It is a subcategory of artificial intelligence and linguistics. NLP is divided into two: NLU (Natural Language Understanding), NLG (Natural Language Generation). The field we will work on in this project is NLU. Natural language processing stages are:

Phonological Analysis

Phonology is the study of how speech sounds function as a system, and phonological analysis involves analyzing the sound systems of languages.

Morphological Analysis

It is done right after the steps of extracting the sentences from the data pool and parsing them into words. Words are analyzed by separating their affixes and roots. Morphological Analysis is very important for morphologically rich languages such as Turkish.

Syntactic Analysis

Syntactic analysis is the process of analyzing natural language with the rules of a formal grammar.

Semantic Analysis

Semantic analysis is the arrangement of words into groups (or areas) based on a shared element of meaning.

2.4. BINDING THEORY

Binding theory is describes the conditions on the structural relations between nouns. Concerned with three types of nouns:

- **R-expressions** (R-expressions is an NP(Noun Phrase) that gets it meaning by referring to an entity in the world. e.g. Bill Clinton, Travis, The woman in the blue suit.)
- **Pronouns** (Pronoun is an NP that may (but need not) get its meaning from another word in the sentence. It can also get its meaning from a noun previously mentioned in the discourse, or by context. e.g. I, me, you, he, him, she, her, it, one, we, us, they, them, his, her, our, my, its, your, their.)
- **Anaphors** (Anaphors is an NP that obligatorily gets its meaning from another NP in the sentence. e.g. myself, yourself, himself, herself, itself, oneself, ourselves, yourselves, themselves, each other.)

Antecedent

Antecedent is an NP that gives its meaning to a pronoun or anaphor. e.g. John loves himself. (antecedent: John, anaphor: himself)

Indexing
Indexing is means of representing the meaning of an NP. Each index is represents a different reference. Start at the left and assign each NP an index starting with i and working down the alphabet. e.g.: [Heidi]$_i$ bopped [herself]$_i$ on [the head]$_j$ with [a zucchini]$_k$

Co-indexing & Co-reference
Two NPs that have the same index are said to be co-indexed. Two NPs that are co-indexed are said to co-refer. (that is, refer to the same entity in the world) e.g.:
[Art]$_i$ said that [he]$_j$ played [basketball]$_k$ in [the dark]$_l$
[Art]$_i$ said that [he]$_i$ played [basketball]$_k$ in [the dark]$_l$

Syntactic Restrictions on Anaphors
The antecedent for an anaphor can be the subject of the sentence, but not an NP inside the subject. e.g.:
[Heidi$_i$'s mother]$_k$ bopped herself$_k$ on the head with a zucchini.
[Heidi$_i$'s mother]$_k$ bopped herself$_i$ on the head with a zucchini.

C-command
Let's look at this topic in terms of the structural relation of c-command. Binding is a special kind of c-command. It is c-command with co-indexing. Binding requires a c–command relationship between the co-indexed elements.

- A binds B if and only if A c-commands B and, A and B are co-indexed.

3. ANALYSIS

Using the python programming language, we wrote a chatbot code that generates an answer to a question received from the user, either speech or text, and transmits the answer to the user, either speech or text. We have written a test code that can test the accuracy of this chatbot. Using prolog, we wrote the morphological analyzer code in order to use the grammar rules of Turkish and we added it to the chatbot. We created an ontology by analyzing the project we developed. We wrote the prolog code of this ontology and added it to the chatbot.

With the help of the source codes, we first created a chatbot that can generate answers with keywords. Then, with the help of the morphological analyzer, we were able to produce answers to questions that could not be answered because Turkish grammar rules were not taught in the chatbot before. With the help of ontology, the chatbot is able to make inferences and produce correct answers.

The another goal of this project is finding the antecedent of reflexive and reciprocal pronouns using the c-command relationship. For this, we first found a data set. This dataset contains almost every name in the world. In addition to this dataset, which includes names and genders, we created the dataset that includes reflexive pronouns. We wrote a program that detects the anaphor in the entered sentence and determines which name its antecedent is or not. However, since it could not show some sentences that are not suitable for the English sentence structure, we found the antecedent of anaphor by creating the tree structure of the sentence and making use of the c-command relationship between the node.

4. DESIGN

The design stages we made for our project:

1. Creating a dataset
2. Creating and testing the chatbot
3. Adding Morphological analyzer
4. Adding Ontology
5. Binding Theory

4.1. DATASET

Four municipal buses (numbers: 605, 606, 607 and 608) operating in Aydın province have been identified. A data set containing 1074 questions and answers about these buses was prepared.

4.2. CHATBOT (CREATE and TEST)

A source code was created for the chatbot using python. Again, the test code was created using python. The reason we wrote the test code is to compare the chatbot's response with the dataset's response to determine the chatbot's accuracy rate. However, we are likely to find errors in the dataset we created with these tests. In other words, it allows us to test both the chatbot and the dataset.

4.2.1. Modules

The modules used while developing the chatbot are:

Speech-To-Text (SpeechRecognition) (For Command Line Interface)
Library for performing speech recognition, with support for several engines and APIs, online and offline.

Text-To-Speech (gTTS) (For Command Line Interface)
gTTS (Google Text-to-Speech), a Python library and CLI tool to interface with Google Translate's text-to-speech API.

4.3. MORPHOLOGICAL ANALYZER

A morphological analyzer is a program for analyzing the morphology of an input word, it detects morphemes of any text. A morphological analyzer was used to analyze the words affected by phonetic events such as consonant softening and vowel drop.

4.4. ONTOLOGY

An ontology is the way of showing the properties of a subject area and how they are related, by defining a set of concepts and categories that represent the subject. Ontology is created to limit complexity and organize data as information. Thus, it provides a more flexible and effective response mechanism. It has been used to create a chatbot that can make its own inferences without being satisfied with just keywords.

4.5. BINDING THEORY

Binding theory, the part of syntactic theory that is concerned with how the interpretation of noun phrases is constrained by syntactic considerations. For the purposes of binding theory, it is useful to distinguish several types of noun phrases: full noun phrases (the question, the student that asked the question, and so on), ordinary pronouns (I, you, they, and so on), reflexive pronouns (myself, yourself, themselves, and so on) and the reciprocal pronoun each other.
There are two alternative approaches to binding theory. The first approach, due to **Hellan 1988**, was proposed on the basis of Norwegian. The second approach, due to **Chomsky 1981**, was proposed on the basis of English and does not cover the full range of Norwegian facts. However, it includes an important condition on the distribution of ordinary noun phrases that is missing from Hellan's binding theory.

4.5.1. Chomsky 1981

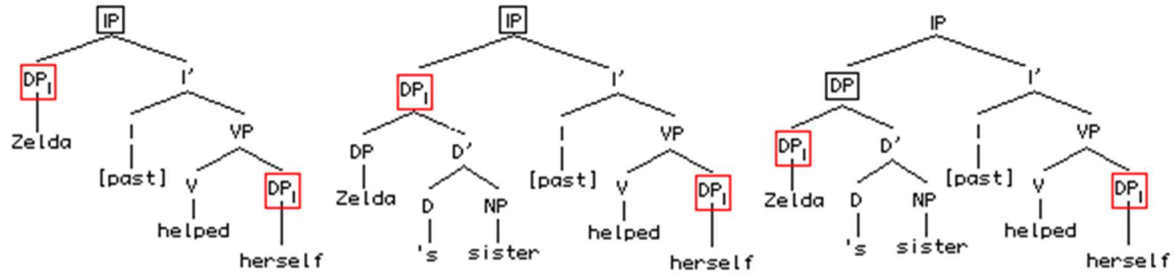
Chomsky's binding theory contains three conditions (or principles, as they are more commonly referred to), which govern the distribution of reflexive and reciprocal pronouns, ordinary pronouns, and full noun phrases, respectively. In this project, we will only deal with principle A.

4.5.1.1. Principle A

Chomsky 1981 derives the grammaticality pattern on the basis not of co-argument hood, but on the basis of the structural relation of c-command.

- A c-commands B iff (= if and only if) neither A nor B dominates the other, and the first branching node that dominates A also dominates B.

a. [Zelda]$_i$ helped [herself]$_i$.
b. [Zelda's sister]$_i$ helped [herself]$_i$.
c. [Zelda's]$_i$ sister helped [herself]$_i$.



a. b. c.

Figure 1. The Structural Relation of C-command

In all three of the structures, the intended antecedent of the anaphor herself and the anaphor itself are boxed in red. The first branching node dominating the intended antecedent is boxed in black. Notice now that the black-boxed nodes dominates that anaphor in (a, b), but not in (c). In other words, the anaphor is c-commanded by the intended antecedent in (a, b), but not in (c).

An anaphor must be c-commanded by a coindexed antecedent.

Principle A: An anaphor must be bound within its governing category.
Governing category: The governing category for an expression is the lowest IP or DP that contains that expression, a specifier, and the expression's case-licensing head.

5. IMPLEMENTATION, TESTS and TEST DISCUSSIONS

5.1. 1ST RELEASE OF PROJECT

Chatbot created. A written input has been received from the user. The chatbot's response to this input has been tested.

Process of the 1st Release

- Keywords were created in the JSON file for the first 100 questions in the dataset.
- The data in JSON format has been turned into a dict structure that python can understand.
- All keywords added to a single list. The same keywords were not included in the list again.
- To the question we received from the user, first normalization and then tokenization (capital letters were reduced, punctuation marks were removed, spaces at the beginning and end of sentences were removed...) were applied. The keywords in the question were added to an empty array that was opened before.
- Another empty array is opened. The words in the question asked by the user and matching the keywords pool we created have been added to the array.
- It was checked whether there are elements in the array we created.
- The Array is not empty and if there is a match in the keywords list with the question asked by the user, the answer with the matching keywords is returned.
- If array in is empty, console a "Sorry I can't answer this question!!!" text was suppressed.

Evaluation of 1st Release

With the test code we wrote, the chatbot's response was compared with the dataset's response to determine the chatbot accuracy rate.

As a result, accuracy rate: 20/80 - %80

Shortcomings of the 1st Release

- Keyword analysis of words affected by phonetic events such as consonant softening and vowel drop cannot be performed. (for example: durak, durağı)
- Cannot answer questions that require directional knowledge. (for example: ADÜ'den Otogar'a, Otogar'dan ADÜ'ye)
- If the keywords in one question are a subset of the keywords of another question, it returns the answer to the other question.

5.2. 2ND RELEASE OF PROJECT

Morphological analyzer and ontology were created. Added to the chatbot code. Modules have been added.

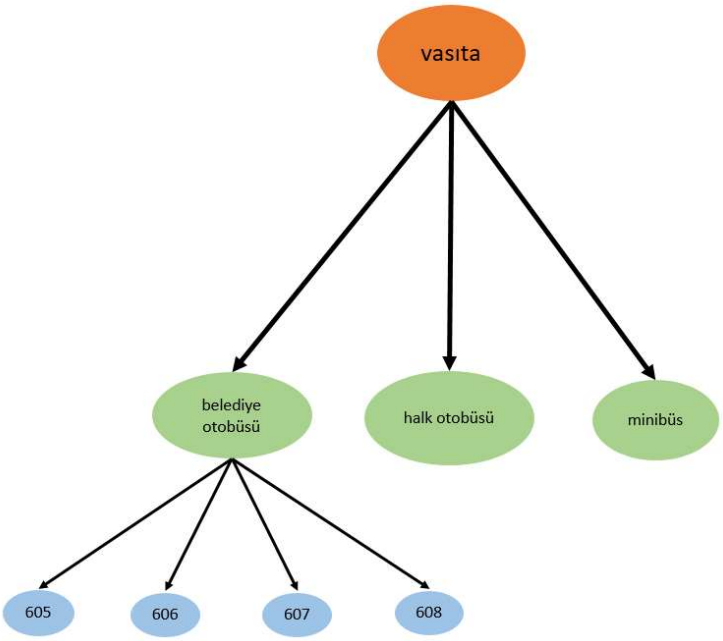


Figure 2. Ontology of a Small Part of Chatbot

Process of 2nd Release

- If the keywords in one question are a subset of the keywords in another question, the answer to the question with the most matching keywords is returned.
- Keyword analysis of words affected by phonetic events such as consonant softening and vowel drop is done with the morphological analyzer.

Evaluation of 2nd Release

With the test code we wrote, the chatbot's response was compared with the dataset's response to determine the chatbot accuracy rate.

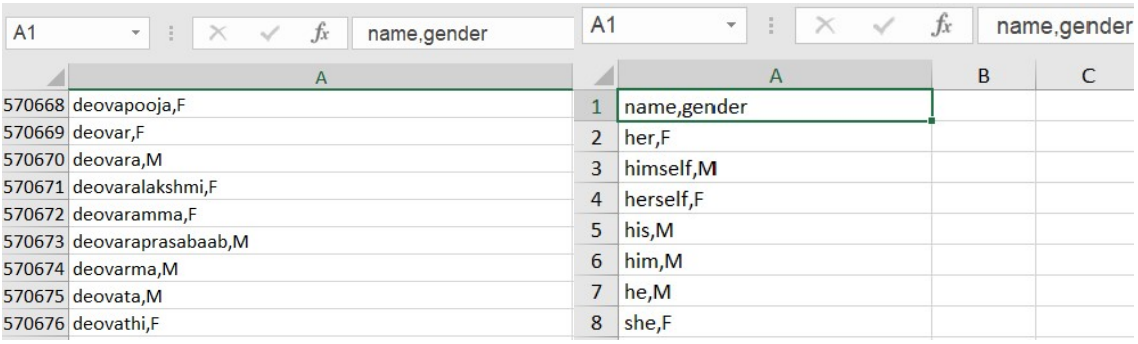
As a result, accuracy rate: 48/1026 - %95.53

Shortcomings of 2nd Release

- It gives the same answers to meaningless questions that contain keyword groups.
- The chatbot cannot make logical inferences.
- Cannot answer questions that require directional knowledge. (for example: ADÜ'den Otogar'a, Otogar'dan ADÜ'ye)

5.3. 3RD RELEASE OF PROJECT

The data set that allows us to find the gender of the noun in the entered sentence was found. A data set containing the gender information of reflexive pronouns was created. A program was written to find the antecedent of the reflexive pronoun in the entered sentence by comparing this gender information.



	A
570668	deovapooja,F
570669	deovar,F
570670	deovara,M
570671	deovaralakshmi,F
570672	deovaramma,F
570673	deovaraprasabaab,M
570674	deovarma,M
570675	deovata,M
570676	deovathi,F

	A
1	name,gender
2	her,F
3	himself,M
4	herself,F
5	his,M
6	him,M
7	he,M
8	she,F

Figure 3. Data Sets

Process of 3rd Release

- We asked the user to enter a sentence containing a reflexive pronoun.
- We separated all the words in the entered sentence and keep them in a list.
- We looked for all the words in the sentence in both data sets. If there is a match, we added it to separate lists.
- We have shown those whose genders match in the noun and pronoun data sets as the antecedent of the entered pronoun can be the entered noun.

Evaluation of 3rd Release

- The rate of finding the antecedent of the reflexive pronoun in the entered sentences: 100%

Shortcomings of 3rd Release

- Since we found the antecedent of the reflexive pronoun by only using gender equality between the pronoun and the noun, the program we wrote also analyzed the sentences that did not comply with the English grammar rules. e.g.:
    - Entered sentence: Şehnaz and Refiye love herself.
      The answer of the program: Himself and herself are reflexive pronouns. Reflexive pronouns must have an antecedent in the same sentence.

      Result 1: HERSELF (anophor) is a reflexive pronoun. The antecedent of herself can be: şehnaz.
      Result 2: HERSELF (anophor) is a reflexive pronoun. The antecedent of herself can be: refiye.

5.4. 4TH RELEASE OF PROJECT

We wrote a program that finds the antecedent of reflexive and reciprocal pronouns using the c-command relation.

Process of 4th Release

- We produced the English grammar structure by using the nltk library of Python.
- We asked the user to enter a sentence containing a reflexive pronoun.
- We separated all the words in the entered sentence and keep them in a list.
- We created the tree structure of the sentence by using the functions of the nltk library.
- We reached subtrees through the tree created.
- We reached the nodes with the help of the created subtrees.
- We reached the noun, which is the antecedent of the pronoun, by advancing on the nodes with the c-command relationship.

Figure 4. Sentence Structure Tree

Evaluation of 4th Release

- The rate of finding the antecedent of the reflexive pronoun in the entered sentences: 100%

Shortcomings of 4th Release

- Since we do not use the found data set in this program, it can only find antecedent on given nouns and pronouns.
- Some verbs are not used semantically in some sentences. However, the program we have written is not yet advanced enough to make this distinction. (This problem can be solved by making use of FrameNet or VerbNet.) e.g.:
    - Şehnaz showed herself.

6. CONCLUSION

The goal of this project was to model Turkish at phonological, morphological, syntactic and semantic levels by using language theories and to develop a chatbot based on these models by creating an ontology. The purposes of binding theory are distinguishing several types of noun phrases. We have obtained a source code containing all of these.

The chatbot we developed is related to the transportation of Aydın province. By choosing four numbers from the municipal buses, we created a chatbot that can answer any questions you may have about the routes, stations, times and passenger fares of the buses with these numbers. We wrote a program that detects the anaphor in the entered sentence and determines which name its antecedent is or not.

In the future, the chatbot may not be limited to these four numbers, but can be turned into a chatbot that can generate answers for all buses. A mobile application can be developed and offered to users.

7. APPENDİX

Project Activities and Schedule (Thesis 1)

WEEK	DATE	COMPLETED TASK
First Week	04.10.2021	A literature search was done.
Second Week	11.10.2021	Question and answer dataset created.
Third Week	18.10.2021	Chatbot and test code algorithm were discussed.
Fourth Week	25.10.2021	Chatbot code was written.
Fifth Week	01.11.2021	Chatbot code was written.
Sixth Week	08.11.2021	Test code was written.
Seventh Week	15.11.2021	Test code was written.
Eighth Week	06.12.2021	We talked about syntactic and semantic analysis.
Ninth Week	13.12.2021	We talked about ontology.
Tenth Week	27.12.2021	Ontology, syntactic and semantic analysis topics started to be integrated into the project.
Eleventh Week	03.01.2022	The ontology scheme was drawn.
Twelfth Week	10.01.2022	Ontology code was written.

Table 1. Project Activities and Schedule (Thesis 1)

Project Activities and Schedule (Thesis 2)

WEEK	DATE	COMPLETED TASK
First Week	21.02.2022	The topics that can be done in the thesis were explained.
Second Week	28.02.2022	Topic selected.
Third Week	07.03.2022	Literature search was done.
Fourth Week	14.03.2022	Literature search was done.
Fifth Week	21.03.2022	The binding theory started to be coded with prolog.
Sixth Week	28.03.2022	The binding theory started to be coded with prolog.
Seventh Week	04.04.2022	Due to the problems in the prolog, binding theory started to be coded with python.
Eighth Week	25.04.2022	We developed the program to find anaphor and its antecedent in a single sentence.
Ninth Week	09.05.2022	We developed the program to find anaphor and its antecedent in more than one sentence.
Tenth Week	23.05.2022	The relation of c-command started to be added to the program.
Eleventh Week	30.05.2022	The thesis report was written.
Twelfth Week	06.06.2022	The thesis report was written.

Table 2. Project Activities and Schedule (Thesis 2)

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