Is it blue?

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Abstract

In this paper the Higgins spoken dialogue system is being examined. Higgins was designed as a test bed for error handling, but serves well to illustrate natural language processing techniques and issues related to spoken dialogue systems. Higgins includes modules for semantic interpretation of natural language utterances as well discourse modelling including techniques for resolving ellipses and anaphora. This paper describes the implementation of a new domain, a guessing game for language learning, using the Higgins architecture.

1. Introduction

Spoken language is a natural and efficient way for humans to communicate. To create a conversational computer has been a challenging goal for a long time. Many techniques associated with the field of natural language understanding are originally developed for written language. These techniques are also essential when processing speech. There are however significant differences between spoken and written language; the rules for written language have often been formalized while the syntactics of speech is still unexplored. Spontaneous speech is characterized by disfluencies, false starts, pauses and fragments. To deal with the issues and specific features that characterize speech, natural language processing techniques need to be adapted. This paper will discuss how the Higgins spoken dialogue system addresses some of these problems.

1.1 Components of spoken dialogue systems

Spoken dialogue systems have to deal with a number of challenges including: speech recognition, natural language understanding, dialogue management, response generation and speech output. Techniques for doing this will be discussed here briefly.

1.1.2 Speech Recognition

It is a well-known fact that automatic speech recognition (ASR) is far from being as accurate and reliable as human recognisers [2]. Speech recognition is difficult because of the complex nature of the speech signal. The same utterance has different acoustic realizations depending on linguistic, speaker and channel variability. Age, gender, mood and shape of the vocal tract are factors that result in intra-speaker variability. Speech recognition in a spoken dialogue system has to challenge these obstacles and handle the following factors: speaker independence, vocabulary size, continuous speech and spontaneous conversational speech. The size of the vocabulary varies between different applications. An application with only a few words in the vocabulary constrains the user while an application with a larger vocabulary is more flexible, but also more complex.

Apart from strings of words the output from speech recognizers often includes a measure of confidence for the hypothesized recognitions.

1.1.3 Language understanding

Components for language understanding analyse output from the speech recognizer and derive a meaning that can be processed by a dialogue manager. Language understanding involves both syntactic and semantic analysis. Syntactic analysis is done to determine the structure of a sequence of words from the speech recogniser. The semantic analysis attempts to derive a meaning from the constituents. Language understanding is problematic for many reasons. Semantic and syntactic analyse is not trivial even for a perfectly recognized string of words. The language understanding component has to deal with lexical and structural ambiguity. Moreover, speech is often “ill formed”, i.e. it is ungrammatically structured and contains hesitations, pauses and fragmental speech. It is therefore difficult to use traditional syntactic analysis methods designed for written language.

1.1.4 Dialogue Management

The task of the dialogue manager is to control the flow of the dialogue. This includes determining if the system has elicited adequate information from the user, contextual understanding, information retrieval and response generation. The dialogue manager tries to find out what information the user asks for, optionally consults an external application, such as a database, and finally reports the information back to the user. In many cases the system has to use error-handling strategies such as verifications and clarifications in order to retrieve sufficient information.

1.1.5 External communication

Generally spoken dialogue systems require some kind of communication with an external source such as a database. This is necessary to retrieve the information that the user is asking for. For example: the data collected from an external source in a timetable information system contains information such as departure times, prices and destinations.

1.1.6 Response Generation

The response generation component composes a message that will be sent to the speech output component to be reported back to the user. The process includes deciding which information should be included, how the information should be structured and its syntactic structure. The response generation component can use simple pre-defined templates or complex natural language generation. A good guideline to follow is to only let the response generation component use words that can be processed by the recogniser, since users tend to mimic its behaviour [6].

1.1.7 Speech output

The speech output component transforms the output from the response generation component into spoken form. Some spoken dialogue systems use a template-filling mechanism with pre-recorded sound. In more complex natural language systems with varying and unpredictable output *text to speech synthesis* (TTS) is an alternative. Text to speech synthesis involves two tasks: text analysis and speech generation. Text analysis

results in a linguistic representation, which the speech generation component uses to synthesize speech into waveform. Speech generation also involves generation of prosodic description such as rhythm and intonation.

1.2 Purpose

Spoken dialogue systems are complex and it is often difficult to get a comprehensive overview of the various components and their processes. Neither is it obvious how and at what level the issues should be addressed. The purpose of this paper is to illustrate natural language processing techniques and issues related to spoken dialogue systems in the Higgins project. This will be done while building an application using modules from the Higgins spoken dialogue system [4]. The modules are designed to be generic and support implementation in new domains. To study how this could be done we implemented the modules in a language tutoring game domain which is different from the original map task domain in Higgins. The organization of this paper is as follows. Section 2 provides a detailed description of the dialogue system modules developed within the Higgins project. The implementation of the language tutoring game is described in 3 and section 4 presents conclusions.

2. Higgins

The Higgins project started at CTT (Centre for Speech Technology) in 2003 [4]. The aim of the project is to investigate error handling strategies at various levels in a spoken dialogue system. The practical goal of the project is to build a system with fully functional components in which error handling can be studied empirically. The initial Higgins domain is pedestrian navigation and guiding in a virtual city. The user gives the system a destination and the system guides the user to the destination by giving verbal instructions. One of the main contributions of Higgins is an architecture which provides visualizations of data on all levels. Inter-process messaging in Higgins is coded in XML which support visualization. The semantics at utterance level, the discourse model, the database and the generation content (before synthesized) are represented as XML tree structures. The trees can be used directly to search for matching structures in the domain model.

2.1 Pickering

The Higgins system has a modified chart parser, Pickering [3], implemented in Oz []. Pickering is designed to analyze continuous and incremental input from a probabilistic speech recognizer. Incremental and continuous processing has several advantages; It is more efficient since much processing can be done while the user is still talking. Furthermore, speech is unpredictable and chunking the string of words into utterances is difficult since pauses and hesitations will likely be incorrectly interpreted as end of utterance markers. Pickering use context free grammars (CFG) and build deep semantic tree structures. The CFG grammar consists of a rule-set, lexical entries and an optional morphology all encoded in XML. All instances are capable of carrying semantics. The CFG grammar rules can be relaxed to handle unexpected, ungrammatical and misrecognized input robustly. To support robust interpretation the rules can be relaxed to: (1) allow insertions of words inside phrases, (2) allow non-agreement, and (3) combine

fragmental input to find the solution with the best coverage. This is a small grammar example:

```
<entry name="det">
  <match num="sing" info="given">den</match>
  <sem><object/></sem>
</entry>
<entry name="colour">
  <match genus="utr" type="blue">blå</match>
  <sem><colour/></sem>
</entry>
<entry name="shape">
  <match num="sing" genus="utr" info="given">stjärnan</match>
  <sem><object><colour/></object></sem>
</entry>


<rule>
  <agreement attributes="num info genus"/>
  <match>
    <entry name="det" link="1"/>
    <entry name="colour" link="2"/>
    <entry name="shape" link="3"/>
  </match>
  <sem>
    <unify copy="info num">
      <ref link="1"/>
      <ref link="2"/>
      <ref link="3"/>
    </unify>
  </sem>
</rule>
```

Both rules and lexical entries contains `<match>`, `<sem>` and a list of features. The `<match>` part assigns features (in boldface) which specify the entries they match. The semantics is specified in the `<sem>` part. The grammar rules also contain instructions for how to combine semantics from matching lexical entries and rules. The `<unify>` tag unifies the semantics in the order of the `link` attribute. The `copy` attribute state which attributes resulting from the agreement should be included as extra semantic information in the nodes of the semantic representation. Parsing result in a sorted list with the best solution first. The best solution has larger word coverage, fewer insertions and less non-agreement.

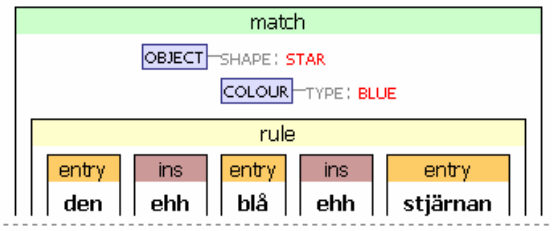

Figure 1: Pickering example with relaxed CFG rules which allows insertions.

The `info` feature specifies which information is *new* and which is *given* depending on definiteness and sentence structure. If the utterance had been “stjärnan är blå”, another rule is applied which specifies “blå” as new and “stjärnan” as given. The semantic representation of an utterance can be used to search for matching objects in the domain model.

2.2 Galatea

The semantic analysis in Pickering is strictly done on utterance level and no consideration is taken to the surrounding utterances. Galatea [5] is the discourse modeller in the Higgins system also implemented in Oz. Galatea interprets utterances in context, including ellipses and anaphora. There are three main tasks in Galatea:

2.2.1 Resolving ellipses

Galatea keeps list of the communicative acts in chronological order. When resolving ellipses the CA-list is used to transform the utterance into full propositions. Galatea use domain depended *context rules* to transform the communicative acts based on previous acts in the CA-list. It is possible to represent utterances from more than one speaker in the CA-list.

2.2.2 Resolving anaphora

Galatea has no access to the database and cannot map entities in the CA-list to real objects. The CA-list however, assigns variable IDs to its entities. As mentioned earlier the semantic structures created in Pickering are marked with status *given* or *new*. In Galatea an entity marked with new is added to the CA-list. An entity marked as given is used to search the entity list from top to bottom for a matching entity which the anaphora potentially refers to. The entity that matches the anaphora entity will be moved to the top of the CA-list and unified with the added entity. If no match is found the entity will be added to the top of the list and assigned a new id.

2.2.3 Grounding status

The nodes in the semantic representation are assigned with *Grounding status* to mark how well established the entities are in the dialogue model. Grounding status includes information about who added the concept, in which turn the concept was introduced and how confident the system is in the concept. Many concepts are mentioned several times during the dialogue and grounding status over time can be tracked in Galatea and used for various error handling techniques.

2.2.4 Utilizing confidence scores at concept level

Galatea is designed to address ASR problems at concept level. Speech recognition is far from perfect and errors in spoken dialogue system often occur at the speech recognition level. A low ASR confidence score is an indication of a potential misrecognition. Clarifications and verifications can be used when the system is unsure of what was said. Normally confidence scores are calculated on utterance level and if confidence scores are low, the whole utterance is verified. This is not a good idea when scores are unevenly distributed over the utterance. In systems which allow for longer and relatively free input and utterances are only partly correctly recognized, confidence scores can be better utilized at a concept level.

3. Implementation

When deciding on a domain for our implementation there were a number of issues to consider. We wanted to combine a spoken dialog system with a language learning application, and we wanted to build the dialog system with the Higgins platform in order to learn how to use it and to explore its potential. We needed to find a domain that was small, and possible to semantically describe in a precise manner. Making a complete description of a larger domain is a huge task beyond the scope of a term paper. We also wanted to find a domain where it was possible to express linguistic phenomena such as ellipsis and anaphora, in order to investigate how these issues were resolved within Higgins. As for the language learning aspects of the application, it was important to have a domain that was easy to transfer to another target language. Finally, it was desirable to make an application that could be a useful and entertaining exercise for the tentative language learner.

3.1 Domain

The domain we finally decided on, has as we see it, several properties that makes it well suited for our purposes. It is a guessing-game, with two actors. The first is an embodied conversational agent (ECA), also known as a talking head. The second player is a tentative human language student. The rules of the game are as follows: A checker board is filled up by random objects, and the ECA selects one of them. The task of the human is to find out which object the agent has chosen by asking yes/no questions. The fewer questions needed; the higher his score. There are four colours: [red, green, blue, and yellow], and four shapes: [triangle, rectangle, circle, and star], which combines into 16 different types of shapes (red circle, green star etc.) On the easiest level, with a small board (up to 4x4), colour and shape will uniquely identify an object. On larger boards, such as the one displayed in the picture below, colour and shape attributes are not enough to identify an object, since there are more than one object with the same colour and shape. Therefore information about the neighbouring objects is needed in order to solve the game. The user must ask the agent questions such as: “Does it have a blue star to its right?” It is possible to express ellipsis and anaphora within the domain. For example by first asking “Is it red?” and then “Blue?” we are referring the object that the agent has chosen. If we however are asking “Is the object to its right red?” and then “Is it blue?” we are referring to an object to the right of the chosen object. If we ask: “Does it have a circle to its right?” and then “To its left?” we are switching objects, but still asking whether it is a circle etc.

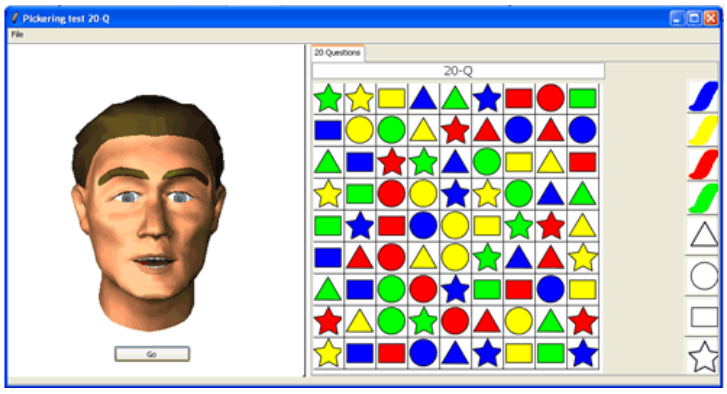

Figure 2: An example outline of the game

The buttons to the far right in the picture are 'help buttons' for a user that is not familiar with the vocabulary in the target language. If the user for example pushes the button in the lower right corner, the agent will say the word 'star' in the target language. (Iconic pictures representing 'over', 'under', 'to the left of', and 'to the right of' should be added – as well as something for 'is it?').

The animated talking head to the left in the picture has been developed at CTT [1]. The agents speech can be either synthetic (TTS) or natural, pre-recorded speech. The head is capable of producing lip-synchronised speech. The model can also convey extra-linguistic signs such as frowning, nodding, and eyebrow movements. In this implementation we have chosen to use pre-recorded utterances rather than synthetic speech. For a language learner it is important to have a good role-model for pronunciation, hence the superior quality of the speech in pre-recorded utterances is preferable to synthetic speech.

3.2 Components

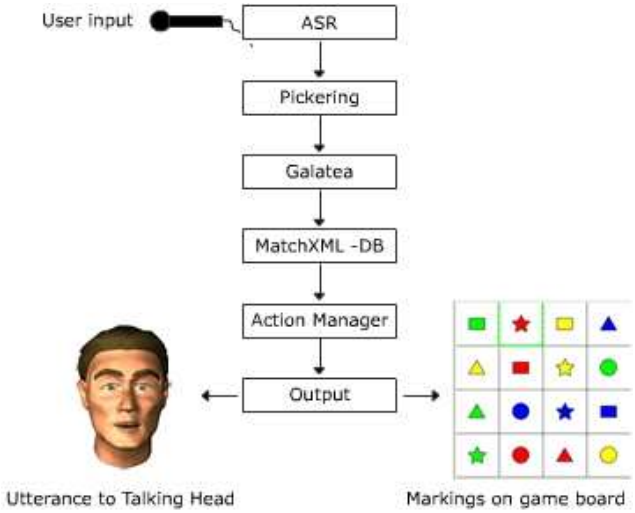

Figure 3: The components

3.3 Speech Recognition

The automatic speech recognizer (ASR) used in the application is from Nuance (http://www.nuance.com/). Some of the arguments for using Nuance are that it is well documented, and relatively easy to get up and running. In the Nuance recognition process there are:

- Acoustic models for phonetic recognition
- Dictionary files containing descriptions of the phonetic pronunciations for the words
- Recognition grammars that defines the set of utterances that can be recognized.

The output from the ASR is a textual representation of the recognized words and a confidence score on word level. This is wrapped in an XML-wrapper and sent to Pickering

3.4 Pickering

Before writing CFG rules and semantics for Pickering the domain of the application needs to be defined. Since the domain of the language tutoring guessing game is small and rather limited this was reasonably easy. The first version of the application is restricted to yes/no questions about the attributes of the objects, such as shape and colour, and the attributes of the surrounding objects (as described in 3.1). The CFG rules were written based on a few example utterances from the domain. An empirical data collection is needed to extend the rule set and lexicon for better coverage of what real users actually say. Still, the system domain is very limited and a small grammar is enough to cover the possible utterances types.

1.4.1 Context free grammar rules

The top rule in the language tutoring guessing game (see appendix 6.1) is a communicative act (<ca>) which can be of type *question* or *ellipsis*. The role of ellipses will be further discussed in relation to discourse modelling in Galatea. The rules include a small morphology for noun and adjective declination (6.1) and linguistic features which can be used for agreement in the unification. However, in use, the agreement rules should probably be relaxed since misrecognitions are likely to occur when the acoustic difference is small ("ett rött objekt" – "en röd objekt").

2.4.2 Semantics

The semantics in Pickering have the same form as the objects in the database. The top node is the communicative act of type *question* which includes objects and their attributes.

Figure 4: The semantics for the utterance "Är det en blå triangel?

Figure 5: and Figure 6: represent Pickering results of questions where the user asks for information about the objects surrounding the object selected by the system. There is a significant syntactic difference between the questions which will result in different semantic representations. In Figure 5:5 the `POS-REL` attribute is assigned the value `LEFT-OF` and in Figure 6:6 the `POS-REL` attribute is assigned the value `RIGHT-OF`.

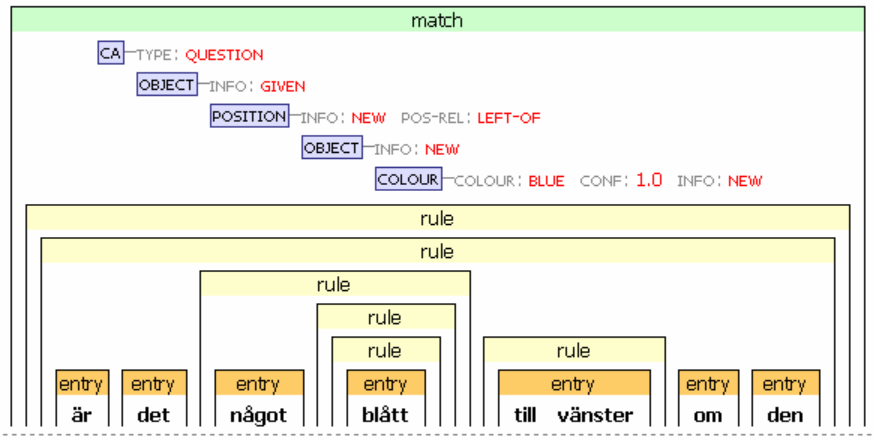

Figure 5: Is it something blue to the left?

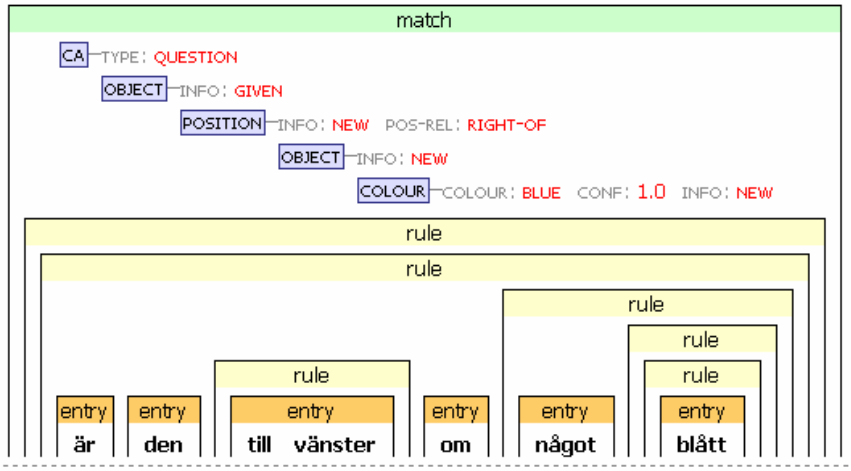

Figure 6: Is it left of something blue?

3.5 Galatea

The Galatea rules implemented for this version of the language tutoring guessing game are relatively simple. The objects in the guessing game are defined by two attributes, colour and shape. The user can ask yes/no questions about the value of these attributes and value of the attributes of the four surrounding objects. Accordingly, the user can at most refer to five objects (depending on where on the board the object is placed). The rules of the game imply that there is one object which will be in focus during the whole dialogue. This object will therefore always be assigned info status *given* in Pickering. The

fact that there is an object which has been selected by the system is the only thing the user knows when the game starts. The colour, shape, and position of the surrounding objects as well as the attributes of these objects are unknown to the user. The attributes and the surrounding objects will therefore be assigned info status *new* when introduced by the user. Moreover, these objects and attributes will not be included in the entity list until the have been confirmed by the system. The transformation rules in Galatea transform a "yes" from the system into an assertion which confirms the attribute and the attribute is included in the entity list:

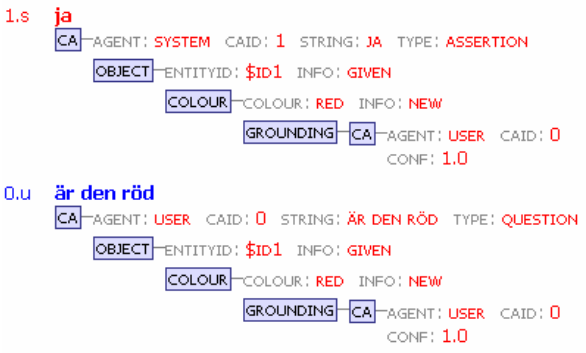

Figure 7: Example of transformation rules

The Galatea rules implemented in the present version of the system include status for given and new entities as well as grounding status. Imagine the following scenario: The user asks if the object is a square. The object selected by the system is a square and the system reply is yes. In the next question about the colour of the object the user refers to the object as "fyrkanten" (the square). The shape of the object will now be assigned the status *given*. The shape of the object is now grounded twice by the user. The semantic representation in Galatea will look like this:

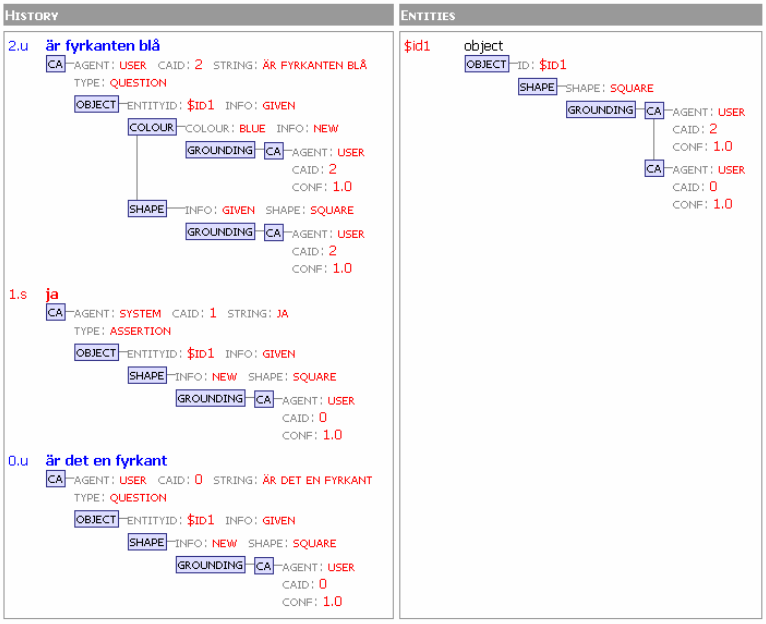

Figure 8: A discourse modelling example from Galatea

The domain is complex enough to allow for anaphora and ellipses. For example:

User:	Är objektet blått? Is the object blue?
System	Nej No
User	Rött? Red?

Figure 9: Ellipse dialogue example

The ellipse in Figure 9: will be resolved into a full question using the context rules in Galatea and the CA-list.

Context: Is the object blue?	CA AGENT: USER CAID: 0 STRING: ÄR OBJEKTET BLÅTT TYPE: QUESTION OBJECT ENTITYID: $ID1 INFO: GIVEN COLOUR COLOUR: BLUE INFO: NEW
Ellipses: Red?	CA AGENT: USER TYPE: ELLIPSES COLOUR COLOUR: RED INFO: NEW
Transformation: Is the object red?	CA AGENT: USER CAID: 2 STRING: RÖTT TYPE: QUESTION OBJECT ENTITYID: $ID1 INFO: GIVEN COLOUR COLOUR: RED CONF: 1.0 INFO: NEW

Figure 10: Transformation example

3.6 Database

An XML representation of the game board is created between each round of the game, as a new set of objects is laid out. This is used as a database description of the world, that may be queried whenever questions are asked by the user. For every object the following attributes are stored. A unique ID, X and Y position on the checker board, the colour and shape of the object, and the ID number of the object's neighbours to the left, to the right, above, and below.

```
<object id="4">
        <x>1</x>
        <y>2</y>
        <shape>star</shape>
        <colour>yellow</colour>
        <position rel="left-of">
                <object xsi-type="w:ref" id="0"/>
        </position>
        <position rel="right-of">
                <object xsi-type="w:ref" id="6"/>
        </position>
        <position rel="over">
                <object xsi:type="w:ref" id="1"/>
        </position>
        <position rel="under">
                <object xsi-type="w:ref" id="9"/>
        </position>
</object>
```

Figure 11: One object in the domain model database

In order to ask a question such as "Does it have a red circle to its right?" the database unifies the link `<object xsi-type="w:ref" id="6"/>` with the body of the object with

ID=6 and looks if it has the properties ‘red’ and ‘circle’. The search in the database will from such a query return a list of ID numbers of all objects that has red circles to its right. This list is passed over to the action manager.

3.7 Action manager

What is commonly known as a dialog manager (sect 1.1.4) is in our system referred to as the action manager, due to the lack of proper dialogue. The Higgins system does not have an integrated ’Dialog/Action Manager’. In fact, part of the philosophy behind the design of Higgins has been to separate the module(s) responsible for what actions to take, from the modules responsible for interpreting the user input. The particular domain of this game, in combination with the design of the rest of the system, makes the job of the action manager in this version of the application simple. As seen in the description above, a question like “Is it blue?” is transformed into a database query that returns a list of the IDs of all objects that are blue. The action manager stores the ID of the chosen object and compares it with the set of IDs that the database query returns. If the chosen object is in the set, the answer is “Yes”, otherwise the answer is “No”.

3.8 Output

Although the yes/no utterances that our agent is using in the current implementation can be thought of as generated, one is usually thinking of more complex answers when one speaks of a language generator. Particularly in a language learning application, one might wish for a more elaborate answer, - for example “No, it is not blue”, rather that just “No”. By parsing the output from Galatea, which contains the semantic representation of the question, it is possible to generate a more complex answer. Also the Higgins system itself is able to generate spoken language, using the same rules that were used for parsing, but we have not looked further into that aspect of Higgins. We felt it was most important to get a complete system up and running first, and then incrementally add more sophisticated features as the application evolved. In that process, other features have taken precedence. In the current implementation, the talking head receives a command from the action manager that contains a pointer to a pre-recorded audio file (.wav) and a precompiled .dat file containing animation parameters for lip-sync. In addition, animation data for frowning, nodding etc. is supplied at a separate channel. The action manager also displays the data it has received in a visual manner by highlighting the objects that are being queried on the game board.

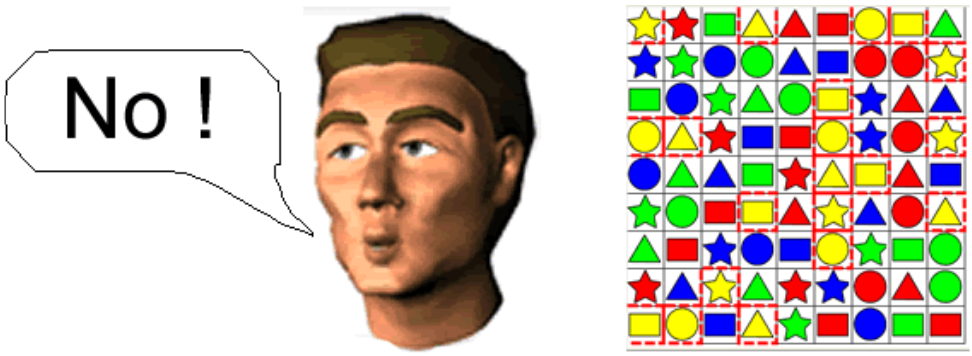

Figure 12: Visual representation of the question “is it yellow?”

4. Conclusions

With this first implementation of the language tutoring game, we have shown that building a spoken dialog system based on the Higgins architecture, is relatively straight forward. However, there are many ways in which the system can be improved and the system domain can be extended. A first step would be to collect empirical data of what real users actually say. To further explore the potential of the dialogue tutoring game it would be interesting to extend the domain to include more types of objects with a larger set of attributes. Changing the target language of the application would also be an interesting adaptation to look at. For many target languages it seems quite straight forward. We may change the input language by changing language model in the ASR or by manually making phonetic labelling of the target words. The lexical entries and the rules specifying word order and morphology in Pickering must be changed, and the spoken output of the agent is simply switched to the target language.

Another interesting aspect would be to have more complex components for dialogue management and language generation. The system would gain usability if some meta dialogue and a few error handling strategies were implemented. Meta dialogue can be used to help novice users to understand the rules of the game and which properties define the objects. Confidence scores from Nuance can be used to verify and clarify user input when confidence is low. The implementation of error handling strategies can also be used to further explore the potential of Higgins, since this is what Higgins originally was designed as a test bed for. In general, the Higgins modules will be better utilized in a conversational dialogue system capable of engaging in a more complex natural language interaction than y/n questions.

5. References

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6. Appendix

6.1 Pickering

```
----------------------------------------objects.xml---------------------------------------------
<?xml version="1.0" encoding="ISO-8859-1"?>
<?xml-styslesheet type="text/xsl"
href="http://www.speech.kth.se/higgins/2003/pickering/grammar/transformations/grammar2xhtml_include.xs
l"?>
<g:grammar xsi:schemaLocation="http://www.speech.kth.se/higgins/2003/pickering/grammar/
http://www.speech.kth.se/higgins/2003/pickering/grammar/grammar.xsd
                http://www.speech.kth.se/higgins/2003/buildxml/
                http://www.speech.kth.se/higgins/2003/buildxml/buildxml.xsd"
xmlns:g="http://www.speech.kth.se/higgins/2003/pickering/grammar/"
xmlns:twq="http://www.speech.kth.se/ville/twq/" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:b="http://www.speech.kth.se/higgins/2003/buildxml/"
xmlns:f="http://www.speech.kth.se/higgins/2003/pickering/grammar/feature/"
xmlns:a="http://www.speech.kth.se/higgins/2003/annotation/">
        <a:annotation>
                <desc/>
        </a:annotation>
        <g:rules>
                <g:rule twq:name="colour">
                        <g:match>
                                <g:entry twq:name="colour" propagate="twq:colour"/>
                        </g:match>
                        <g:sem>
                                <twq:colour twq:colour="$colour" twq:info="new"/>
                        </g:sem>
                </g:rule>
                <g:rule twq:name="shape">
                        <g:match>
                                <g:one-of>
                                        <g:entry twq:name="shape" twq:definiteness="indef"
propagate="twq:shape"/>
                                        <g:entry twq:name="adj_shape" propagate="twq:shape"/>
                                </g:one-of>
                        </g:match>
                        <g:sem>
                                <twq:shape twq:shape="$shape" twq:info="new"/>
                        </g:sem>
                </g:rule>
                <g:rule twq:name="shape">
                        <g:match>
                                <g:one-of>
                                        <g:entry twq:name="shape" twq:definiteness="def"
propagate="twq:shape"/>
                                </g:one-of>
                        </g:match>
                        <g:sem>
                                <twq:shape twq:shape="$shape" twq:info="given"/>
                        </g:sem>
                </g:rule>
                <!--  Är det en blå fyrkant/ Är det en fyrkant? -->
                <g:rule twq:name="noun-query" top="true">
                        <g:match>
                                <g:one-of>
                                        <g:item>
                                                <g:entry twq:name="query"/>
                                                <g:entry twq:name="pronoun"/>
                                        </g:item>
                                        <g:entry twq:name="thinking"/>
                                </g:one-of>
                                <g:rule twq:name="noun-phrase" propagate="twq:colour twq:shape
twq:info" link="1"/>
                        </g:match>
                        <g:sem>
                                <b:ref link="1"/>
                        </g:sem>
                </g:rule>
                <!--  Är figuren/den blå/fyrkantig? -->
                <g:rule twq:name="attr-query" top="true">
                        <g:match>
                                <g:entry twq:name="query"/>
                                <g:one-of>
                                        <g:entry twq:name="pronoun"/>
                                        <g:rule twq:name="object"/>
                                        <g:rule twq:name="shape" propagate="twq:shape" link="1"/>
```

```
                                </g:one-of>
                                <g:one-of>
                                        <g:rule twq:name="attr-add" link="2"/>
                                        <g:rule twq:name="noun-phrase" link="2"/>
                                </g:one-of>
                        </g:match>
                        <g:sem>
                                <b:unify>
                                        <twq:object twq:info="given"/>
                                        <b:ref link="1"/>
                                        <b:ref link="2"/>
                                </b:unify>
                        </g:sem>
                </g:rule>
                <!-- Är den till vänster om något blått ?-->
                <g:rule twq:name="place-query" top="true">
                        <g:match>
                                <g:one-of>
                                        <g:entry twq:name="query"/>
                                        <g:entry twq:name="pos_query"/>
                                </g:one-of>
                                <g:one-of>
                                        <g:rule twq:name="object"/>
                                        <g:entry twq:name="pronoun"/>
                                </g:one-of>
                                <g:rule twq:name="direction" propagate="twq:opp-rel"/>
                                <g:optional>
                                        <g:entry twq:name="prepositions"/>
                                </g:optional>
                                <g:rule twq:name="noun-phrase" link="1" propagate="twq:info
twq:colour twq:shape"/>
                        </g:match>
                        <g:sem>
                                <b:unify>
                                        <twq:object twq:info="given">
                                                <twq:position twq:pos-rel="$opp-rel"
twq:info="new">
                                                        <b:ref link="1">
                                                                <b:add twq:info="new"/>
                                                        </b:ref>
                                                </twq:position>
                                        </twq:object>
                                </b:unify>
                        </g:sem>
                </g:rule>
                <!-- Är det något blått till vänster om den? -->
                <g:rule twq:name="place-query" top="true">
                        <g:match>
                                <g:one-of>
                                        <g:item>
                                                <g:entry twq:name="query"/>
                                                <g:entry twq:name="pronoun"/>
                                        </g:item>
                                        <g:item>
                                                <g:entry twq:name="pos_query"/>
                                                <g:entry twq:name="pronoun"/>
                                        </g:item>
                                </g:one-of>
                                <g:rule twq:name="noun-phrase" propagate="twq:colour twq:shape"
link="1"/>
                                <g:rule twq:name="direction" propagate="twq:pos-rel"/>
                                <g:entry twq:name="prepositions"/>
                                <g:one-of>
                                        <g:rule twq:name="noun-phrase-given" propagate="twq:shape
twq:colour" link="2"/>
                                        <g:entry twq:name="object"/>
                                        <g:entry twq:name="pronoun"/>
                                </g:one-of>
                        </g:match>
                        <g:sem>
                                <b:unify>
                                        <twq:object twq:info="given"/>
                                        <b:ref link="2"/>
                                        <twq:object>
                                                <twq:position twq:pos-rel="$pos-rel"
twq:info="new">
                                                        <b:ref link="1">
                                                                <b:add twq:info="new"/>
                                                        </b:ref>
                                                </twq:position>
                                        </twq:object>
```

```
                                </b:unify>
                        </g:sem>
                </g:rule>
                <!-- är den till höger grön -->
                <g:rule twq:name="place-query" top="true">
                        <g:match>
                                <g:entry twq:name="query"/>
                                <g:entry twq:name="pronoun"/>
                                <g:rule twq:name="direction" propagate="twq:pos-rel"/>
                                <g:rule twq:name="attr-add" propagate="twq:colour twq:shape"
link="1"/>
                        </g:match>
                        <g:sem>
                                <b:unify>
                                        <twq:object twq:info="given">
                                                <twq:position twq:pos-rel="$pos-rel">
                                                        <twq:object twq:info="new"/>
                                                        <b:ref link="1"/>
                                                </twq:position>
                                        </twq:object>
                                </b:unify>
                        </g:sem>
                </g:rule>
                <!-- grön och fyrkantig -->
                <g:rule twq:name="attr-add">
                        <g:match>
                                <g:one-of>
                                        <g:item>
                                                <g:rule twq:name="colour" propagate="twq:colour"
link="1"/>
                                                <g:optional>
                                                        <g:entry twq:name="and"/>
                                                        <g:rule twq:name="shape"
propagate="twq:shape" link="2"/>
                                                </g:optional>
                                        </g:item>
                                        <g:item>
                                                <g:rule twq:name="shape" propagate="twq:shape"
link="2"/>
                                                <g:optional>
                                                        <g:entry twq:name="and"/>
                                                        <g:rule twq:name="colour"
propagate="twq:colour" link="1"/>
                                                </g:optional>
                                        </g:item>
                                </g:one-of>
                        </g:match>
                        <g:sem>
                                <b:unify>
                                        <twq:object>
                                                <b:ref link="1"/>
                                                <b:ref link="2"/>
                                        </twq:object>
                                </b:unify>
                        </g:sem>
                </g:rule>
                <!--den blå/a fyrkanten-->
                <g:rule twq:name="noun-phrase-given" top="true">
                        <g:match>
                                <g:entry twq:name="pronoun"/>
                                <g:optional>
                                        <g:rule twq:name="att-add" propagate="twq:colour twq:shape"
link="1"/>
                                </g:optional>
                                <g:one-of>
                                        <g:rule twq:name="shape" twq:definiteness="def" link="2"/>
                                        <g:rule twq:name="object" twq:definiteness="def" link="2"/>
                                </g:one-of>
                        </g:match>
                        <g:sem>
                                <b:unify>
                                        <twq:object info="given"/>
                                        <b:ref link="1">
                                                </b:ref>
                                        <b:ref link="2">
                                                </b:ref>
                                </b:unify>
                        </g:sem>
                </g:rule>
                <!--en blå fyrkant-->
                <g:rule twq:name="noun-phrase" top="true">
```

```
                        <g:match>
                                <g:entry twq:name="article"/>
                                <g:optional>
                                        <g:rule twq:name="attr-add" propagate="twq:colour twq:shape"
link="1"/>
                                </g:optional>
                                <g:one-of>
                                        <g:rule twq:name="shape" propagate="twq:shape twq:info"
link="2"/>
                                        <g:rule twq:name="object" propagate="twq:shape twq:colour"
link="2"/>
                                </g:one-of>
                        </g:match>
                        <g:sem>
                                <b:unify>
                                        <twq:object/>
                                        <b:ref link="1"/>
                                        <b:ref link="2"/>
                                </b:unify>
                        </g:sem>
                </g:rule>
                <!-- något blått (och fyrkantigt)-->
                <g:rule twq:name="noun-phrase" top="true">
                        <g:match>
                                <g:entry twq:name="something"/>
                                <g:rule twq:name="attr-add" link="1"/>
                        </g:match>
                        <g:sem>
                                <b:ref link="1"/>
                        </g:sem>
                </g:rule>
                <g:rule twq:name="colour-ellipses">
                        <g:match>
                                <g:rule twq:name="colour" info="new" link="1"/>
                        </g:match>
                        <g:sem>
                                <b:ref link="1"/>
                        </g:sem>
                </g:rule>
                <g:rule twq:name="shape-ellipses">
                        <g:match>
                                <g:optional>
                                        <g:entry twq:name="something"/>
                                </g:optional>
                                <g:one-of>
                                        <g:rule twq:name="shape" link="1" info="new"/>
                                        <g:rule twq:name="adj_shape" link="1" info="new"/>
                                </g:one-of>
                        </g:match>
                        <g:sem>
                                <b:ref link="1"/>
                        </g:sem>
                </g:rule>
                <g:rule twq:name="object" top="true">
                        <g:match>
                                <g:optional>
                                        <g:entry twq:name="article"/>
                                </g:optional>
                                <g:one-of>
                                        <g:entry twq:name="object" propagate="twq:definiteness
twq:genus"/>
                                        <g:entry twq:name="pronoun" propagate="twq:genus"/>
                                        <g:entry twq:name="something"/>
                                </g:one-of>
                        </g:match>
                        <g:sem/>
                </g:rule>
                <g:rule twq:name="direction">
                        <g:match>
                                <g:one-of>
                                        <g:item>
                                                <g:entry twq:name="position" twq:type="sideways"
propagate="twq:pos-rel twq:opp-rel"/>
                                                <g:entry twq:name="prepositions"/>
                                        </g:item>
                                        <g:item>
                                                <g:entry twq:name="position" propagate="twq:pos-rel
twq:opp-rel"/>
                                        </g:item>
                                </g:one-of>
                        </g:match>
```

```
                        <g:sem>
                                <twq:position/>
                        </g:sem>
                </g:rule>
        </g:rules>
        <g:lexicon>
                <g:entry twq:name="shape" twq:info="new">
                        <g:match twq:shape="square" twq:genus="utr" declination="noun-
1">fyrkant</g:match>
                        <g:match twq:shape="square" twq:genus="utr" declination="noun-
1">kvadrat</g:match>
                        <g:match twq:shape="circle" twq:genus="utr" declination="noun-
1">ring</g:match>
                        <g:match twq:shape="circle" twq:genus="utr" declination="noun-
2">cirkel</g:match>
                        <g:match twq:shape="star" twq:genus="utr" declination="noun-
2">stjärna</g:match>
                        <g:match twq:shape="triangle" twq:genus="utr" declination="noun-
1">trekant</g:match>
                        <g:match twq:shape="triangle" twq:genus="utr" declination="noun-
2">triangel</g:match>
                        <g:sem>
                                <twq:shape/>
                        </g:sem>
                </g:entry>
                <g:entry twq:name="and">
                        <g:match>och</g:match>
                        <g:sem/>
                </g:entry>
                <g:entry twq:name="adj_shape" twq:info="new">
                        <g:match twq:shape="square" declination="adj"
twq:genus="utr">fyrkantig</g:match>
                        <g:match twq:shape="circle" declination="adj" twq:genus="utr">rund</g:match>
                        <g:match twq:shape="triangle" declination="adj"
twq:genus="utr">trekantig</g:match>
                        <g:match twq:shape="square" twq:genus="neutr">fyrkantigt</g:match>
                        <g:match twq:shape="circle" twq:genus="neutr">runt</g:match>
                        <g:match twq:shape="triangle" twq:genus="neutr">trekantigt</g:match>
                        <g:sem>
                                <twq:shape/>
                        </g:sem>
                </g:entry>
                <g:entry twq:name="position">
                        <g:match twq:pos-rel="right-of" twq:opp-rel="left-of"
twq:type="sideways">till höger</g:match>
                        <g:match twq:pos-rel="left-of" twq:opp-rel="right-of"
twq:type="sideways">till vänster</g:match>
                        <g:match twq:pos-rel="over" twq:opp-rel="under">ovanför</g:match>
                        <g:match twq:pos-rel="over" twq:opp-rel="under">över</g:match>
                        <g:match twq:pos-rel="under" twq:opp-rel="over">under</g:match>
                        <g:sem>
                                <twq:position/>
                        </g:sem>
                </g:entry>
                <g:entry twq:name="object" twq:info="given">
                        <g:match twq:genus="utr" declination="noun-1">figur</g:match>
                        <g:match twq:genus="neutr" declination="noun-3">objekt</g:match>
                        <g:sem/>
                </g:entry>
                <g:entry twq:name="something">
                        <g:match>något</g:match>
                        <g:sem/>
                </g:entry>
                <g:entry twq:name="pronoun" twq:info="given">
                        <g:match twq:person="third" twq:genus="utr">den</g:match>
                        <g:match twq:person="third" twq:genus="neutr">det</g:match>
                        <g:sem/>
                </g:entry>
                <g:entry twq:name="prepositions">
                        <g:match>om</g:match>
                        <g:sem/>
                </g:entry>
                <g:entry twq:name="colour" declination="adj">
                        <g:match twq:genus="utr" twq:colour="blue">blå</g:match>
                        <g:match twq:genus="neutr" twq:colour="blue">blått</g:match>
                        <g:match twq:genus="utr" twq:colour="red">röd</g:match>
                        <g:match twq:genus="neutr" twq:colour="red">rött</g:match>
                        <g:match twq:genus="utr" twq:colour="yellow">gul</g:match>
                        <g:match twq:genus="neutr" twq:colour="yellow">gult</g:match>
                        <g:match twq:genus="utr" twq:colour="green">grön</g:match>
                        <g:match twq:genus="neutr" twq:colour="yellow">grönt</g:match>
```

```
                        <g:sem/>
                </g:entry>
                <g:entry twq:name="col_noun" twq:info="given">
                        <g:match twq:colour="blue">blåa</g:match>
                        <g:match twq:colour="yellow">gula</g:match>
                        <g:match twq:colour="red">röda</g:match>
                        <g:match twq:colour="green">gröna</g:match>
                        <g:sem/>
                </g:entry>
                <g:entry twq:name="article">
                        <g:match>en</g:match>
                        <g:match>ett</g:match>
                        <g:sem/>
                </g:entry>
                <g:entry twq:name="query">
                        <g:match>är</g:match>
                        <g:match>finns</g:match>
                        <g:sem/>
                </g:entry>
                <g:entry twq:name="pos_query">
                        <g:match>ligger</g:match>
                        <g:sem/>
                </g:entry>
                <g:entry twq:name="thinking">
                        <g:match>tänker du på</g:match>
                        <g:match>du tänker på</g:match>
                        <g:sem/>
                </g:entry>
        </g:lexicon>
        <g:morphology>
                <g:declination id="noun-1">
                        <a:annotation>
                                fyrkant - fyrkanten
                        </a:annotation>
                        <g:form twq:definiteness="indef"/>
                        <g:form twq:definiteness="def">en</g:form>
                </g:declination>
                <g:declination id="noun-2">
                        <a:annotation>
                                stjärna - stjärnan
                        </a:annotation>
                        <g:form twq:definiteness="indef"/>
                        <g:form twq:definiteness="def">n</g:form>
                </g:declination>
                <g:declination id="noun-3">
                        <a:annotation>
                                objekt - objektet
                        </a:annotation>
                        <g:form twq:definiteness="indef"/>
                        <g:form twq:definiteness="def">et</g:form>
                </g:declination>
                <g:declination id="adj">
                        <a:annotation>
                                blå - blåa
                        </a:annotation>
                        <g:form twq:definiteness="indef"/>
                        <g:form twq:definiteness="def">a</g:form>
                </g:declination>
        </g:morphology>
</g:grammar>
<?xml version="1.0" encoding="ISO-8859-1"?>
<?xml-styslesheet f:type="text/xsl"

----------------------------------------ca.xml----------------------------------------------------
href="http://www.speech.kth.se/higgins/2003/pickering/grammar/transformations/grammar2xhtml_include.xs
l"?>
<g:grammar
        xsi:schemaLocation="
                http://www.speech.kth.se/higgins/2003/pickering/grammar/
                        http://www.speech.kth.se/higgins/2003/pickering/grammar/grammar.xsd
                http://www.speech.kth.se/higgins/2003/buildxml/
               http://www.speech.kth.se/higgins/2003/buildxml/buildxml.xsd
        "
        xmlns:g="http://www.speech.kth.se/higgins/2003/pickering/grammar/"
        xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
        xmlns:b="http://www.speech.kth.se/higgins/2003/buildxml/"
        xmlns:f="http://www.speech.kth.se/higgins/2003/pickering/grammar/feature/"
        xmlns:a="http://www.speech.kth.se/higgins/2003/annotation/"
        xmlns:twq="http://www.speech.kth.se/ville/twq/"
>
        <a:annotation>
```

```
                <desc>
                Communicative acts in the 20q domain:
                - questions
                - ellipsis
                </desc>
        </a:annotation>
        <g:rules>

                <g:rule f:name="ca" top="true">
                        <a:annotation>
                                Top rule for matching questions.
                        </a:annotation>
                        <g:match>
                                <g:one-of>
                                        <!--g:rule twq:name="shape_query" propagate="info"
link="1"/-->
                                        <g:rule twq:name="attr-query" propagate="info" link="1"/>
                                        <g:rule twq:name="place-query" propagate="info" link="1"/>
                                        <g:rule twq:name="noun-query" propagate="info" link="1"/>
                                </g:one-of>
                        </g:match>
                        <g:sem>
                                <twq:ca twq:type="question">
                                        <b:ref link="1"/>
                                </twq:ca>
                        </g:sem>
                </g:rule>

                <g:rule f:name="ca" top="true">
                        <a:annotation>
                                Top rule for matching ellipses.
                        </a:annotation>
                        <g:match>
                                <g:one-of>
                                        <g:rule twq:name="colour-ellipses" propagate="info"
link="1"/>
                                        <g:rule twq:name="shape-ellipses" propagate="info"
link="1"/>
                                        <g:rule twq:name="both-ellipses" propagate="info" link="1"/>
                                </g:one-of>
                        </g:match>
                        <g:sem>
                                <b:unify>
                                        <twq:ca twq:type="ellipses">
                                                <b:ref link="1"/>
                                        </twq:ca>
                                </b:unify>
                        </g:sem>
                </g:rule>

                <g:rule f:name="ca" top="true">
                        <a:annotation>
                                Top rule for matching assertions.
                        </a:annotation>
                        <g:match>
                                <g:rule twq:name="assertion"/>
                        </g:match>
                        <g:sem>
                                <twq:ca twq:type="assert"/>
                        </g:sem>
                </g:rule>


        </g:rules>
</g:grammar>



----------------------------------------system.xml---------------------------------------------------


<?xml version="1.0" encoding="ISO-8859-1"?>
<?xml-styslesheet type="text/xsl"
href="http://www.speech.kth.se/higgins/2003/pickering/grammar/transformations/grammar2xhtml_include.xs
l"?>
<g:grammar xsi:schemaLocation="http://www.speech.kth.se/higgins/2003/pickering/grammar/
http://www.speech.kth.se/higgins/2003/pickering/grammar/grammar.xsd
                http://www.speech.kth.se/higgins/2003/buildxml/
                http://www.speech.kth.se/higgins/2003/buildxml/buildxml.xsd"
xmlns:g="http://www.speech.kth.se/higgins/2003/pickering/grammar/"
xmlns:twq="http://www.speech.kth.se/ville/twq/" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
```

```
xmlns:b="http://www.speech.kth.se/higgins/2003/buildxml/"
xmlns:f="http://www.speech.kth.se/higgins/2003/pickering/grammar/feature/"
xmlns:a="http://www.speech.kth.se/higgins/2003/annotation/">
        <a:annotation>
                <desc/>
        </a:annotation>
        <g:rules>
                <g:rule twq:name="assertion">
                        <g:match>
                                <g:entry twq:name="yes"/>
                        </g:match>
                        <g:sem/>
                </g:rule>
        </g:rules>
        <g:lexicon>
                <g:entry twq:name="yes">
                        <g:match>ja</g:match>
                        <g:sem/>
                </g:entry>
                <g:entry twq:name="nej">
                        <g:match>nej</g:match>
                        <g:sem/>
                </g:entry>
                </g:lexicon>
</g:grammar>


----------------------------------------template.xml----------------------------------------------
<?xml version="1.0" encoding="ISO-8859-1"?>
<?xml-stylesheet type="text/xsl" href="http://www.speech.kth.se/higgins/xsl/xml_view.xslt"?>
<g:grammar xsi:schemaLocation="
        http://www.speech.kth.se/higgins/2003/pickering/grammar/
                http://www.speech.kth.se/higgins/2003/pickering/grammar/grammar.xsd
        http://www.speech.kth.se/higgins/2003/pickering/grammar/feature/
                http://www.speech.kth.se/higgins/2003/pickering/grammar/feature/feature.xsd"
xmlns:g="http://www.speech.kth.se/higgins/2003/pickering/grammar/"
xmlns:dm="http://www.speech.kth.se/higgins/2003/galatea/model/"
xmlns:num="http://www.speech.kth.se/higgins/2005/semantics/numbers/"
xmlns:time="http://www.speech.kth.se/higgins/2005/semantics/time/"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:f="http://www.speech.kth.se/higgins/2003/pickering/grammar/feature/"
xmlns:a="http://www.speech.kth.se/higgins/2003/annotation/"
xmlns:twq="http://www.speech.kth.se/ville/twq/"
xmlns:xref="http://www.speech.kth.se/higgins/2005/xref/">
        <a:annotation>
                <desc>
                        Template file for the Pickering example grammar example_1.xml.
                </desc>
        </a:annotation>
        <g:template>
                <twq:object id="object" attributes="xsi-type id  twq:info" count="1">
                        <xref:ref xref:idref="colour_id" count="1"/>
                        <xref:ref xref:idref="shape_id" count="1"/>
                        <xref:ref xref:idref="position" count="1"/>
                </twq:object>
                <twq:colour id="colour_id" attributes="info colour f:conf">
                        <dm:grounding count="1" id="grounding_def">
                                <dm:ca count="*"/>
                        </dm:grounding>
                </twq:colour>
                <twq:shape id="shape_id" attributes="info shape f:conf">
                        <xref:ref xref:idref="grounding_def"/>
                </twq:shape>
                <twq:position id="position" attributes="pos-rel">
                        <xref:ref xref:idref="object" count="1"/>
                </twq:position>
                <twq:ca count="1">
                        <xref:ref xref:idref="object" count="1"/>
                </twq:ca>
        </g:template>
</g:grammar>
```

6.2 Galatea

```
----------------------------------------mappings.xml-------------------------------------------------
<?xml version="1.0" encoding="iso-8859-1"?>
<m:mappings
        xmlns:m="http://www.speech.kth.se/higgins/2003/galatea/mappings/"
        xmlns:match="http://www.speech.kth.se/higgins/2004/match/"
        xmlns:twq="http://www.speech.kth.se/ville/twq/"
        xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
        xmlns:f="http://www.speech.kth.se/higgins/2003/pickering/grammar/feature/"
        xsi:schemaLocation="http://www.speech.kth.se/higgins/2003/galatea/mappings/
http://www.speech.kth.se/higgins/2003/galatea/mappings.xsd"
>
        <m:cas>
                <!-- input markup of communicattive acts -->
                <m:ca>
                        <twq:ca/>
                </m:ca>
                <!-- what to generate on nomatch -->
                <m:nomatch>
                        <twq:ca f:understanding="none"/>
                </m:nomatch>
                <!-- list of types of communicative acts to "parse" for _given_ entities that will
raise focus
                        "The building is red" => focus building
                -->
                <m:integrate_given_entities>
                        <twq:ca/>
                </m:integrate_given_entities>

                <!--
                        which communicative acts results in addition of new entities to entity list
                        "there is a red building in front of me" => adds "red buidling"
                -->
                <m:integrate_new_entities>
                        <twq:ca twq:type="assertion"/>
                </m:integrate_new_entities>

                <!--
                        in which cases should new  be included when raising focus to a given object
(as above)
                        " The red building is large" => raises "building", adds "large"
                -->
                <m:integrate_new_info>
                        <twq:ca twq:type="assertion"/>
                </m:integrate_new_info>

                <!--
                        At what point should Galatea send reset to Pickering and send results onwards
                -->
                <m:send_model>
                        <twq:ca/>
                </m:send_model>
        </m:cas>

        <m:entities>
                <!--
                        What elements are objects (may use <match:element/>)
                -->
                <m:entity>
                        <twq:object/>
                </m:entity>

                <!-- elements that causes object search to cease -->
                <m:entity_exceptions/>

                <!--
                        attributes (and elements) that should not be considered when matching for
anaphora
                 -->
                <m:match_anaphora_exceptions attributes="twq:info"/>
                <!--
                        attributes (and/or elements that are removed when the entity is added to the
entity list
                -->
                <m:remove_in_entity_list attributes="twq:info"/>
                <!--
                        What a "given" entity looks like
                -->
                <m:given>
```

```
                        <match:element twq:info="given"/>
                        <!--<match:element/>-->
                </m:given>
                <!--
                        What a "new" entity looks like
                -->
                <m:new>
                        <match:element twq:info="new"/>
                        <!--<match:element/>-->
                </m:new>
        </m:entities>

</m:mappings>
----------------------------------------context.xml-------------------------------------------------
<?xml version="1.0" encoding="iso-8859-1"?>
<g:transformations xmlns:g="http://www.speech.kth.se/higgins/2003/galatea/rules/"
xmlns:match="http://www.speech.kth.se/higgins/2004/match/"
xmlns:twq="http://www.speech.kth.se/ville/twq/" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:f="http://www.speech.kth.se/higgins/2003/pickering/grammar/feature/"
xmlns:b="http://www.speech.kth.se/higgins/2003/buildxml/"
xsi:schemaLocation="http://www.speech.kth.se/higgins/2003/galatea/rules/
        http://www.speech.kth.se/higgins/2003/galatea/rules.xsd
        http://www.speech.kth.se/higgins/2003/buildxml/
        http://www.speech.kth.se/higgins/2003/buildxml/buildxml.xsd">
        <g:rule>
                <g:annotation>Elliptical question.</g:annotation>
                <g:context agent="same" turn="2">
                        <twq:ca twq:type="question" match:link="1">
                                <match:tree>
                                        <match:element match:name="colour|shape" match:link="2"/>
                                </match:tree>
                        </twq:ca>
                </g:context>
                <g:new>
                        <twq:ca twq:type="ellipses">
                                <match:element match:name="colour|shape" match:link="3"/>
                        </twq:ca>
                </g:new>
                <g:transform>
                        <b:ref link="1">
                                <b:replace link="2">
                                        <b:ref link="3"/>
                                </b:replace>
                        </b:ref>
                </g:transform>
        </g:rule>
        <g:rule>
                <g:annotation>YN-answer to request.</g:annotation>
                <g:context turn="1">
                        <twq:ca twq:type="question">
                                <match:tree match:link="1">
                                        <match:element match:name="colour|shape"/>
                                </match:tree>
                        </twq:ca>
                </g:context>
                <g:new>
                        <twq:ca twq:type="assert"/>
                </g:new>
                <g:transform>
                        <b:unify>
                                <twq:ca twq:type="assertion">
                                        <b:ref link="1">
                                        </b:ref>
                                </twq:ca>
                        </b:unify>
                </g:transform>
        </g:rule>
</g:transformations>
```