APPLICATIONS IN NATURAL LANGUAGE PROCESSING

NATURAL LANGUAGE INTERFACES AND DIALOGUE SYSTEMS
Natural Language Interfaces and Dialogue Systems

- Introduction
  - Tasks of the dialogue systems
    - Interpreting user intervention
    - Dialogue Management
    - Generating system's intervention
- Architecture
- Development and evaluation
Introduction

• **Main goal in human/machine communication**
  Help users perform specific tasks according to their objectives

• **Two metaphores**
  - Human conversation
    question/answering, menu systems, forms, command language dialogue
  - World model
    Direct access to the domain objects (the icons representing them). **WYSWYG**
Using the Natural Language Mode

**Advantages**
- Human Language (natural, friendly)
- Complex ideas can be expressed
- References to other entities are easy to express

**Disadvantages**
- High cost
- Ambiguity -- mistakes
- Limitations for accessing several applications (such as graphics)

**Appropriate for occasional access to applications that need to express complex operations (especially when domain can be restricted)**
Using the Natural Language Mode

**Advantages** of the speech mode
- Convenient
- Typing is not needed
  - Small devices
  - Hands cannot be used (i.e.: driving cars, airplanes)
  - Handicapped

**Disadvantages** of the speech mode
- Technical limitations to recognize voice
- Ambiguity, mistakes
- High cost
- Not appropriate for specific applications

**Appropriate for expressing simple operations on restricted domains**
The Need for Dialogue Systems

- User cannot express a requirement in only one intervention
- User need the system intervention to make the communication friendlier
An Example of Conversational System

System: Welcome to the information service, what do you want?
User: I want to go from Barcelona to Valencia
System: When do you want to go?
User: Next Tuesday
System: At what time, morning or afternoon?
User: Morning, please
System: There are 3 Euromed trains on Tuesday morning
The Terms

- Human Computer Interfaces
- Natural Language Interfaces
- Speech Based Interfaces
- Conversational Interfaces
- Conversational Agents
- Dialogue Systems
- Spoken Dialogue Systems
- Spoken Language Systems
Basic cycle in an interaction question/answering

- User
  - Expression in NL
- ILN
- Interface to application
  - Interpretation
  - Generation of the answer
  - Application
Main trends in Natural Language Interfaces

• Evolution parallel to Language Engineering
• Improving adaptability and friendliness
• Portable (or adaptable) interfaces.
  • They are usually developed for a specific domain or application.
    • They use domain (or application) restricted knowledge (domain model)
  • Interfaces to specific application
• They are usually developed for one (or more) specific languages
Main trends in Natural Language Interfaces

• Improving portability: Reusability of basic components
  - Speech recognizer
  - Language interpretation and generation: lexicon, parsers, grammars
• Improving friendliness
  • Multimodality
  • Friendly systems
Improving friendliness

- Quality of the interaction
- Supporting possible mistakes in the user intervention
  - Spelling and grammar mistakes
  - Short names, colloquial expressions, other language words
- Mixed and user initiative
- User models
Multimodality

• Integration of graphics and language for input and output expressions.
• Supporting complex reference across graphics and text.
• Integration of gestures and text
• Considering the content, the context and the user model to choose the best presentation of the output (and the best way to combine different modes of interaction)
General Schema of a Natural Language Interface

- Obtaining and organizing
- Linguistic knowledge
- Application
- NLI
  - Dynamic Information
- User
Tasks of the Dialogue Systems

- Interpreting the user’s intervention
  - Using dialog and domain knowledge
- Dialogue Management
  - Determine next system actions considering user's intention
- Answer Generation
  - Generate the system's sentences most appropriate at each state of the dialogue
Interpreting the user intervention

• Goal: understanding user's intention
• Knowledge involved
  • Phonetics and phonology
  • Morphology
  • Syntax
  • Semantics (lexical and compositional)
  • Pragmatics
  • Discourse
Interpreting the user intervention

• Goal: understanding the user's intention
• Precise information from the user is required
• The complexity of this process depends on the system
  – Complete (deep) syntactic and semantic analysis
  – Partial (shallow) syntactic and semantic analysis
  – Processing key words

• This process is restricted by considering limited applications tasks
Interpreting the user intervention

• Main tasks
  • Reference resolution
  • Intention recognition

• The use of the context
  • Dialogue history
  • Domain knowledge
Interpreting the user intervention

• Main problems
  • Establish syntactic relations
  • Quantification.
  • Coordination and subordination
  • References
  • Elipsis
  • Ungrammatical expressions
U: Where the movie Heroes is shown in Sant Cugat?
S: Heroes is shown at Cinema Cinesa in Sant Cugat
U: At what time is it shown?
S: It is shown at 8:30pm, 10pm and 11:30pm.
U: I want 2 tickets for adults and 2 for children for first session. How much is it?

- **Knowledge Sources:**
  - Domain Knowledge
  - Dialogue Knowledge
  - Domain (world) knowledge
Reference resolution (real systems)

• There is no reference resolution
• Only simple references are processed
  • A stack with entities focus is used
  • No discourse structure is used
Reference resolution

• Central elements of the sentences have to be selected
  - They are grammatically related to the main verb (subject, object,…)
    – They can connect a sentence with previous
    – They can connect a sentence with next
• When pronouns are found several rules are used to rank and filter the possible central elements
Reference resolution

- Most references are solved using knowledge discourse
- Central elements (focus) are stored in a stack
  - Only lasts nominal groups are stored
- Objects satisfying syntactic, semantic and pragmatic restrictions are selected
  - Starting by the stack top
    - “There” is a place
  - Considering discourse structure
    - Relating objects and subdialogs
Intention Recognition

• User's interventions are interpreted as one (or more) dialogue act (speech act or dialogue move)

• Examples of dialogue moves
  – Switchboard DAMSL
    • Ini/final conventional
    • Opinion
    • Confirming/Accepting
    • Recognizance
    • Question/Answer/Yes-No
    • No-verbal
    • Quit
  – Verbmobil
    • Greet/Thank you/Goodbye
    • Suggestion
    • Accepting/Not accepting
    • Confirmation
    • question/clarification/Answer
    • Giving the reason
    • Thinking

• Efforts for standard definition
Intention Recognition

• Dialogue grammars (finite state machine)
  Greet $\rightarrow$ Question $\leftrightarrow$ Answer $\rightarrow$ Thankyou $\rightarrow$ Goodbay

• Plans
  • Receipts: General frames to perform actions
  • Inference rules
    • AI planification rules
Intention Recognition (Real systems)

• The system infers the application task the user is asking for
  • Application: Giving information on cultural events
    • *Time or place where a specific event takes place*
    • *Events that take place in a specific place*
  • Application: Giving information on trains
    • *Schedule for a specific train*

• The system asks the user the information the application needs
  • The system ignores the information not useful for the application
Intention Recognition (Real systems)

- System initiative
- User initiative very limited
  - Not allowed in complex acts such as confirmation, clarification and indirect answers

S1: Which is your account number?
U1: My account number in Online Bank?

S2: Would you want to transfer 1500 euros to your new account?
U2: If I have this amount, ok
Intention Recognition (Real systems)

- Content obtained from the user's intervention
  - The application task that has to be performed
    - Information on classical music concerts in Barcelona
  - The information needed to perform the specific task
    - The specific date and place
    - The next Saturday on the Auditori
Intention Recognition (Real systems)

Several methods can be used

• *Frames* representing the information needed for each task
  • Trains schedule: departure and destination
  • Similarity measurement based on vectors
Using frames

- Representing tasks as frames described by attributes that correspond to input and output task parameters
  - Representing the tasks of giving information about a specific train as a frame where
    - departure and destination station are represented as attributes which value has to be provided by the user
    - time and price are the attributes obtained from the application and presented to the user
Representation of a user intervention asking for a ticket

**Reservation**
- What
- Quantity: 1

**Train ticket**
- Date
- Type
- From: Barcelona
- To: Valencia
- Hour
- Prize
- Type: Euromed
Semantic Grammar

Ticket_re -> initial, quantification, ticket,[mods]
initial -> “I want”| “I want to make”
quantification -> “one”| “two”| 1
ticket -> “tickets”| “tickets”| “reservation”
mods -> mod,[mods]
mod -> “from”, city| “to”, city| “on”, typetrain
city -> barcelona| valencia
typetrain -> euromed
Intention Recognition (Real systems)

U: At what time *Madagascar* is shown in *Sant Cugat*?

Intention: asking for information about a particular movie

**Frame: Movie_information**

**Attributes which value is given by the user**

*Movie:* Madagascar

*Place:* Sant Cugat

**Attributes which value is obtained by the application:** time
Intention Recognition (Real systems)

- Using keywords and measures based on similarity vectors
- Representing question and goal (answer) as vectors
- Searching the goal vector most similar to the question
- Similarity metrics
  - cosinus of the angle between the two vectors
Tasks of the Dialogue Systems

• Interpreting user intervention
  – Using dialog and domain knowledge

• **Dialogue Management**
  – Determine next system actions considering user's intention

• Answer Generation
  – Generate the system's sentences most appropriate at each state of the dialogue
Dialogue Management

• Controlling dialog to help the user to achieve his goals
  – At each step of the conversation
    • Who can speak
    • What can be said

  – Used information
    • Interpretation of the user intervention
    • Application (domain) knowledge
Dialogue Management

• Determine the next system's action(s)
  – Answer user's questions
  – Ask the user for more information
  – Confirm/Clarify user's interventions
  – Notify problems when accessing the application
  – Suggest alternatives

• Generation of the system's messages
  – The content
  – The presentation
## Dialogue Management

### Example: Application giving information on flights

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Optional question</th>
</tr>
</thead>
<tbody>
<tr>
<td>DepartureAirport</td>
<td>“From which airport you leave?”</td>
</tr>
<tr>
<td>ArrivalAirport</td>
<td>“Where do you want to flight?”</td>
</tr>
<tr>
<td>DepartureTime</td>
<td>“At what time do you flight”</td>
</tr>
<tr>
<td>ArrivalTime</td>
<td>“At what time it arrives?”</td>
</tr>
<tr>
<td>Class</td>
<td></td>
</tr>
<tr>
<td>Company</td>
<td></td>
</tr>
</tbody>
</table>
Dialogue Management

At each turn, preparing next system’s intervention

Obtaining information from the user:
  • Ambiguities because recognition problems
    * Did you said Barcelona o Badalona?
  • Uncompleted specification
    * On which day do you want to travel?

  • Giving an answer to the user’s question
    • Asking the user to restrict the question when many results are found:
      * I found 10 flights, do you prefer any special flight?
    • Asking the user to relax the question when no results are found
      * The are flight on the morning, would you mind flying at night?
Dialogue Management

• Guiding the user about accessible information
  • Presenting new goals
    *Do you want to know the flight price?*
  • Presenting alternatives

*There is no information about Girona airport, only about Barcelona*

• Guiding the user about system’s limitations:

When there is more user’s initiative there are more problems caused by the lack of information of:

• Application tasks
• Domain information
• Language recognized by the system
• Helping guides: initial indications, system’s messages
Dialogue Management

- Errors recovery
  - Different causes: noise environment, accents, vocabulary
  - Several strategies to deal with problematic input
    - Directed dialog
    - Explicit confirmation: asking to confirm only what has not been completely understood
    - Using statistics
    - Others
- Dealing with interruptions
Dialogue Management

• Main design decisions
  • **Functionality**: The tasks the system has to perform
  • **Processing**: How these tasks have to be performed

• Considerations
  • Task complexity
  • Dialogue complexity: Which dialogue phenomena will be allowed
    • User initiative?

• Results
  • Robustness
  • Natural
Dialogue Management

• Content of dialogues
  • Restricted to the information related to the application
  • Subdialogs: clarification, confirmation
  • Meta-dialogs (about the dialog)
    • *Are you still here?*

• Who can initiate different types of dialogues
  • Only the system
  • Only the user
  • Both
Functionality of dialogue manager

- Determine the set of possible goals the system can select at each turn
- Conditioned
  - Task complexity
  - Dialogue complexity
    - Are subdialogues allowed? Who is allowed to use them?
    - Are meta-dialogues allowed? Who is allowed to use them?
Funtionality of dialogue manager (Research)

• Task complexity: from medium to complex
  • Travel planning
• Dialogue complexity
  • Subdialogues supporting complex features
    • Mixed initiative
    • Collaboration to solve tasks
  • Meta-dialogues
Functionality of dialogue manager (Real systems)

• Tasks complexity: from simple to moderate
  • *Information about the weather*
  • *Information about train schedule*

• Dialogue complexity
  • Tasks restricted
  • System initiative
    • Limited subdialogues
Processing of dialogue manager

• Initiative strategies
  • System
  • User
  • Mixed
  • Variable

• Mechanisms for modeling initiative
  • System and mixed initiative: finite state machine
  • Variable initiative, depending on:
    • Dialogue history
      • Understanding errors
      • Others
Knowledge sources

- Dialogue Manager can use
  - Dialogue models
    - Define general dialogue phenomena
  - Tasks models
    - Define specific application tasks
    - *Frame based systems*. Obtain parameter values
      - *Flight information: departure, arrival, date*
  - Domain models
    - Concepts and relations in a specific domain
    - Appropriate for complex domain
  - These models can be implicit
    - Finite state systems
Dialogue Model

• Dialogue model
  • Define the framework under which the user interventions have to be interpreted

• Dialogue state
  • Reference entities, relationship between them
Dialogue Management (Abstract)

- Decide system’s respond to user's intervention
  - Inferring user's needs
    - Dealing with ambiguity and not complete information
  - Accessing the application (or knowledge source)
  - Presenting the answer to the user
Dialogue Management (Abstract)

• **Research systems**
  • Focused on the development of models and algorithms for supporting several dialogue phenomena for complex tasks

• **Real systems**
  • Focused on the development of robust strategies, to deal efficiently with most common dialogue phenomena for simple applications
Tasks of the Dialogue Systems

• Interpreting user’s intervention
  – Using dialog and domain knowledge
• Dialogue Management
  – Determine next system actions considering user's intention
• Answer Generation
  – Generate the system's sentences most appropriate at each state of the dialogue
Answer Generation

• Generation of sentences to achieve the goals the dialogue manager has selected

• Tasks
  • Content selection: what has to be said
    • Belongs to the discourse plan
  • Superficial realization: how has to be said
    • Presenting content correctly
Content Selection

• Determine the content of the system sentences in order to achieve the goals

• Examples:
  • *Madagascar is not shown in Sant Cugat* [Nucleus]
  • *It is shown in Barcelona* [Satellite]
  • *Would you like a suite?* [Nucleus]
  • *It is the same price than the doble room* [Satellite]
  • *Magic Flaute is not shown this year at Liceu* [Nucleus]
  • *But Figaro Wedding is* [Satellite]
Content selection (Research)

- Knowledge Bases
  - Domain knowledge
  - User believes
  - User model: preferences, language.
  - Dialogue history

- Mechanisms for content selection
  - Schemes - patterns
    - First object name, then attributes
  - Rules
  - Plans
  - Reasoning
Content selection (Real systems)

- Knowledge sources
  - Domain knowledge
  - Dialogue history
- Strategies pre-defined for content selection
  - Only nucleus, not satellite
  - Nucleus + satellite fixed
Superficial realization

• Goal: to determine how content selected is presented

• Examples:
  * Madagascar is shown at CINESA cinema in Sant Cugat

• Tasks
  * Construction of phrases
  * Lexical selection
Superficial realization (Research)

• The generator input is
  • Semantic representation
  • Phrase structures

• The generator uses a grammar and a lexicon for generating the sentence
Superficial realization (Real systems)

- Predefined (canned) sentences
  - Sentences to achieve specific goals
    - Initial and final sentences
    - Ask the user to repeat
  - Specially appropriate for speech
- Patterns
  - Patterns for goals
    - Notification: You have been assigned number X.
    - Information: A, B, C, D, and E are shown at cinema F.
    - Clarification: Did you said X or Y?
Components of spoken dialogue systems

**Voice input: From acoustic signal to meaning**
Conversion of the signal to a set of words
Obtention of meaning from words

**Voice output: From content to acoustic signal**
Conversion of content to text sentences
Conversion from text to signal

**Dialogue Manager**
Voice input: From acoustic signal to meaning

Transforming the signal to a set of words

• Disfluences
  • Pauses, expressions like: umm, aah
  • Fragments of words
  • Models using pauses
• Words that do not appear in the lexicon used
  • Models that can learn new words
• Mobile: more difficult
Obtention of meaning from words

Probabilistic model (i.e. n-gram)

it specifies the probability of a particular word once previous word has been recognized

• It is not understanding

• Probability of previous word is not one : many alternative hypothesis

  ▪ Example: *Euthanasia o youth in Asia*

• Not grammatically correct, fragments, disfluencies
Voice input: From acoustic signal to meaning

Obtention of meaning from words

• NLP is based in a complete syntactic analysis
• The approach in voice is different
  • Many recognition mistakes, unknown words
• Semantic approach (in restricted domain systems)
Design of dialogue systems

Gould and Lewis principles (1985)

• Study users and application tasks
  • Interviews to users
  • Obtaining person-person dialogues
• Development of a prototype
  • Using *Wizard-of-Oz* method. A person substitutes the machine
• Interactive design
  • Users have to prove the system. Incorporation of new information
Evaluation

• Goal: to determine how well the system is working

• Difficulties
  • Determine correct and incorrect dialogues
  • Comparing strategies and dialogs
  • Metrics selection
    • Efficiency versus correctness
  • Determine the relationship between different metrics
    • Long or short dialogues?
  • High cost
Evaluation

- Only system’s initiative
  - More successful dialogues
  - Less recognition errors

- Only user’s initiative
  - More natural
  - Shorter (advantage?)
  - More subdialogs for detecting errors
Evaluation

• Evaluation paradigm
  • Evaluation of the final result success

• Evaluation of the final result success and also the process
  • Different metrics for different components
  • Only one function to evaluate the set
Evaluation

Evaluation only of the success of final result

• Appropriate for question/answering systems
• Easy to define correct answers
• For each question
  • Obtaining the correct answer
  • Obtaining system’s answer
  • Comparing answers
  • Quantification of the processing of the system

• Advantages: simple
• Disadvantages: ignore other important aspects
Evaluation

Evaluation of the final result and the process

Different metrics for different components

• Voice recognition
  • errors in word recognition (WER)
• Interpretation: attribute-value matrix
• Dialogue Manager
  • Quality of system’s responds
  • Strategies for recovery of errors
• Dialogue system
  • Success of final result
  • Number of turns
  • Time
Evaluation

Different metrics for each component

• Advantages:
  • Considering all the process to complete the task

• Limitations:
  • The metrics may not be independent from each other
  • Difficulties for comparing different dialogue systems
Evaluation

Only one function to evaluate all the process

- PARADISE [Walker et al]
- Maximizes user’s satisfaction
  - Maximizes task success
  - Minimizes cost
- Efficiency measurements
  - Number of interventions
  - Waiting time
- Quality measurements
  - Ratio of errors recovery
Evaluation

PARADISE

• Function of measurements
  • Values on user satisfaction
    • Questionnaires
  • Values of several metrics
  • Applying multiple linear regression to obtain a function that relates user satisfaction and other metrics
Evaluation

• Advantages
  • It compares different systems
  • It specifies the contribution of each system component to the global performance
  • It can be used for predicting future versions

• Disadvantages
  • High cost for obtaining the function
  • High cost for adapting the function to other systems.
**An example of conversation in a Dialogue System**

C

D {tema: bienvenida}

Interc {objetivo: saludar}

S> Welcome to the information service, what do you want

D {tema: viaje en tren de Barcelona a Valencia}

Interc {objetivo: petición de una información}

U> Quisiera ir de Barcelona a Valencia

Sub {tema: fecha del viaje}

Interc {objetivo: precisión}

S> ¿En qué fecha?

U> el martes que viene

Sub {tema: hora del viaje}

Interc {objetivo: precisión}

S> ¿qué horario, mañana o tarde?

U> a primera hora

Interv

S> Hay 3 trenes, el Euromed ....

Interc {objetivo: petición de una información}

U> ¿Cuánto vale el billete en segunda?

S> 8000 pesetas

D {tema: despedida}

Interc {objetivo: despedirse}

U> Gracias, buenas tardes

U> Gracias a Vd, buenas tardes