APPLICATIONS IN NATURAL LANGUAGE PROCESSING

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). *WYSIWYG*
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
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
- Interpretation
- Interface to application
- Generation of the answer
- Application

ILN

Expression in NL
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)
• 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 references 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
First Natural Language Interfaces

- **NLI to Databases**
  - **70s**: LUNAR (Woods), RENDEZVOUS (Codd, 1974)
  - **80s**: LADDER (Hendrix), TEAM (Grosz), CHAT-80 (Warren, Pereira), DATALOG (Hafner)

- **Accessing other applications**
  - Operating systems, experts systems, tutoring systems, consulting systems, ...
  - Research systems
    - LDC, TELI, XTRA, INKA, XCALIBUR, UC, GISE
  - Commercial systems
    - INTELLECT, PARLANCE, HAL, Q&A, LOQUI, NAT, NL, SESAME
Complex Natural Language Interfaces

- Multimodal systems
  - MMI2 (Multimodal Interface for Man Machine Interaction), MATIS (Multimodal Airline Travel Information System), ALFRESCO

- Using voice
  - Dictation systems, telephone interfaces
  - VOYAGER (MIT), Office Manager (CMU), MASK (Multimodal Multimedia Automated Service Kiosk), ATIS (MIT, CMU), Railtel, Sundial, Verbmobil

- VoiceXML
Architecture of a Dialogue System
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
  • Processing syntactic relations
  • Quantification
  • Coordination and subordination
  • References
  • Ellipsis
  • 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 the entities that are the possible 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
  - Efforts for standard definition
    - Verbmobil
      - Greet/Thank you/Goodbye
      - Suggestion
      - Accepting/Not accepting
      - Confirmation
      - Question/Clarification/Answer
      - Giving the reason
      - Thinking
Intention Recognition

• Dialogue grammars (finite state machine)
  Greet → Question ↔ Answer → Thankyou → Goodbay

• Plans
  • Receipts: General frames to perform actions
  • Inference rules
    • Planification rules (Artificial Intelligence)
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

**Train ticket**
- Date
- Type
- From
- To
- Hour
- Prize

**What**
- Quantity: 1

**Type**
- Euromed
- From: Barcelona
- To: Valencia
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 questions and goals (answers) 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 do 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

Preparing next system’s intervention
Obtaining information from the user:

• Ambiguities because recognition problems
  \textit{Did you said Barcelona o Badalona?}

• Uncompleted specification
  \textit{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:
    \textit{I found 10 flights, do you prefer any special flight?}
  • Asking the user to relax the question when no results are found
    \textit{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 airport*

• Guiding the user about the system’s limitations:
  • When there is 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
Dialog 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 at 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 and D are shown at cinema E.
    - Clarification: Did you said X or Y?
## Components of spoken dialogue systems

<table>
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<tr>
<th><strong>Voice input:</strong> From acoustic signal to meaning</th>
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<tbody>
<tr>
<td>Conversion of the signal to a set of words</td>
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<table>
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<tr>
<th><strong>Voice output:</strong> From content to acoustic signal</th>
</tr>
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<tbody>
<tr>
<td>Conversion of content to text sentences</td>
</tr>
<tr>
<td>Conversion from text to signal</td>
</tr>
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</table>

**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
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)
VOICEXML: A VOICE STANDARD

• System development easy and fast
  • Low level details are transparent
• Internet access
  • Client/Server architecture
• Multilinguality
  • More than a language
Example: Català and Castellà can be mixed
  “Plaza Sants”
  “Calle Manuel Girona”
Limitations

• Only voice
  • Touch-tone DTMF
• The dialog has to be defined for each application
• System initiative
  • No user initiative
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.
Formas lógicas utilizadas en SISCO

¿Cúal es el caudal del rio Ebro?
→
preg(Y, ex(rio1(X)&X=ebro,caudal(Y,X)))

¿Dónde desemboca el rio Ebro?
→
preg(X, ex(rio1(Y)&Y=ebro,desemboca(Y,X)&lugar(X)))
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?

Interv

U> el martes que viene

S> ¿qué horario, mañana o tarde?

Interv

U> a primera hora

Interv

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

Interc {objetivo: petición de una información}

Interv

U> ¿Cuánto vale el billete en segunda?

Interv

S> 8000 pesetas

D  {tema: despedida}

Interc {objetivo: despedirse}

U> Gracias, buenas tardes

Interv

U> Gracias a Vd, buenas tardes