Natural Language Generation

An Overview

Stephan Busemann

DFKI GmbH
Saarbrücken, Germany
Stephan.Busemann@dfki.de

Acknowledgement: *Part of this overview was inspired by Robert Dale's and Ehud Reiter's tutorial on Applied NL Generation*

Natural Language Generation

AN OVERVIEW

- ***What is NL Generation?***
  a definition, the roots, and scientific directions
- ***What must/should/can a NLG system do?***
  content selection, linguistic planning, realization
- ***How do its components depend on each other?***
  pipelined, integrated, and interacting architectures
- ***Where is the field moving?***
  applications. application areas, and prototypes
- ***Where can I find more information?***
  workshops, books, software, the Web

What is NL Generation?

Natural language generation is the process of deliberately constructing a natural language text in order to meet specified communicative goals.

[McDonald 1992]

- **Goal**
  - computer software which produces understandable text in a human language
- **Input**
  - a communicative goal, including
  - a non-linguistic representation of information
- **Output**
  - a text, either plain ASCII or formatted (LaTeX, HTML, RTF), either solo or combined with graphics, tables etc.
- **Knowledge sources required**
  - knowledge of communication, of the domain, and the language

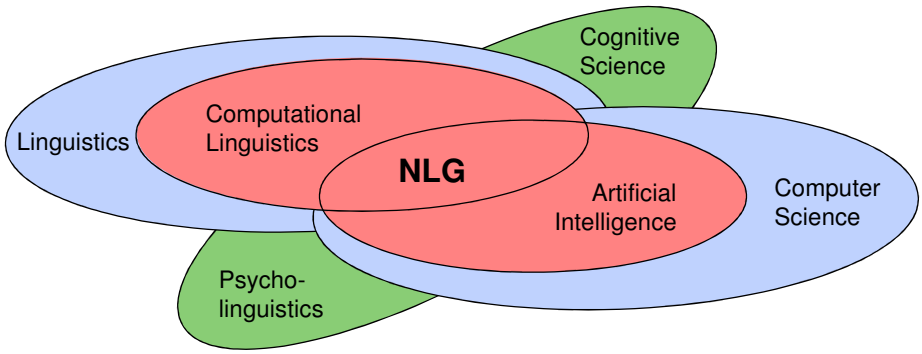
Why is NL Generation Needed?

- **Information of interest is stored on the computer in ways which are not comprehensible to the end user.**
- **NLG systems can present this information to users in an accessible way.**

- **NL dialogue interfaces to application systems**
  - NL DB access, explanations of inferences in XPS, game characters, corrections (false user implicatures)
- **Machine translation**
  - target language text based on result of source language analysis and transfer
- **Text generation**
  - documents, reports, summaries, help messages, etc.

NL Generation is an Interdisciplinary Research Field

- **Artificial Intelligence**
- **Psycholinguistics**
- **Computational Linguistics**



Source: Stephan Busemann

NL Generation in Artificial Intelligence

What are the decision-making and planning processes needed for NL generation?

Research on knowledge-based approaches to developing computer systems capable of human language production

- **Scientific issues**
  - which types of knowledge are necessary, and how should they be represented?
  - how can inferences be modelled and controlled?
  - which representations and interfaces allow efficient processing?
- **Methods**
  - deep modelling for small classes of examples
  - implementation of complex systems
- **Implementations for theory validation or for building research prototypes**

Source: Stephan Busemann

NL Generation in Psycholinguistics

How does human language production work?

Research on human linguistic capabilities (spoken language)

- **Scientific issues**
  - which processes are required for a speaker to produce an utterance?
  - in which order are these processes scheduled?
  - which representations does a speaker access during language production?
- **Methods**
  - experiments with human speakers to retrieve data and to test hypotheses
- **Implementations for theory validation**

NL Generation in Computational Linguistics

Given a semantic representation and a grammar - what are the sentences admitted by the grammar?

Research on the use of modular, linguistically well-founded theories for the mapping between logical formulae and terminal strings

- **Scientific Issues**
  - which semantic and syntactic phenomena should be described by the grammar?
  - which control strategies are suitable for the grammar formalism at hand?
  - under which conditions are the processes reversible?
- **Methods**
  - integrated treatment of semantic and syntax
  - use of constraint-based formalisms (features structures)
- **Implementations for theory validation and as test beds**

Overview

What is NL Generation?

a definition, the roots, and scientific directions

What must/should/can a NLG system do?

content selection, linguistic planning, realization

How do its components depend on each other?

pipelined, integrated, and interacting architectures

Where is the field moving?

applications, application areas, and prototypes

Where can I find more information?

workshops, books, software, the Web

Source: Stephan Busemann

What Must a Generation System Do?

TASKS IN NL GENERATION

- **Content determination**
- **Discourse planning**
- **Sentence aggregation**
- **Lexicalization**
- **Referring expression generation**
- **Surface realization**

more language dependency

more decision-making

Source: Stephan Busemann

Content Determination Selects the Information to be Communicated

- **Construct a set of *messages* from the underlying data source**
- **Messages are aggregations of data that are appropriate for verbalization**
- **A message may correspond to a word, a phrase, a sentence**
- **Messages are based on domain entities (concepts, relations)**

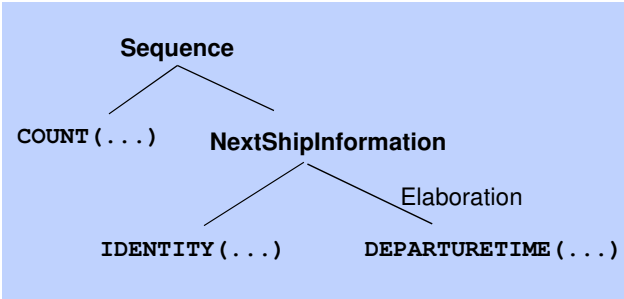
```
IDENTITY(NEXTSHIP, MS-LILLY)
        ;The next ship is the MS-LILLY.
DEPARTURETIME(MS-LILLY, 1000)
        ;The MS-LILLY departs at 10am.
COUNT(SHIP, SOURCE(HAMBURG),
      DESTINATION(COPENHAGEN), 5, PERDAY)
        ;There are five ships daily from Hamburg to
        Copenhagen.
```

Source: Stephan Busemann

Discourse Planning Organizes Messages into a Coherent Text Plan

- **A text is not just a random collection of sentences**
- **Texts have an underlying structure relating the parts together**
- **Two related issues**
  - conceptual grouping
  - rhetorical relationships

There are five ships daily from Hamburg to Copenhagen. The next ship is the MS-LILLY. It departs at 10am.



Source: Stephan Busemann

Sentence Aggregation Distributes Messages Onto Sentences

- **A one-to-one mapping from messages onto sentences may result in disfluent text**
- **Messages need to be combined to produce larger and more complex sentences**
- **The result is a *sentence plan***

Without aggregation	With aggregation
The next ship is the MS-LILLY. It leaves Hamburg at 10am. It has a restaurant. It has a snack bar.	*The next ship, which leaves Hamburg at 10am, is the MS-LILLY. It has a snack bar and a restaurant.*

Lexicalization Determines the Content Words to be Used

- **Knowledge sources include**
  - communicative intention, concepts and relations, focus, user model
- **A variety of subtasks may become critical**
  - consider/choose the discourse focus - *buy* vs *sell*
  - use collocations - *exert influence* vs *administer punishment*
  - consider lexical semantics - *male unmarried adult* vs *bachelor*
  - by default use basic level categories[1] - *dog* vs *poodle*
  - consider underlying situation - *the pole is thick and sufficiently high*
  - consider/choose the attitude - *house* vs *home, father* vs *dad*
  - know about idioms - *kick the bucket*
- **Lexical choice is a mapping from concepts and relations onto lexemes**
- **Lexical choice determines (part of) the syntactic structure**

[1] Basic level categories represent the level of abstraction first named and understood by children (cf work by Eleanor Rosch). People remember and name things more readily at basic level. Languages have simpler names at basic level (e.g. furniture – *chair* – kitchen chair).

Collocations

- **What are collocations?**
  - Constraints on the cooccurrence of two lexeme words
  - One of them – the *basis* – semantically determines the occurrence of the other one – the cooccurring *collocate*
- **Examples of N-V collocations**
  - retenir son admiration, retenir sa haine, retenir sa joie, *retenir son désespoir
- **Heuristics for the lexicalization process**
  - First the basis is lexicalized,then the collocate, depending on which lexeme has been chosen as the basis
  - Knowledge about admissible combinations stored in the lexical entries for the bases
  - For N-V collocations, the basis is the N.
  - This is in contrast to the usual order of first lexicalizing phrasal heads, then arguments and modifiers

Lexical Functions

Heid, U., Raab, S.: Collocations in Multi-Lingual Generation. 4th EACL, 1989.

- Describe regular dependencies between lexical units of a language
- Crosslinguistically constant operators (f), whose application to a lexeme ("keyword", L) yields other lexemes (v).
- *f(L) = v*
- Meaning-Text Theory (Igor Mel'čuk et al.)

	Lexical Functions	Meaning	Examples
1.	OPER, FUNC, LABOR, REAL, FACT, LABREAL	occurrence realization	OPER(*attention*) = *pay* REAL(*promise*) = *keep*
2.	PROX, INCEP CONT, FIN CAUS, PERM LIQU	phases phase + [CAUSE]	INCEP OPER(*form*) = *take* CAUS FUNC(*problem*) = *create, pose*
3.	MAGN, POS, VER	(high) degree	MAGN(*eater*) = *big, hearty* VER(*praise*) = *merited*
4.	ABLE, QUAL	ability	ABLE$_2$(*writing*) = *readable*
5.	MULT, SING	count ↔ mass	MULT(*goose*) = *gaggle*
6.	GERM, CULM	germ, culmination	CULM(*joy*) = *height*

Table 1: Examples of lexical functions used for the description of collocations

Referring Expressions Allow the Hearer to Identify Discourse Objects

- **Task: Avoid ambiguity, but also avoid disfluency**
  - *? the deer next to the two trees on the left of the house*
- **Kinds of referring expressions**
  - Proper names - *Hamburg, Stephan, The United States of America*
  - Definite descriptions - *the ship that leaves at 10am, the next ship*
  - Proforms - *it, later, there*
- **Initial reference**
  - use a full name - *the MS-LILLY*
  - relate to an object that is already salient - *the ship's snack bar*
  - specify physical location - *the ship at pier 12*
- **Choosing a form of reference**
  - proform > proper name > definite description

How should definite follow-on descriptions look like?

Surface Realization Generates Grammatically Correct Text

- **Converts sentence plans into text**
- **Subtasks include**
  - insert function words - *he wants to book a ticket*
  - word inflection - *like+ed → liked*
  - ensure grammatical word order
  - apply orthographic rules
- **Techniques of defining grammatical knowledge**
  - declarative bidirectional grammars, mapping between semantics and syntax
  - grammars tuned for generation, widely used in practice
  - templates, easy and fast to implement

Overview

What is NL Generation?

a definition, the roots, and scientific directions

What must/should/can a NLG system do?

content selection, linguistic planning, realization

How do its components depend on each other?

pipelined, integrated, and interacting architectures

Where is the field moving?

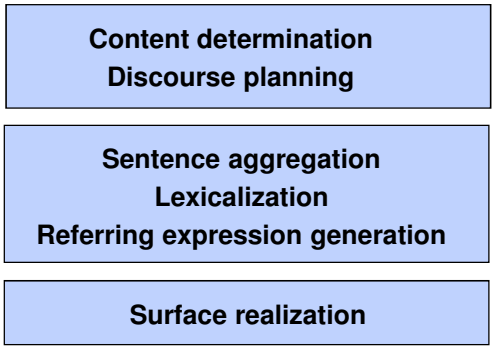
applications. application areas, and prototypes

Where can I find more information?

workshops, books, software, the Web

The NLG Tasks Can be Grouped Into Modules With Interfaces

- **Text planning (Macroplanning)**
- → *Text Plan*
- **Sentence planning (Microplanning)**
- → *Sentence Plan*
- **Linguistic realization**



Applicable techniques include planning systems and rule-based – or constraint-based – systems

A Generated Target Text

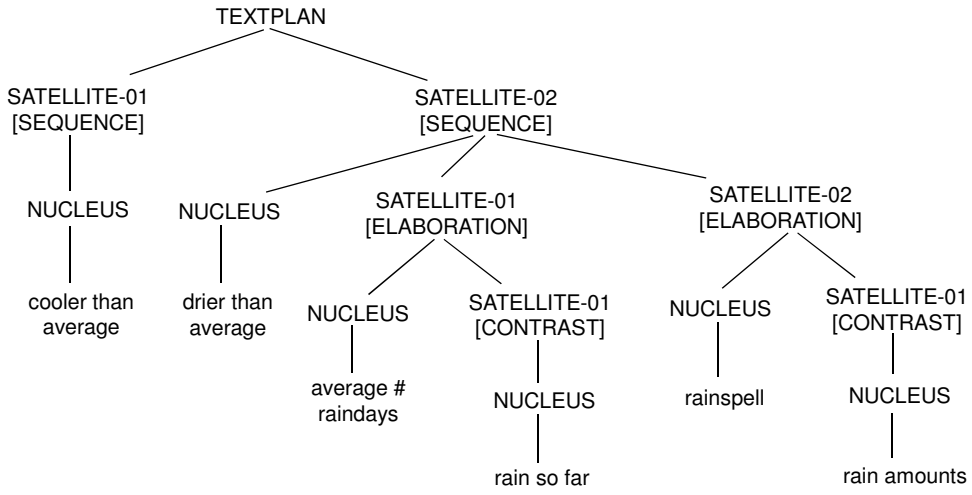
1. The month was cooler than average
2. The month was drier than average
3. The month had the average number of rain days
4. The total rain so far is well below average
5. There was rain on every day for 8 days from 11th to 18th
6. Rainfall amounts were mostly small

The month was cooler and drier than average, with the average number of rain days, but the total rain for the year so far is well below average. Although there was rain on every day for 8 days from 11th to 18th, rainfall amounts were mostly small.

msg1 msg2, msg3, BUT msg4. ALTHOUGH msg5, msg6.

Source: Stephan Busemann

A Sample Text Plan



- **Rhetorical Structure Theory is a basis for discourse planning**

Source: Stephan Busemann

A Sample Sentence Plan (Sentence Plan Language, SPL)

```
(l / greater-than-comparison
   :tense past
   :exceed-q (l a) exceed
   :domain (m / one-or-two-d-time :lex month :determiner the)
   :standard (a / quality :lex average :determiner zero)
   :range (c / sense-and-measure-quality :lex dry)
   :inclusive (r / one-or-two-d-time
     :lex day
     :number plural
     :property-ascription (r / quality :lex rain)
     :size-property-ascription
                          (av / scalable-quality :lex the-av-no-of)))
```

The month was drier than average with the average number of rain days.

- **SPL input to KPML; wide spread surface-semantic representation level**

Interdependencies of Components

EXAMPLES

- **Discourse planning and sentence aggregation**

  The month was cooler and drier than average, with the average number of rain days, but the total rain for the year so far is well below average.

  The month was cooler and drier than average, with the average number of rain days, but the yearly rain so far well below average.

- **Sentence aggregation and syntactic constraints**

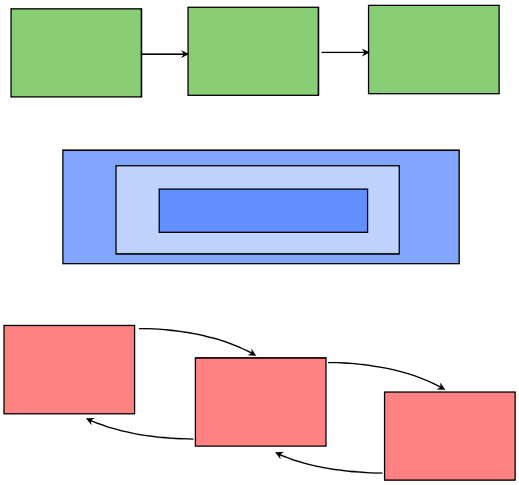
  (1) likes(dog,cat) (2) black(cat) (3) sad(dog) (4) chase(cat,mouse)
  (1, 2, 3) The dog [that likes the [black] cat] is sad.
  (1, 2, 3, 4) ? The dog [that likes the [black] cat [that is chasing the mouse]] is sad.

- **Discourse planning (result causation) and lexicalization (shoot → kill)**

  Mary was killed. She was shot by John.
  ? *Mary was shot. She was killed by John.*

Architectures in NLG

- **Pipelined**
  - simplest
  - inadequate
  - most widespread
- **Integrated**
  - all in one formalism
  - elegant
  - inefficient
- **Interacting**
  - psycholinguistically plausible
  - complex
  - impractical



Source: Stephan Busemann

Overview

What is NL Generation?

a definition, the roots, and scientific directions

What must/should/can a NLG system do?

content selection, linguistic planning, realization

How do its components depend on each other?

pipelined, integrated, and interacting architectures

Where is the field moving?

applications, application areas, and prototypes

Where can I find more information?

workshops, books, software, the Web

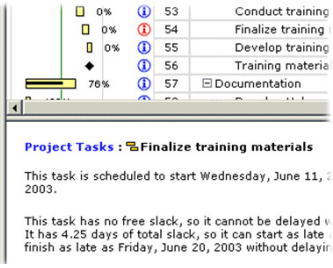
Source: Stephan Busemann

The Complete NLG System Does Not Exist (Yet)

- **Discourse planning**
  - proof of concept for many sample domains
  - Rhetorical/semantic relation classes are hard to define
- **Sentence aggregation**
  - techniques quite well understood
  - applicability conditions unknown
- **Lexicalization**
  - methods understood in isolation
  - often shifted aside due to complex interdependencies
- **Referring expression generation**
  - pronominalization well understood
  - initial object characterization difficult
- **Surface realization**
  - scientifically solved in principle
  - reusable application systems fielded

Some NLG Applications (1)

- **FoG**
  - Function: produces textual weather reports in English and French
  - Input: graphical weather depiction
  - User: Environment Canada (Canadian Weather Service)
  - Developer: CoGenTex (http://cogentex.com/)
  - Status: Fielded, in operational use since 1992
- **Chart Explainer**
  - Function: generates fluent NL summaries of charts and tables
  - Developer: CoGenTex (http://cogentex.com/products/chartex/index.html)



- **Project Reporter**
  - Function: generates project information reports
  - Developer: CoGenTex (http://cogentex.com/products/reporter/index.html)

Some NLG Applications (2)

- **PlanDoc**
  - Function: produces a report describing simulation options an engineer has explored
  - Input: simulation log file
  - User: Southwest Bell
  - Developer: Bellcore and Columbia University
  - Status: Fielded, in operational use since 1996
- **STOP**
  - Function: produces a letter encouraging patients to stop smoking
  - Input: patient data, trials, successes and failures, pros and cons
  - User: patients suffering from nicotine-caused diseases
  - Developer: U Aberdeen
  - Status: field trial in hospital, 2002

Source: Stephan Busemann

Some NLG Applications (3)

- **Applications by Data2Text**
  - Aberdeen based company
  - people who monitor complex systems often have tremendous amounts of data available to them, and it is not possible for them to examine all of this data within realistic time constraints
  - Alarming systems can draw attention to specific problems, but they do not communicate the "big picture" and also may not detect problems in their early stages, when they can be dealt with most cost-effectively
  - Summaries produced by Data2Text systems help the doctor or engineer see the big picture, and detect problems at an early stage
  - http://www.data2text.com

Source: Stephan Busemann

Evaluation – a Research Topic on Its Own

- **Problem: NLG tasks usually have multiple solutions**
  - Edit distance measures wrt gold standard are therefore inappropriate
- **Intrinsic evaluation**
  - Select aspects of NLG, e.g. REG, and measure their quality
  - Annotations relating REs and their properties to concepts and distractors
    - TUNA corpus, 780 human-produced REs, visual domain of furniture and people
    - Compare system output to reference outputs in the corpus
  - Comparative evaluation through Shared Tasks
    - Train systems on set of entities and REs, and test on set of objects (no REs)
- **Extrinsic evaluation**
  - Define application scenario and measure task performance
  - Direct test, e.g. use generated RE to identify an object in a picture
  - Indirect test by embedding NLG systems: measure added value of NLG to task

Research issue: How can intrinsic and extrinsic evaluations be combined?

Shared Task and Evaluation Campaigns in NLG: ASGRE and REG Challenge

- **Why REG?**
- **Attribute Selection for the Generation of Referring Expressions (ASGRE)**
  - Select attributes to distinguish descriptions
  - All participants used same annotated data set (80% of TUNA) for training
  - Had to return remaining 20% of the data annotated

Conclusions

What is NL Generation?

a definition, the roots, and scientific directions

What must/should/can a NLG system do?

content selection, linguistic planning, realization

How do its components depend on each other?

pipelined, integrated, and interacting architectures

Where is the field moving?

applications. application areas, and prototypes

Where can I find more information?

workshops, books, software, the Web

Pointers to NLG Resources

- **SIGGEN (ACL Special Interest Group for Generation)**
  - http://www.siggen.org/
  - Who's who and what's where?
  - Papers, bibliographies, conference and workshop announcements, job offers, …
  - Free software, demos
- **Conferences and Workshops**
  - International Conference on NLG (in even-numbered years)
  - European Workshop on NLG (on odd-numbered years)
  - NLG papers at ACL, ANLP, IJCAI, AAAI, ...
- **Research Labs and Companies**
  - U Aberdeen: http://www.csd.abdn.ac.uk/research/nlg2/
  - Saarbrücken: http://www.dfki.de/service/NLG/
  - CoGenTex: http://www.cogentex.com
- **Key Literature**
  - Ehud Reiter and Robert Dale (2000): *Building Natural Language Generation Systems*. Cambridge University Press.

Questions Answered by Slideset

- **What NLG architectures can be distinguished? What are their pros and cons? Which one is most widely used, and why?**
- **What tasks are identified for an NLG system and how can they be grouped into modules?**
- **What is aggregation and why is it needed in NLG?**
- **What must an NLG system reason about when generating a referring expression for a concept „ship376“?**
- **Which NLG tasks are interfering in the following example, and what went wrong during the generation?**
  - The next ship is the MS-Lilly. It, which has a snack bar, leaves at 10 am.
- **What is the role of basic level categories (BLC) when lexicalizing a concept? Give an example of lexical choice using BLC.**
- **What evaluation methodologies are available?**
- **When is the use of gold standards useful for NLG evaluation? Why does it not work in general?**

Source: Stephan Busemann