Speech recognition and synthesis

Introduction

Speech recognition and synthesis are most useful if combined into a full Human-Machine dialog system

- Human conversations are extremely efficient and effective interactions
- Spoken dialogs are not like a command-line Question-Answer query session
- Conversations include "control" signals at *low* (pre-verbal) and *high* levels
- Humans speak in turns
- In simple automated systems, interactions must be restricted and well structured

Many pictures (and their copyrights) are from [Jurafsky and Martin(2000)]

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In conversations, timing is everything

- Human dialogs are composed of game-like moves
- Turn distribution is crucial for effective Human-Machine interactions
  - who speaks next
  - when should the next speaker start
- Central to human conversations is projection
- Projection is the ability to predict the
  - timing of turns
  - type of upcoming moves

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Turns

What defines a turn?

- A single move in the conversation "game"
- Ends with the end of the last utterance
- Utterance completes a move
- Does not end in a level tone
- Does not end in a filled pause (eg, "uuhh")
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Turns: TRPs

Turns and Turn taking. At each TRP of each turn:

- If during this turn the current speaker has selected A as the next speaker then A must speak next
- If the current speaker does not select the next speaker, any other speaker may take the next turn
- If no one else takes the next turn, the current speaker may take the next turn

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Speech acts

Conversational *moves* are build from *speech acts*

Basic speech acts

- Assertives
  suggesting, putting forward, swearing, boasting, concluding
- Directives
  asking, ordering, requesting, inviting, advising, begging
- Commissives
  promissing, planning, vowing, betting, opposing
- Expressives
  thanking, apologizing, welcoming, deploring
- Declarations changing the world by speech, eg, “I resign”, “You’re fired”

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Basic control tasks, handle conversation flow

- Attention someone is listening
  - Visually, by looking
  - By using *minimal responses* whenever possible
- Acknowledgment move is received
- Grounding move is integrated, or not
  - *Okay*, etc.
  - By minimal responses
  - By (partially) repeating previous move
  - By a relevant next move
- Assessing move is judged
- Relevant move just start a relevant turn
- New turn can subsume Assessing can subsume Grounding can subsume Acknowledgment can subsume Attention

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Timing of responses

- Respond immediately
- If a complex response cannot be given in time, switch to a simpler, faster response type
- If all else fails, start with an Uhhhh placeholder
- Signal problems with a delayed response
- Eg, an immediate repeat signals acknowledgment, a delayed repeat asks for confirmation
- If refusal or repair is dispreferred insert significant silence

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Minimal responses

Also: Backchannels, continuer, acknowledgment tokens

- Uh, Uhm, HmmHmm, Yes, Sure, etc.
- Perform the basic control tasks
- Do not take a turn
- Do not interrupt the speaker
- Are semantically, or even lexically, empty
- Keep the conversation going smoothly
- Without visual "feedback", eg, on the phone, a lack of audible minimal responses interrupts the conversation

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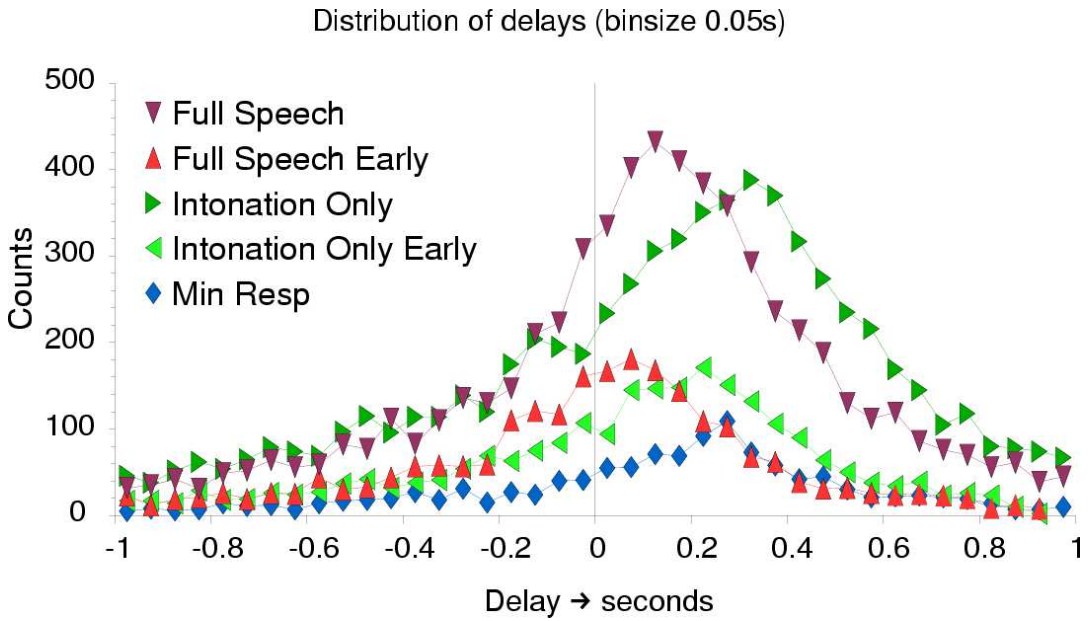

Natural and *elicited* minimal responses

- Responses start directly after the TRP, even for the unintelligible signals ($\approx 200ms$).
- Preparations (the *early responses*) start before the utterance ends

Early responses are laryngial preparation signals. *Intonation Only* responses are unintelligible *uh* sounds
[Wesseling and van Son(2005)][Wesseling and Van Son(2005)]

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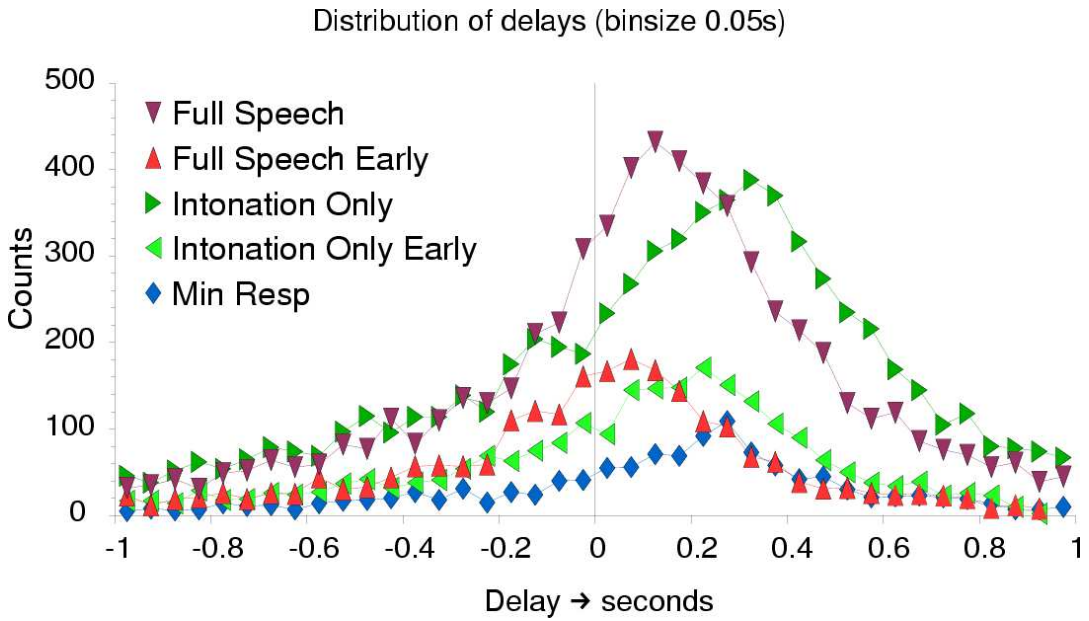

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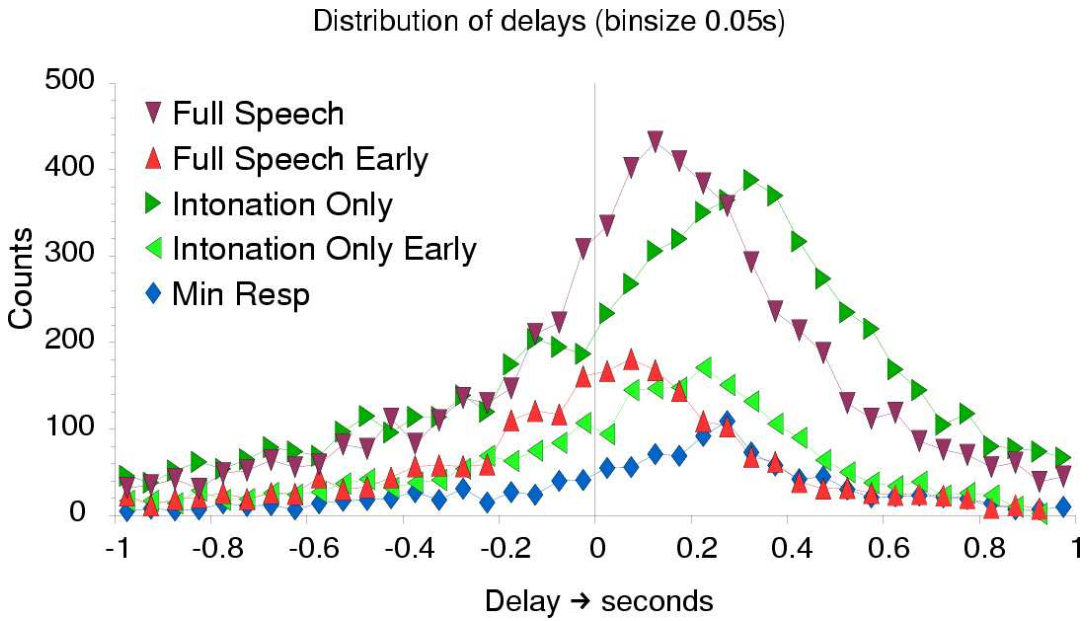

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Conversations: Implicatures

Conversations contain rules of inference

Conversational Maxims of Grice

- Quantity: Be exactly as informative as required
  - Not less informative
  - Not more informative
- Quality: Speak the truth
  - Do not say what you believe is false
  - Do not say that for which you lack evidence
- Relevance: Be relevant
- Manner: Be perspicuous
  - Avoid obscurity
  - Avoid ambiguity
  - Be brief
  - Be orderly

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  - Not *more* informative
- Quality: Speak the truth
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  - Do not say that for which you lack evidence
- Relevance: Be relevant
- Manner: Be perspicuous
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Conversations: Implicatures

Conversations contain rules of inference

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Conversations: Practical dialogs

General conversations are much too complex. Limit *Automatic Dialog Systems* to practical dialogues

Dialogues that are focused on a concrete task, eg,

- Task-oriented
- Information seeking
- Advice and tutoring
- Command and control

[Allen et al.(2001)Allen, Byron, Dzikovska, Ferguson, Galescu, and Stent]

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Conversations: Adjacency pairs

Practical dialogues contain many controlled turn switches, called Adjacency pairs

- Question ⇒ Answer
- Proposal ⇒ Acceptance/Rejection
- Apology ⇒ Acceptance/Rejection
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- Question $\Rightarrow$ Answer
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Conversations: Example dialogue

C_1:	...I need to travel in May.
A_1:	And, what day in May did you want to travel?
C_2:	OK uh I need to be there for a meeting that's from the 12th to the 15th.
A_2:	And you're flying into what city?
C_3:	Seattle.
A_3:	And what time would you like to leave Pittsburgh?
C_4:	Uh hmm I don't think there's many options for non-stop.
A_4:	Right. There's three non-stops today.
C_5:	What are they?
A_5:	The first one departs PGH at 10:00am arrives Seattle at 12:05 their time. The second flight departs PGH at 5:55pm, arrives Seattle at 8pm. And the last flight departs PGH at 8:15pm arrives Seattle at 10:28pm.
C_6:	OK I'll take the 5ish flight on the night before on the 11th.
A_6:	On the 11th? OK. Departing at 5:55pm arrives Seattle at 8pm, U.S. Air flight 115.
C_7:	OK.

Figure 19.4 Part of a conversation between a travel agent (A) and client (C).

- No real minimal responses
- *Uh Hmm* as an *Acknowledgment*
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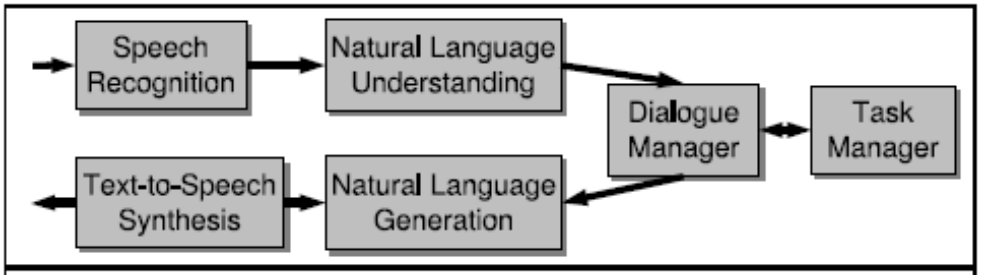

Figure 19.5 Simplified architecture of the components of a conversational agent.

Three part system

- Speech recognition and understanding
  - ASR front end with adapted language model
  - NLP back end for task related semantic parsing
- Language generation and speech synthesis
  - TTS output, can be simple phrase concatenation
  - Frame based or simple grammar sentence generator
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  - Task related manager
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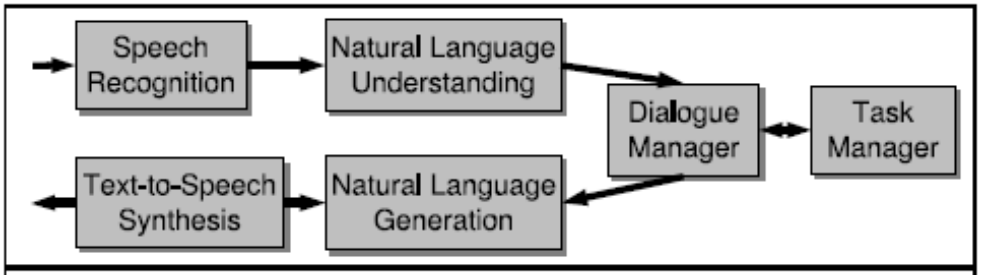

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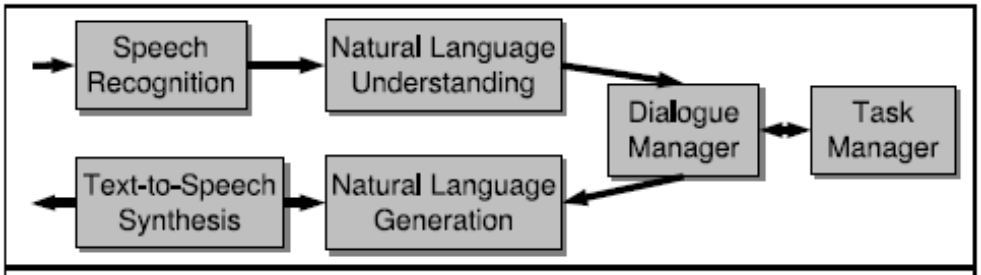

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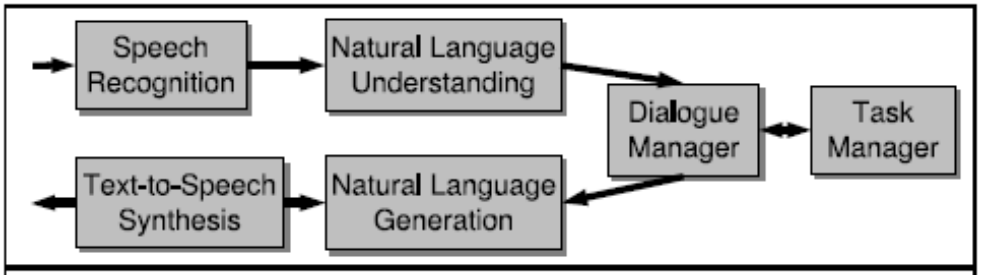

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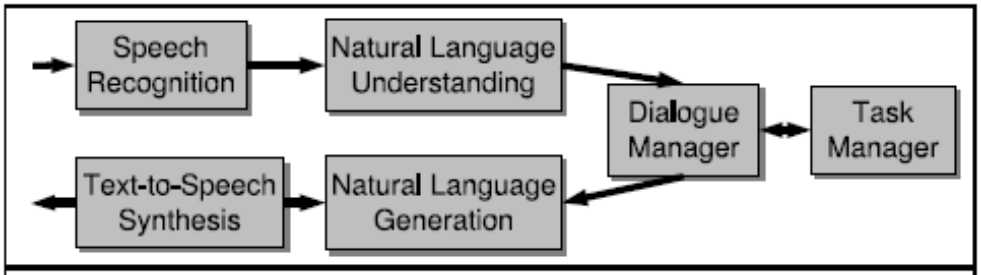

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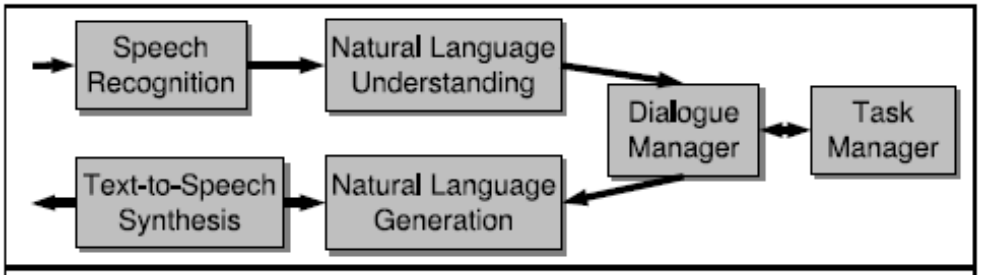

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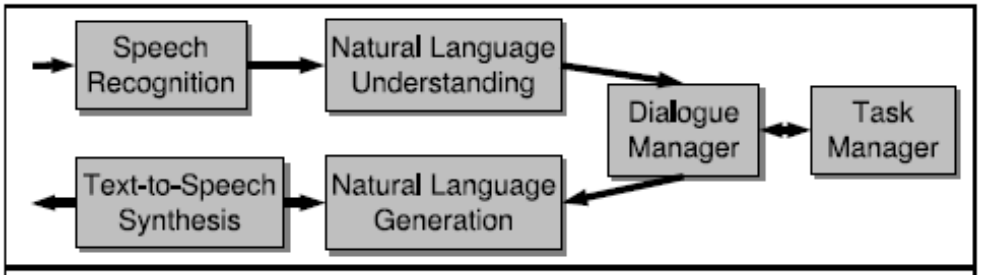

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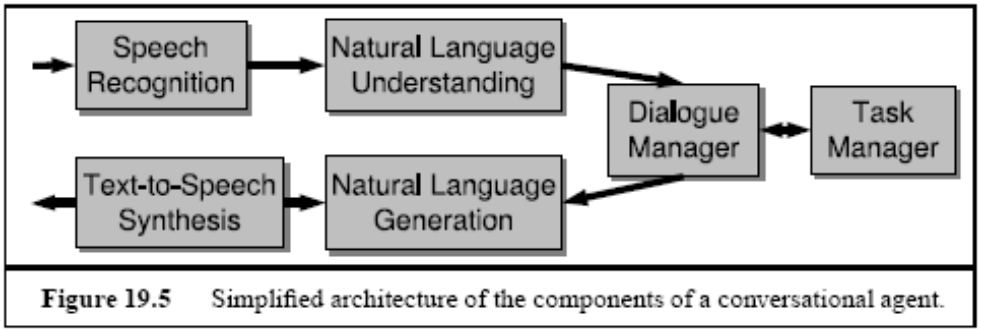

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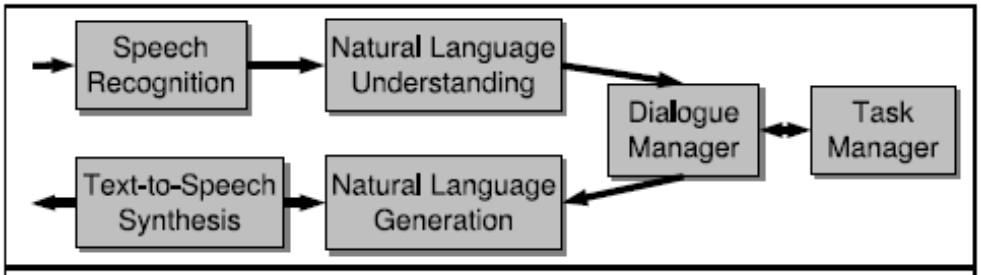

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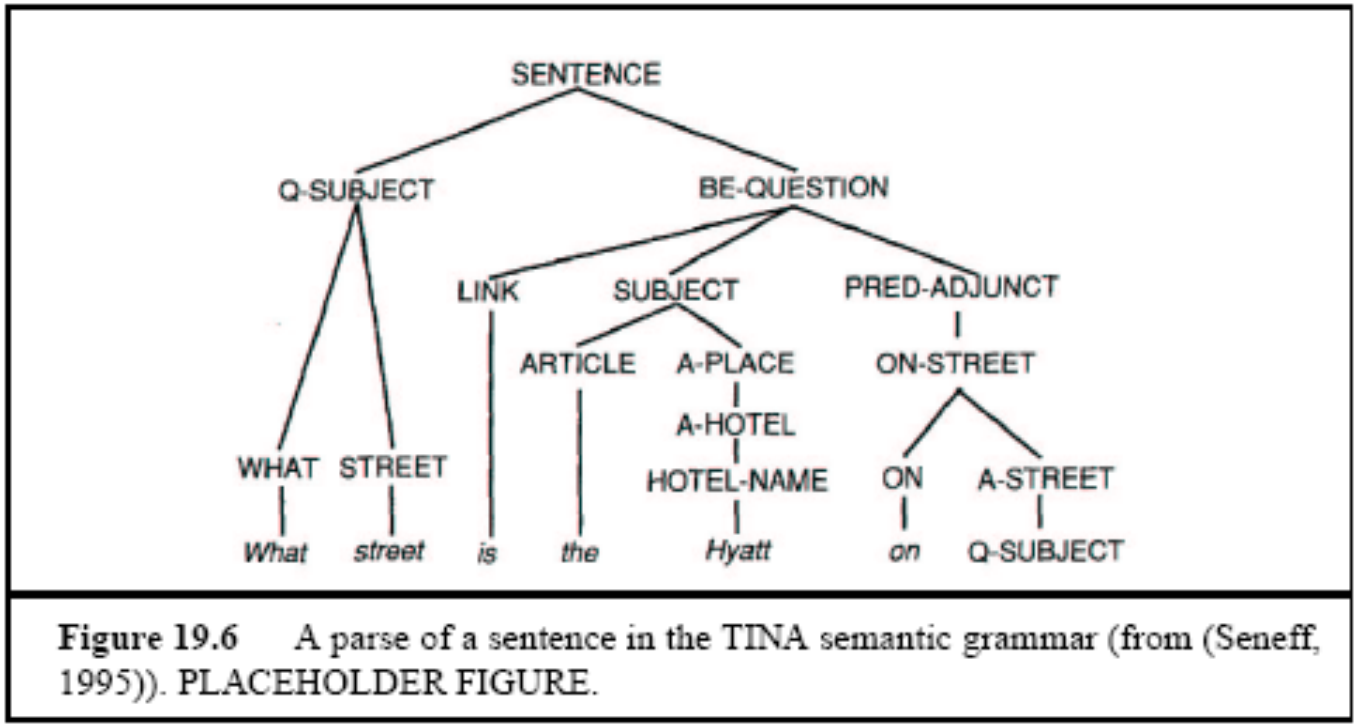

Figure 19.6 A parse of a sentence in the TINA semantic grammar (from (Seneff, 1995)). PLACEHOLDER FIGURE.

Recognizer must deliver semantic message

- Semantic context-free grammar (SCFG) for TINA
- Mixes words and concepts
- Hand written rules

[Jurafsky and Martin(2000)]

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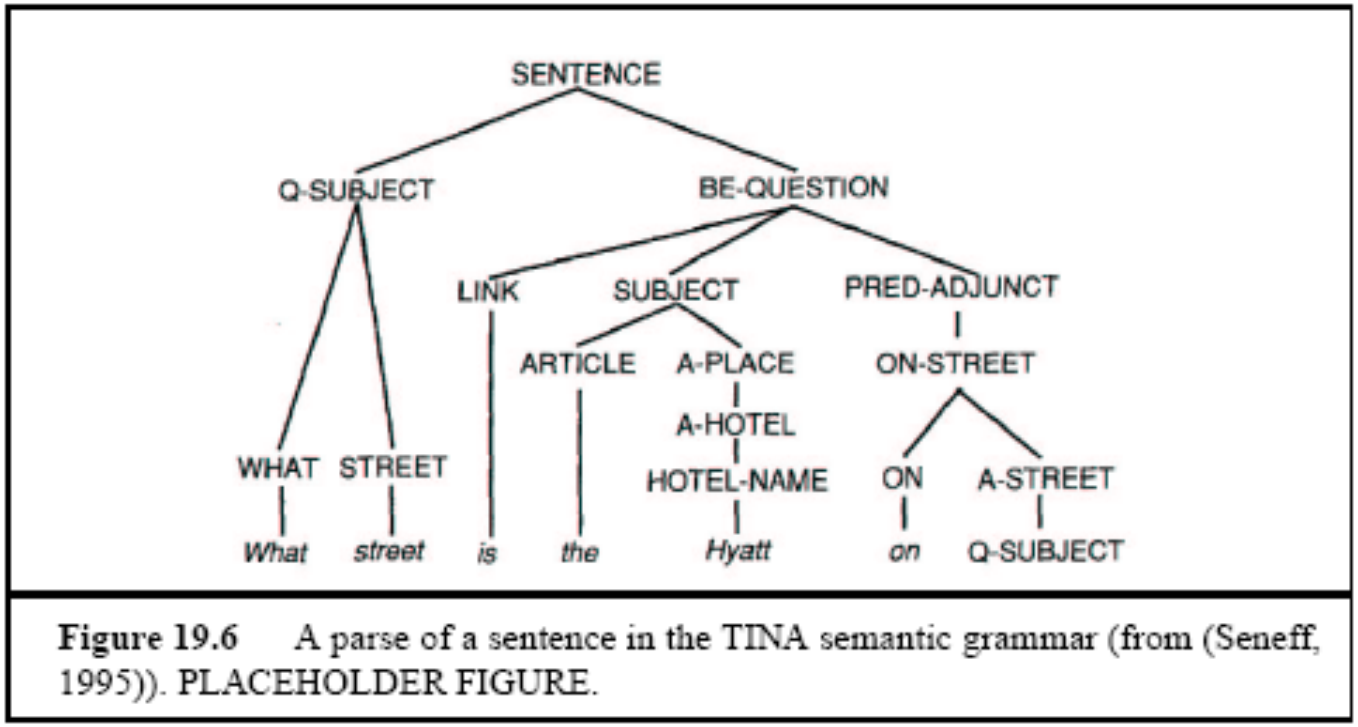

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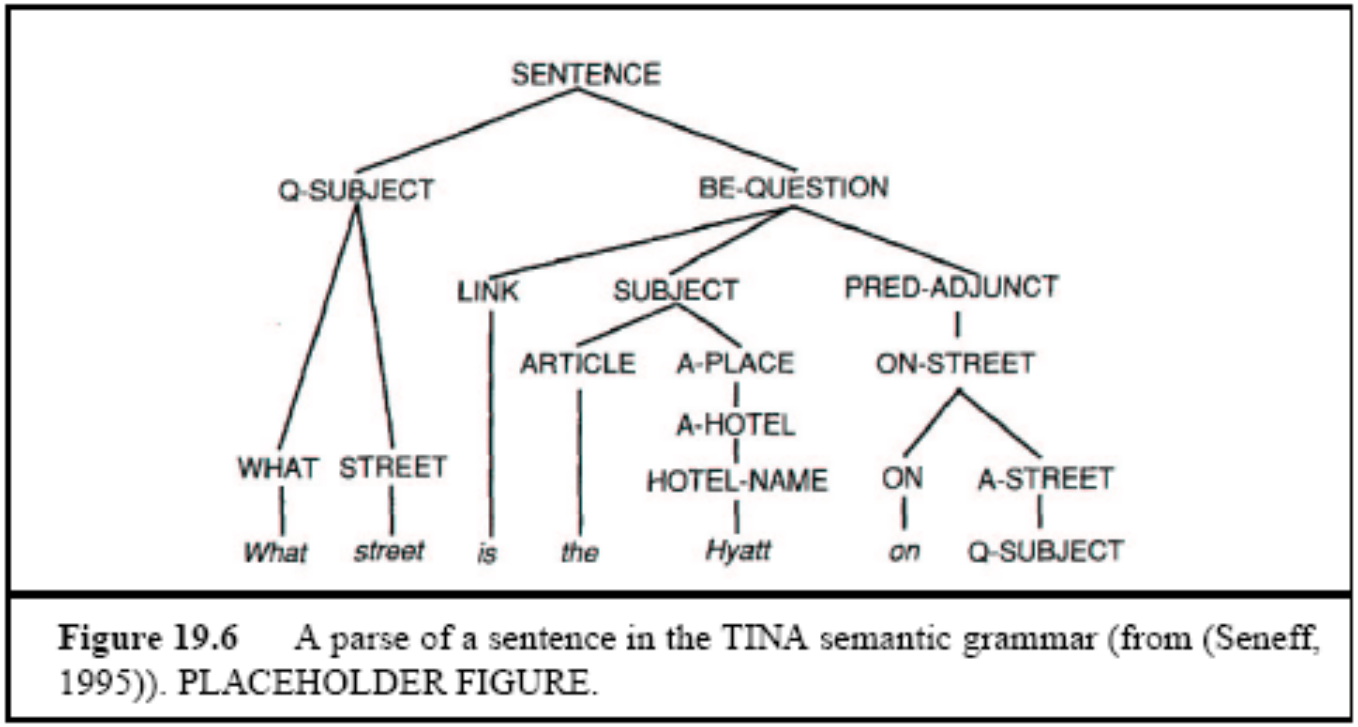

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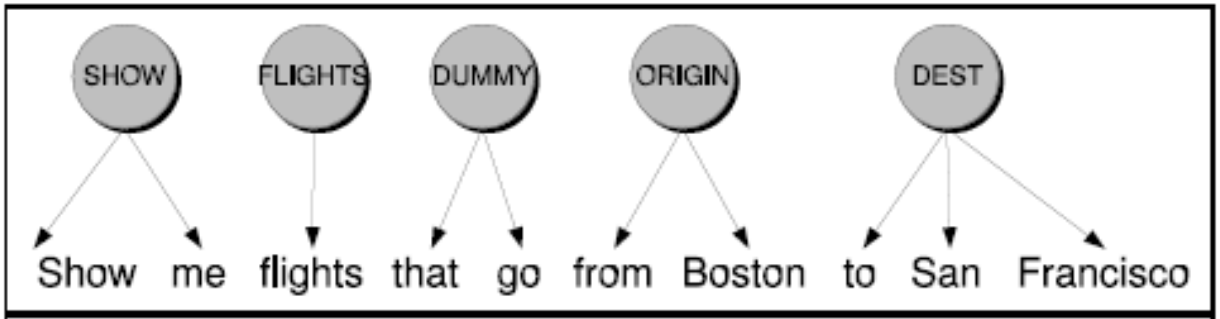

Figure 19.7 The Pieraccini et al. (1991) HMM model of semantics for filling slots in frame-based dialogue systems.

HMM concept grammar

- $\underset{C}{argmax}\ P(C|W) = \underset{C}{argmax}\ P(W|C) \cdot P(C)$
- $P(W|C) = \prod_{i=2,N} P(w_i|w_{i-N+1}, \ldots, w_{i-1}, c_i)$
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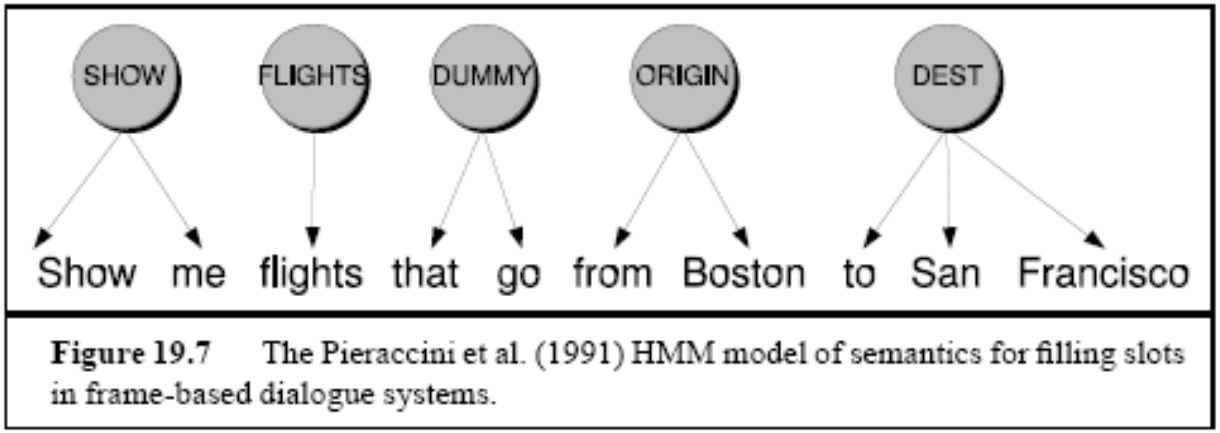

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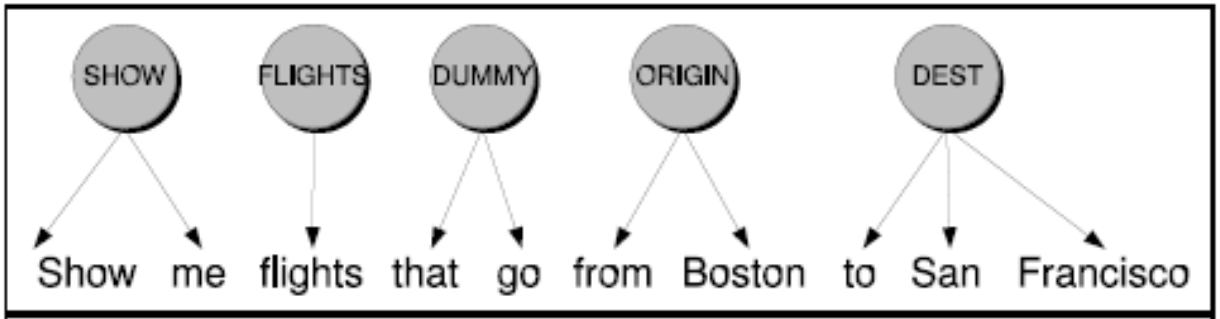

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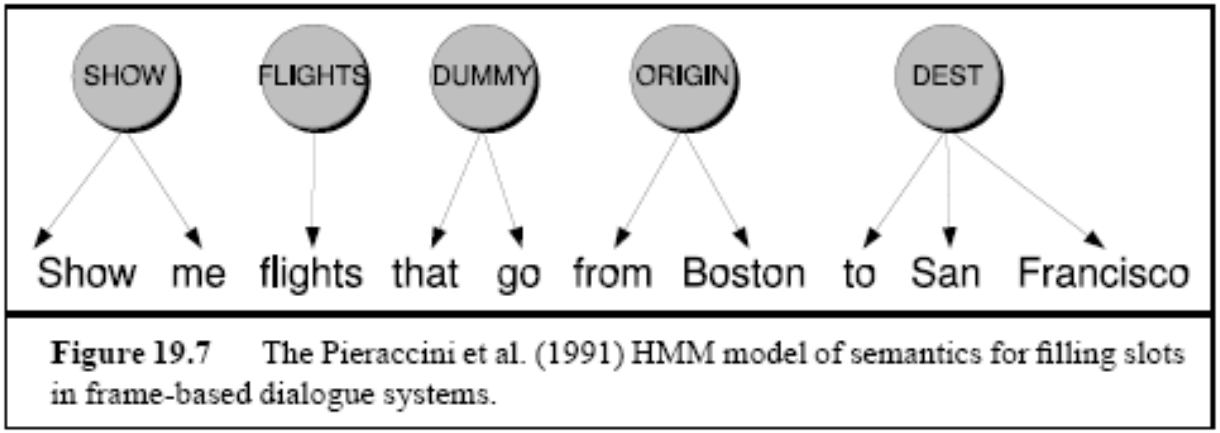

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HMM concept grammar

- $\underset{C}{argmax}\ P(C|W) = \underset{C}{argmax}\ P(W|C) \cdot P(C)$
- $P(W|C) = \prod_{i=2,N} P(w_i|w_{i-N+1}, \ldots, w_{i-1}, c_i)$
- $P(C) = \prod_{i=2,M} P(c_i|c_{i-M+1}, \ldots, w_{i-1})$
- Trained on a concept-labeled corpus

[Jurafsky and Martin(2000)]

Recognizer

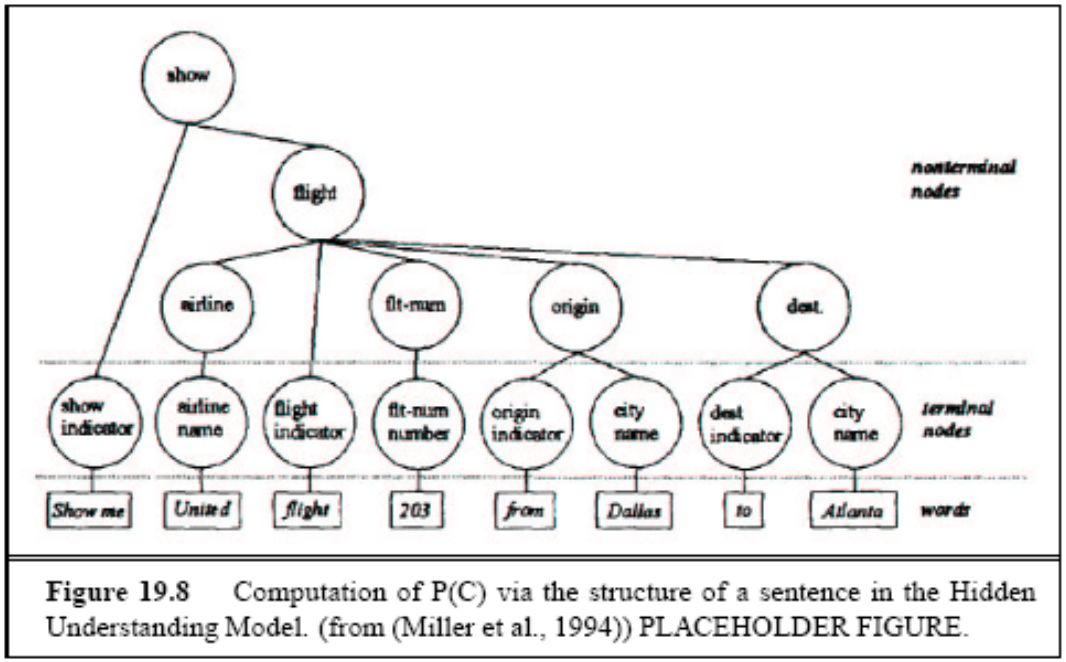


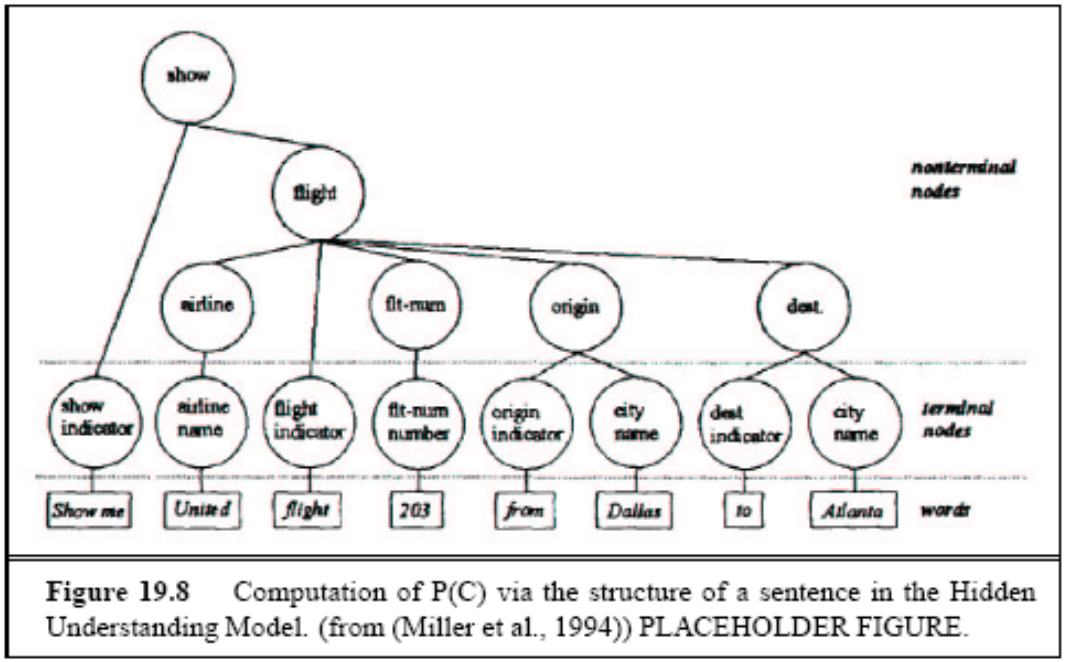
Figure 19.8 Computation of P(C) via the structure of a sentence in the Hidden Understanding Model. (from (Miller et al., 1994)) PLACEHOLDER FIGURE.

Data fragmentation problem

- Identical names can be different concepts
- Eg, cities as *origin* and *destination*
- Use a modified SCFG for $P(C)$
- Add SCFG rules for concepts, ie, non-terminals

[Jurafsky and Martin(2000)]

Recognizer



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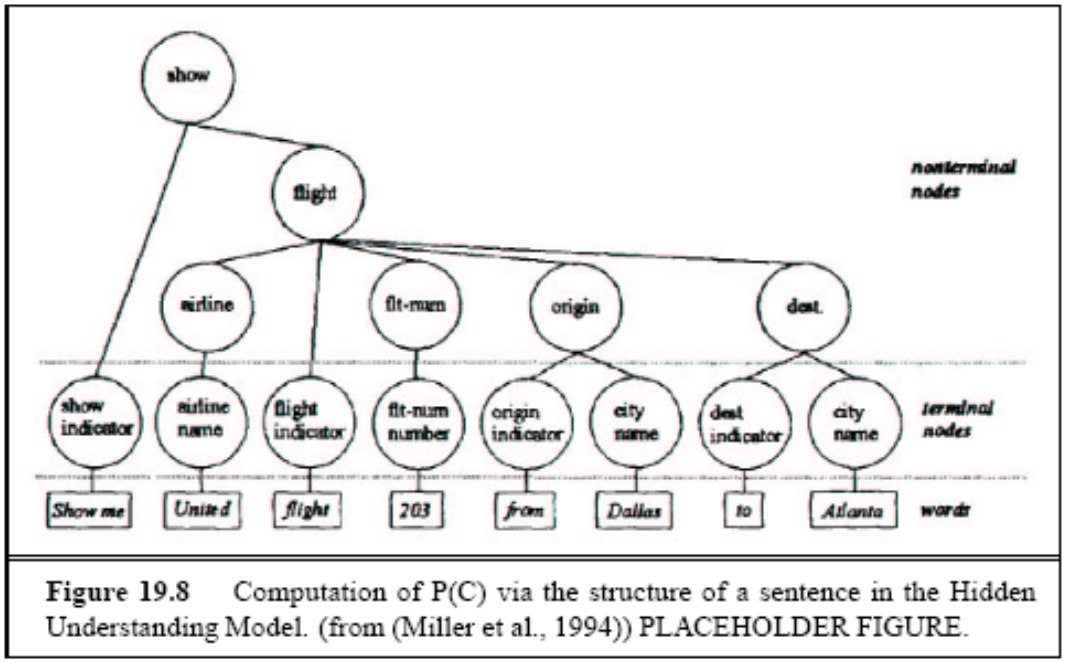

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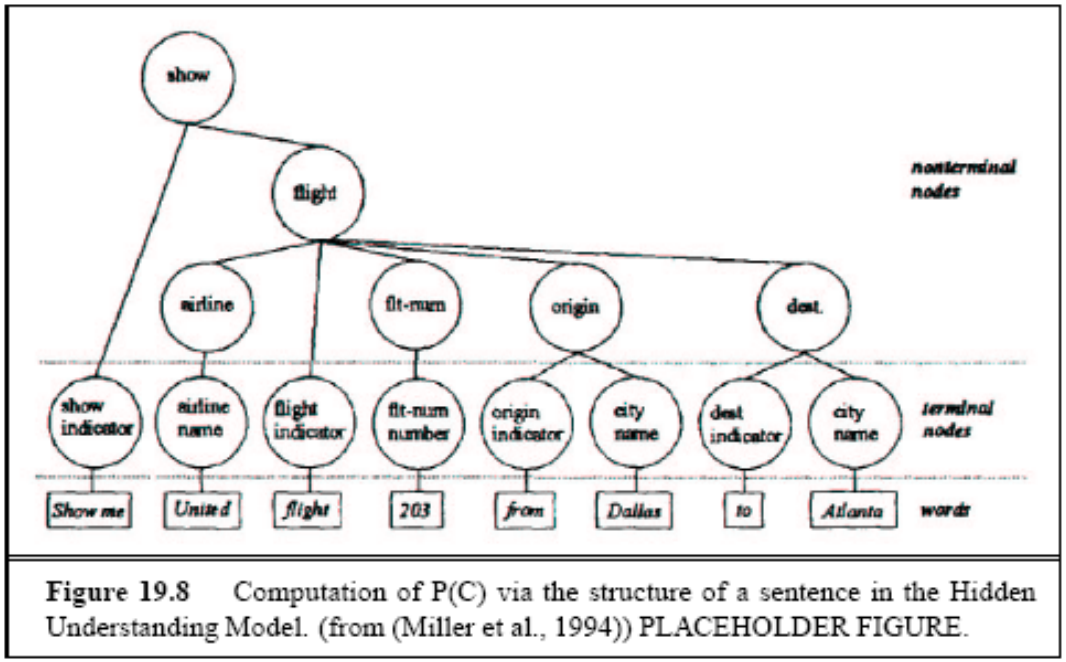

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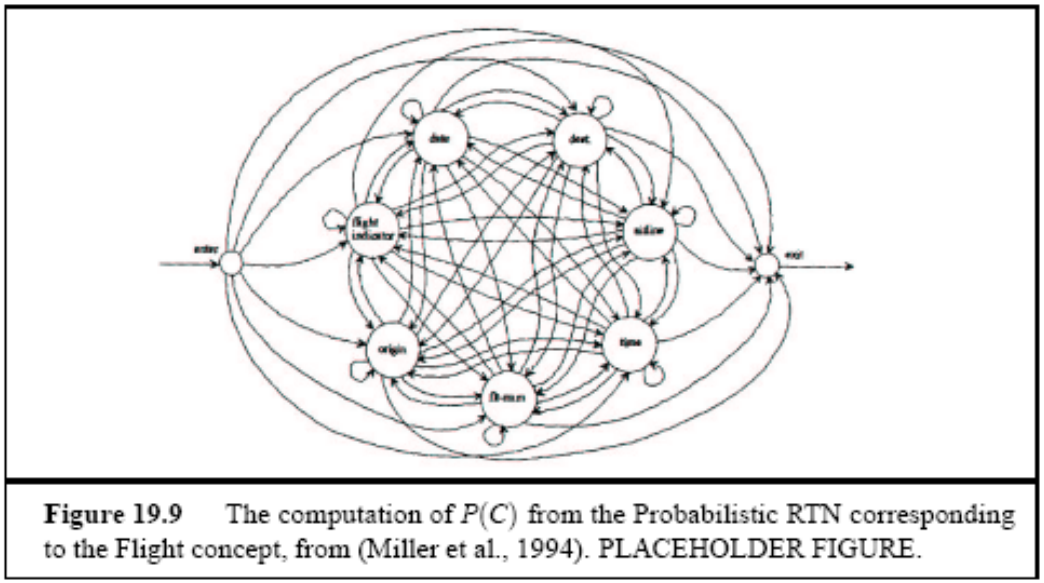

Figure 19.9 The computation of $P(C)$ from the Probabilistic RTN corresponding to the Flight concept, from (Miller et al., 1994). PLACEHOLDER FIGURE.

$P(C)$: Probabilistic finite state concept network

- Enter and Exit states
- Each arrow has a probability
- Circles indicate origin, destination, flight indicator, airline, etc.

[Jurafsky and Martin(2000)]

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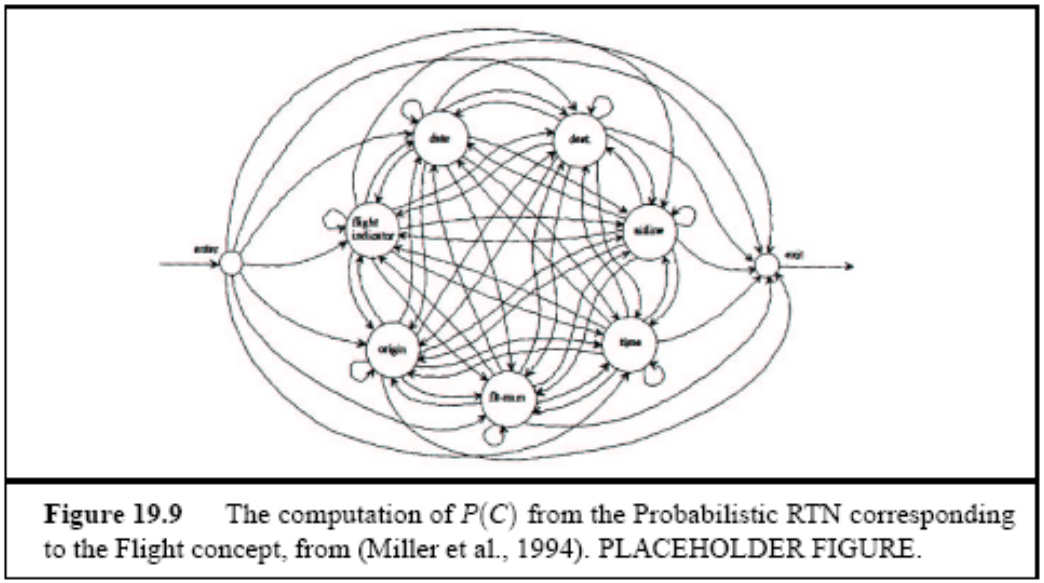

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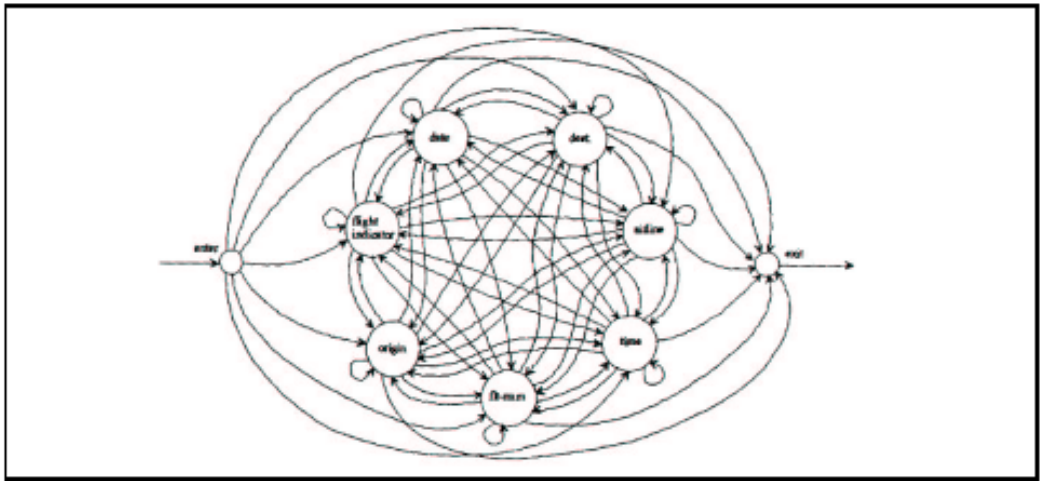

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Speech Generator

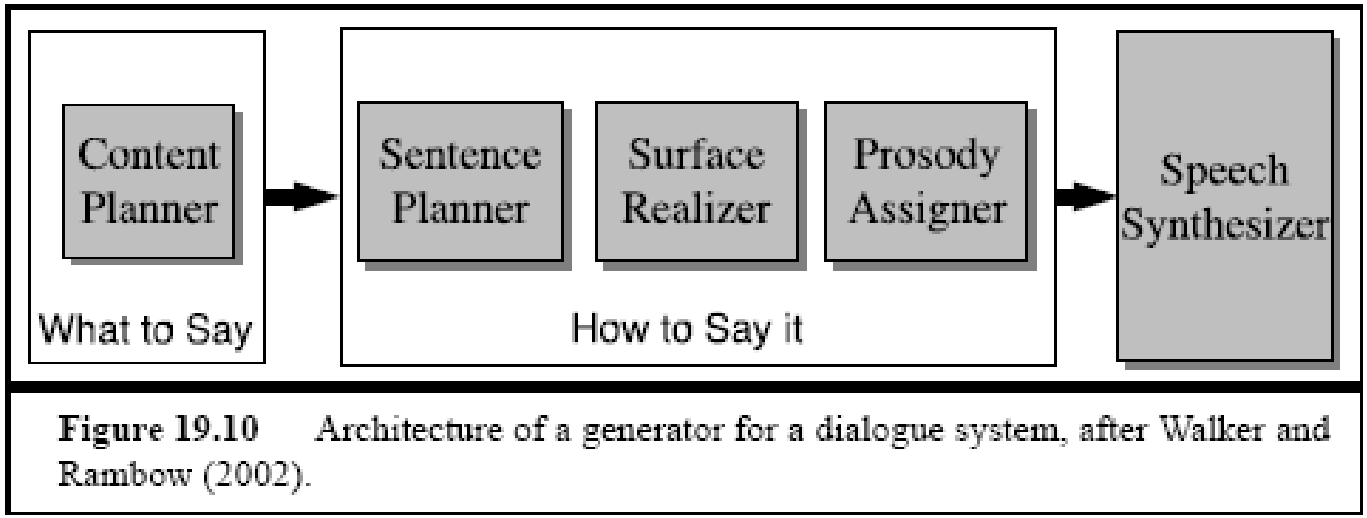

Figure 19.10 Architecture of a generator for a dialogue system, after Walker and Rambow (2002).

Concept to speech

- The database manager generates an abstract message
- Modelled into a sentence structure
- Surface form, ie, the words, are generated
- Prosody generated from words and content,
- Fed into a TTS system

[Jurafsky and Martin(2000)]

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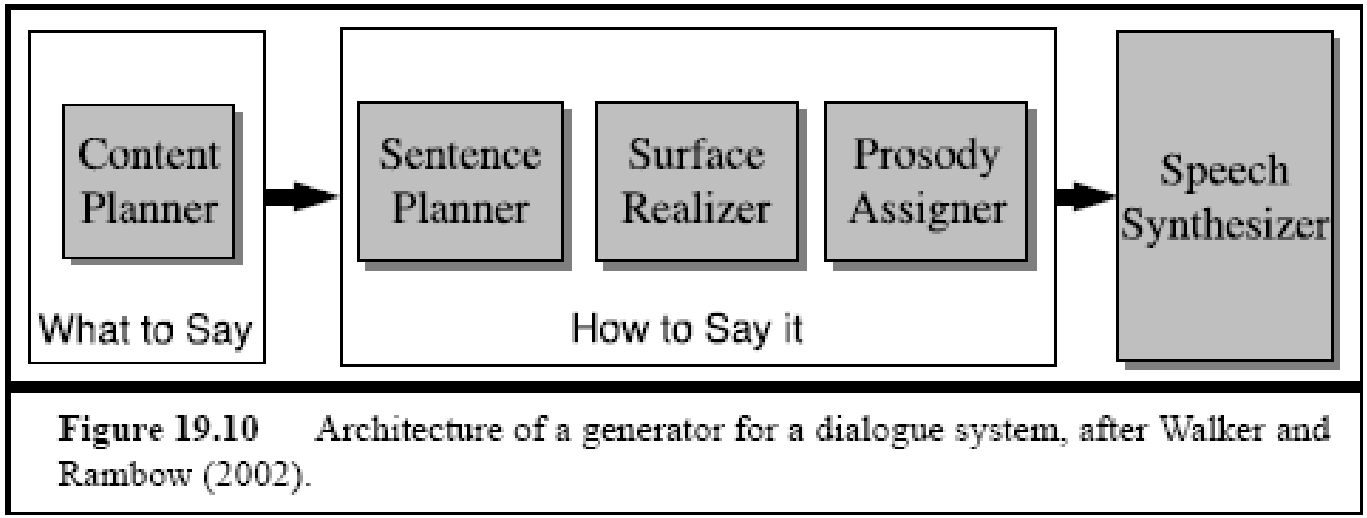

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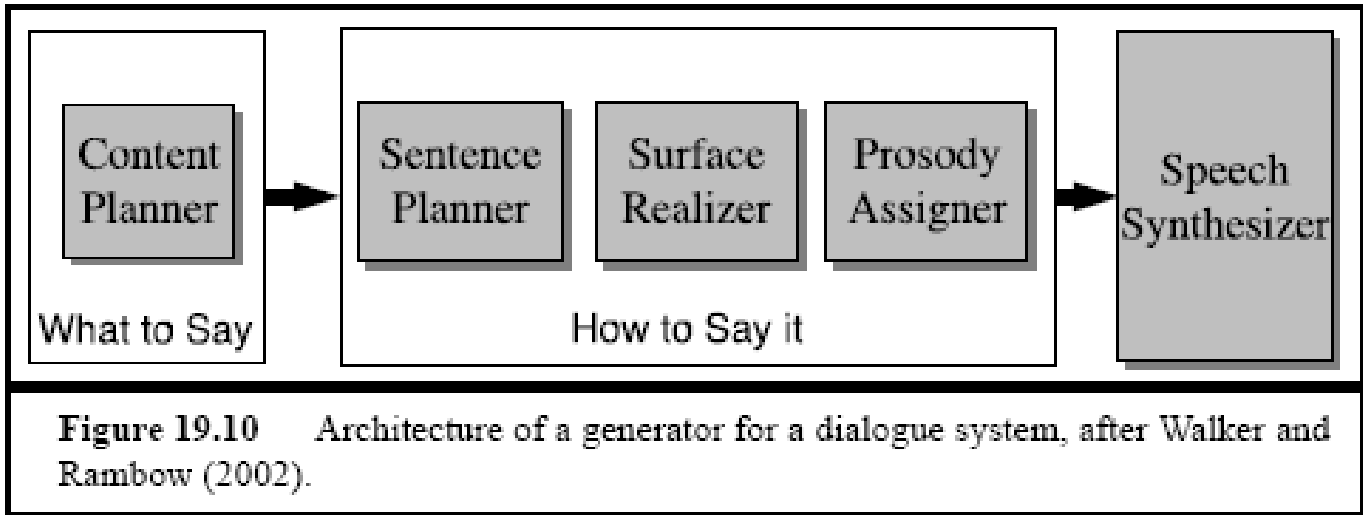

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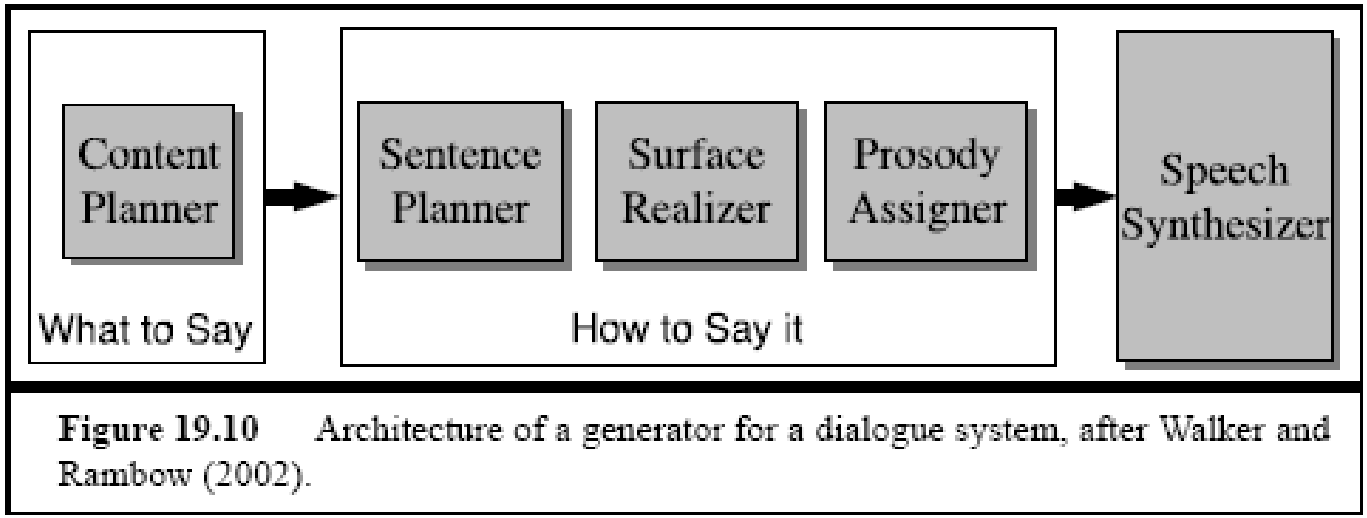

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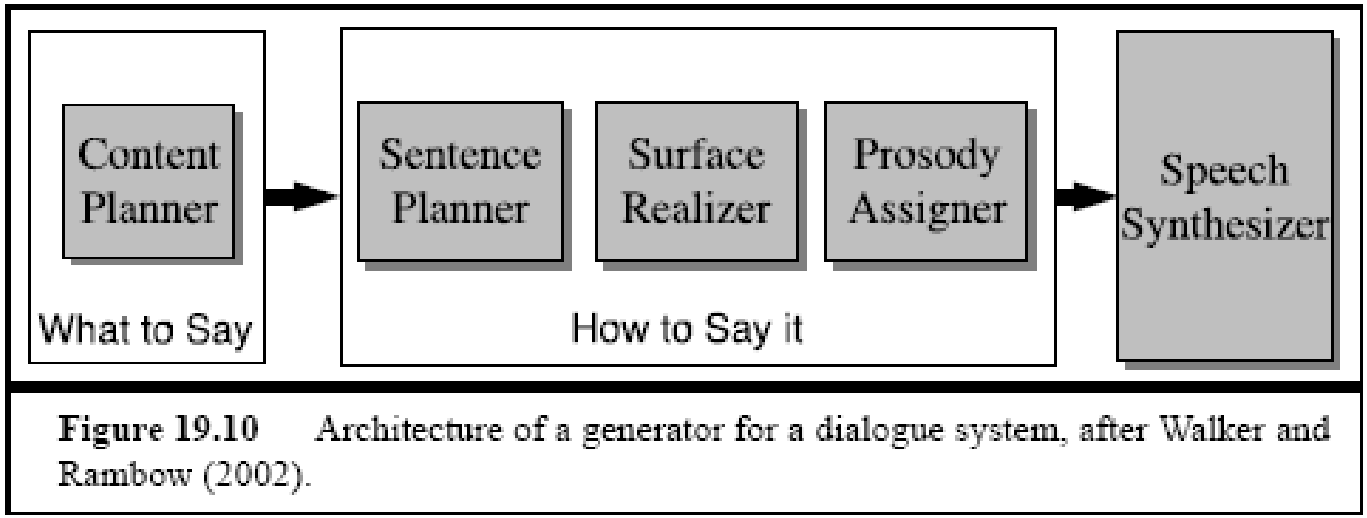

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Dialog management

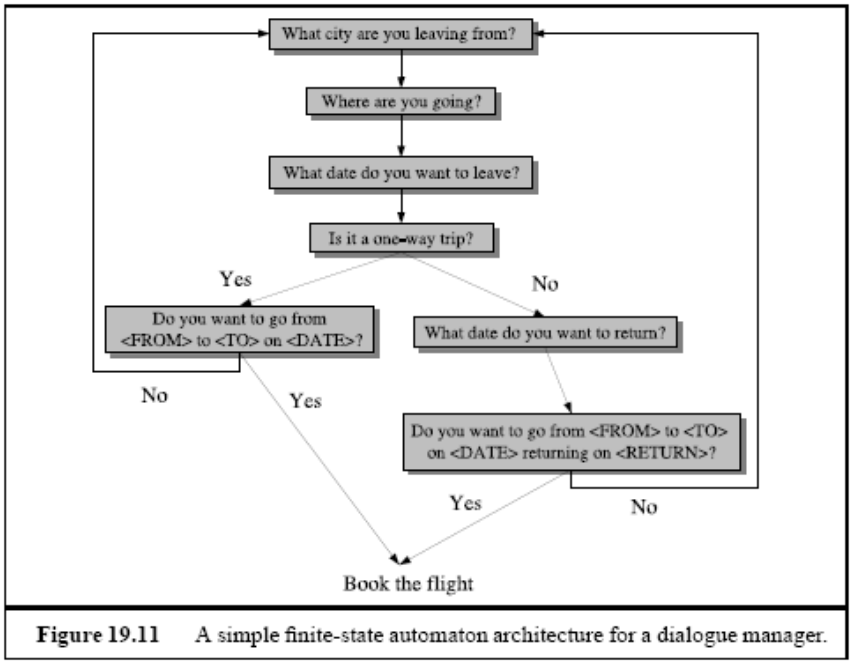


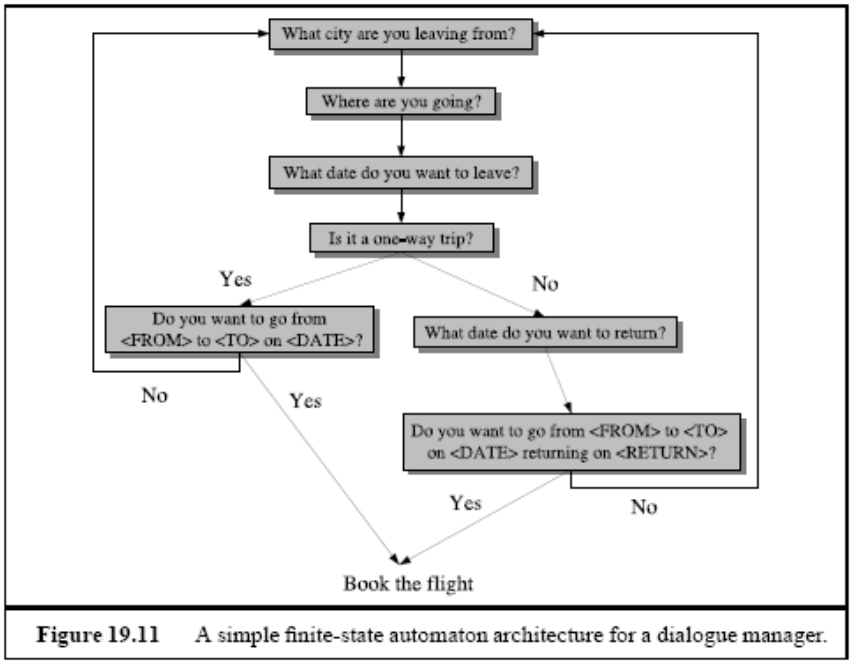
Figure 19.11 A simple finite-state automaton architecture for a dialogue manager.

Finite state automata

- Simple dialog states
- Good for form filling dialogues (frames)
- Can handle frame switching (stochastically)

[Jurafsky and Martin(2000)]

Dialog management



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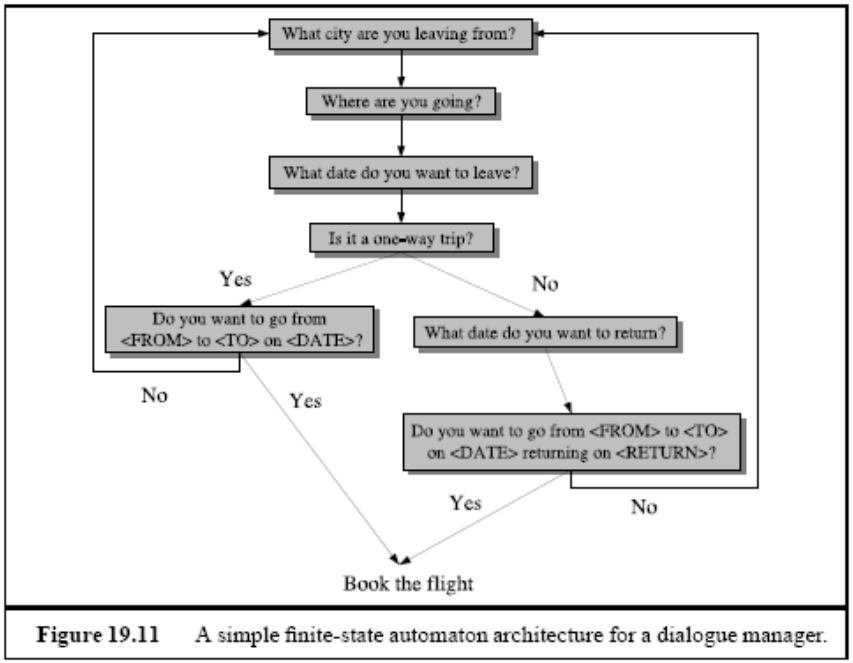

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Dialog management

	Prompt Type	
Grammar	**Open**	**Directive**
Restrictive	*Doesn't make sense*	System Initiative
Non-Restrictive	User Initiative	Mixed Initiative

Figure 19.12 Operational definition of initiative, following Singh et al. (2002).

Who takes the initiative

- Machine prompts all user actions ⇒ Finite state script
- User asks questions ⇒ Single frame
- Machine allows some user initiatives ⇒ Frame switching
- Negotiation ⇒ Plan based models

[Jurafsky and Martin(2000)][Allen et al.(2001)Allen, Byron, Dzikovska, Ferguson, Galescu, and Stent]

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Further Reading I

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Appendix A

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