Latest Developments in Machine Translation Technology

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Introduction

- not a comprehensive survey of all MT research in the past few years
- examples of projects only indicative of trends
- highlight new developments/approaches/methods
- no discussion of projects and systems well established in the late 1980s (e.g. Systran, Logos, EDR, ATR, Mu/JICST, METAL)

Contents

MT during the 1980s

at first MT Summit conference (1987):

- **dominant frameworks**

  indirect translation
  (transfer, interlingua)
  linguistics-based

- **knowledge-based MT still innovative**

- **multinational-multilingual projects**

- **some well-established systems**
  (Systran, Meteo, Weidner/Bravice,
  PAHO systems, Logos)

- **many new systems/projects from**
  Japanese companies
  (NEC, Toshiba, Fujitsu, Oki,
  Ricoh, Sharp, etc.)

Rule-based MT

Transfer-based (typical "second generation")

- three stages: analysis, transfer, synthesis
- abstract semantico-syntactic interfaces
- multiple levels/strata:
  morphology, syntax, semantics
- syntax-oriented, tree-transduction approach
- batch processing, post-edited
- little pragmatic/discourse information

projects: [Ariane, Eurotra], Eurolang (SITE, METAL),
LMT 'Logic programming MT' (IBM centres)

Interlingua-based

- two stages: analysis, synthesis
- abstract language-neutral representation
- multistratal: morphology, syntax, semantics
- semantics-oriented ('understanding')
- [knowledge bases]

projects: [DLT, Rosetta], PIVOT (NEC),
Carnegie-Mellon University (KBMT89,
KANT, CATALYST)
ULTRA (New Mexico State University)
MCC (Microelectronics and
Computer Technology Corporation)
UNITRAN

Formalisms

Non-transformational

Constraint-based formalisms

Unification formalisms

- **Lexical-Functional Grammar**
- **Logic programming (Q-systems,UNITRAN Prolog)**
- **Definite Clause Grammar**
- **Slot grammar (LMT)**
- **Generalized Phrase Structure Grammar**
- **Head-driven Phrase Structure Grammar**
- **Categorial Grammar**

Principles-based MT (Government-Binding Theory)

- **projects: ITS (Geneva), UNITRAN**

Lexicalist approaches
[transfer rules = simple bilingual lexical equivalences]

- **projects: CRITTER, ACQUILEX,**
  'Shake-and-bake' (Sharp)

Reversibility

- **projects: [Rosetta], ISSCO, CRITTER, UNITRAN**

Tree transduction model (Eurotra)

Input text in L

Analysis

Grammar (1) --> Representation (1)

<--- Mapping rules T (1/2)

Grammar (2) --> Representation (2)

<--- Mapping rules T (2/3)

Transfer

Grammar (n) --> Representation (n)

<----Mapping rules T (n/n')

Grammar (n') --> Representation (n')

<-- Mapping rules T (n'/n'-1)

Synthesis

Grammar (2') --> Representation (2')

<---Mapping rules T (2'/1')

Grammar (1') --> Representation (1')

Output Text in L'

Constraint-based formalism (LFG)

John likes Mary <--> Marie plait à Jean

like, V:
(↑PRED) = like <SUBJ, OBJ>
(τ↑PRED FN) = plaire <SUBJ, OBJ>
(τ↑AOBJ OBJ) = τ(SUBJ)
(τ↑SUBJ) = τ(↑OBJ)

john, N:
(↑PRED) = john
(τ↑PRED FN) = jean

mary, N:
(↑PRED) = mary
(τ↑PRED FN) = marie

TL f-structure:

```
⎡PRED    plaire                      ⎤
⎢SUBJ    [PRED marie ]               ⎥
⎣AOBJ    [OBJ      [PRED jean ]  ]   ⎦
```

Student is likely to work <--> Il est probable que l'étudiant travaillera

likely, A:
(↑PRED) = likely <XCOMP> SUBJ
(↑SUBJ) = (↑XCOMP SUBJ)
(τ↑PRED FN) = probable
(τ↑COMP) = τ(↑XCOMP)

probable, A:
(↑PRED) = probable <COMP>SUBJ
(↑SUBJ FORM) = il
(↑COMP COMPL) = que

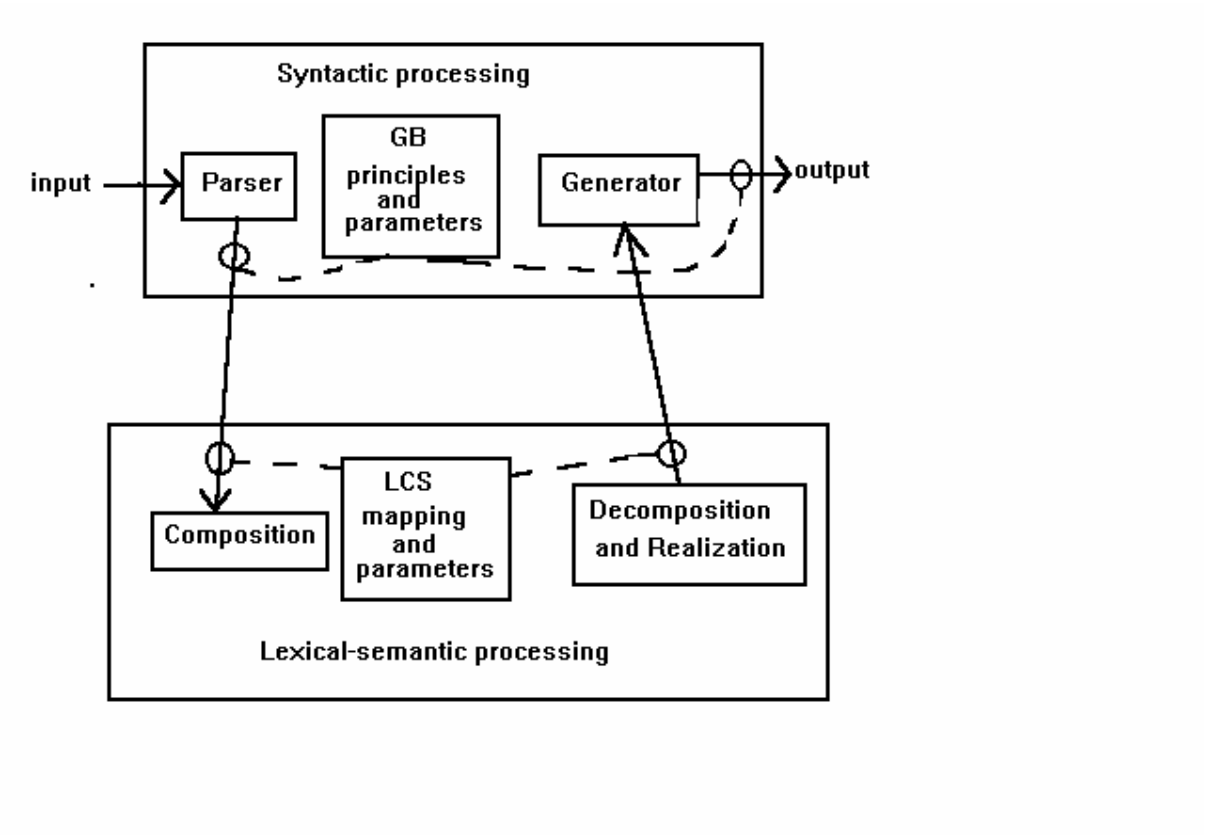
TL f-structure:

```
⎡PRED    probable                    ⎤
⎢SUBJ    [FORM    il ]               ⎥
⎢        ⎡PRED    travailler  ⎤      ⎥
⎢COMP    ⎢COMPL   que         ⎥      ⎥
⎣        ⎣SUBJ    [...]       ⎦      ⎦
```

Knowledge-based MT: lexical entry (CMU)

```
(find
  (make-frame
   +find-v1
  (CAT (value v))
  (STUFF
  (DEFN "to discover by chance, to come across")
  (EXAMPLES "found X in the bedroom"
            "found X sleeping upstairs"))
            "found that X was sleeping on the porch"
  (MORPH
     (IRREG (*v+past* found) (*v+past-part* found))
  (SYN-STRUC
     (*OR*   ((root $var0)
                 (subj (root $var1)(cat N))
                 (obj  (root $var2)(cat N))
              ((root $var0)
                 (subj (root $var1)(cat N))
                 (xcomp(root $var2)(cat N)(form pres-part)))
              ((root $var0)
                 (subj (root $var1)(cat N))
                 (comp (root $var2)(cat V)(form fin))))))
  (SEM
     (LEX-MAP
                 (%involuntary-perceptual-event
                       (experiencer (value ^$var1))
                       (theme (value ^$var2))))))
```

UNITRAN system design



Example parameters:

Syntactic divergences: parameters

Constituent order *I have seen him – Ich habe ihn gesehen*
Null subject *I saw the book – (Yo) Vi el libro*

Lexical–semantic divergences: parameters

structural *X entered the house – X trat ins Haus hinein*
thematic *I like Mary – Mary gefällt mir*
categorial *I am hungry – Ich habe Hunger*
demotional *I like eating – Ich esse gern*

Lexicalist approach ('Shake-and-bake')

monolingual lexical entry (English):

[12]

ORTHO	like	
SEM	E1:	like (E1), role (E1, experiencer, X1), role (E1, stimulus, Y1)
ARG0	E1	
ARG1	X1	
ARG2	Y1	

monolingual lexical entry (Spanish):

[13]

ORTHO	gust-	
SEM	E2:	gustar (E2) role (E2, stimulus, X2) role (E2, experiencer, Y2)
ARG0	E2	
ARG1	X2	
ARG2	Y2	

bilingual lexical entry for *like-gustar*:

SPANISH [13]	SEM	ARG0 E ARG1 X ARG2 Y
ENGLISH [12]	SEM	ARG0 E ARG1 Y ARG2 X

Reversibility (CRITTER)

eat <--> manger
miss (1: X, 2: Y) <--> manquer (1: Y', 2: X')
walk (inv-1: across (2: X)) <-->
traverser (2: X, inv-1: $manner (2: à_pied))

General-purpose NLP systems

ELU
(Environnement Linguistique d'Unification) (ISSCO)

KIELIKONE (Finland)

Core Language Engine (SRI, Cambridge)

PLNLP
(Programming Language for Natural Language Processing) (IBM):
[SHALT-2, C-SHALT, KSHALT, PORTUGA]

Summary of trends in rule-based approaches

mid-1980s	mid-1990s
syntax-orientation	lexicalist orientation
complex transfer rules	simple lexical transfer
stratificational/multi-level representation/monostratal	single
tree transduction [filters]	constraints/unification
analysis/transfer	generation
understanding/disambiguation	style/quality output
uni-directional	reversible
linguistic information databanks	lexical/conceptual
lexicon compilation	lexicon acquisition

Corpus-based MT

a) the direct use of information derived from corpora for the analysis, transfer and generation of translations

b) the indirect use of corpora

- as sources of information for deriving or compiling lexical, grammatical and knowledge databases,

- as sources of statistical information about source and target languages.

Statistics-based MT

Alignment: (IBM Candide, using corpus of the Canadian Hansard)

The proposal will not now be implemented

Les propositions ne seront pas mises en application maintenant

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English: *not*

French	Probability	Fertility	Probability
pas	.469	2	.758
ne	.460	0	.133
non	.024	1	.106
pas du tout	.003		
faux	.003		
plus	.002		
etc.			

Later modifications: syntactic transformations

e.g.

English questions:

Has the store any eggs? -> The store has any eggs QINV

English 'adverbs':

John does not like turnips -> John likes do_not_M1 turnips

French negation:

Je ne sais pas -> Je sais ne_pas

French pronouns:

Je vous le donnerai -> Je donnerai le_DPRO vous_IPRO

Example-based MT

DLT: Bilingual Knowledge Bank

the main fields	les principaux domaines
the following fields	les domaines suivantes
these two fields	ces deux domaines
the specialized fields	les domaines spécialisés
the para-medical fields	activités paramédicales
the magnetic fields	les champs magnétiques
the coal fields	les bassins-houilliers
the corn fields	les champs de blé

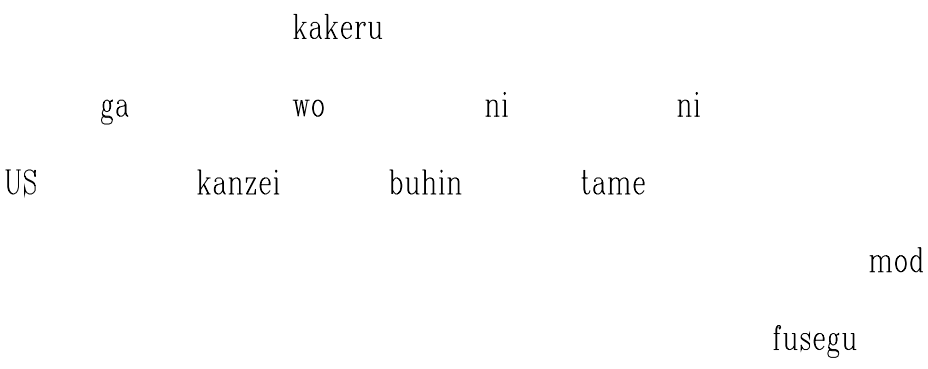
le livre *de* mon père ->	my father's book
un verre *d'*eau - >	glass of water
il est certain *de* réussir ->	certain to succeed
il est capable *de* résister ->	capable of resisting
il vient *de* Paris ->	he comes from Paris
le train *de* Paris ->	the train to/from Paris
il partit *de* nuit ->	he left at night
il partit *de* bonne heure ->	he left in good time
je suis âgé *de* trente ans ->	I am thirty years old

English *...have a/an effect on...* -> French

have a direct effect on ->	ont une influence directe à
have a direct effect on ->	intéressent directement
have a direct effect on ->	ont eu une répercussion directe sur
has had a marked effect on ->	a largement influencé
had a positive effect on ->	s'est avérée positive dans
had a highly negative effect on [X] ->	[X] en auraient été gravement affectés
will have a decisive effect on ->	influencera de façon déterminente
would have a detrimental effect on ->	aurait de fâcheuses répercussions sur

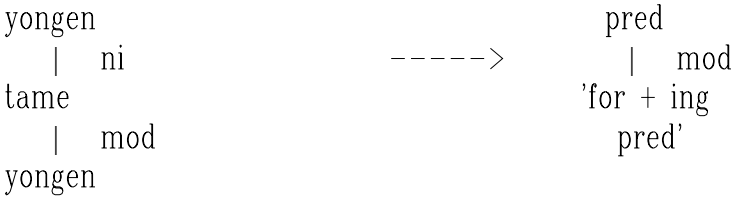
Example-based method with probabilistic scores

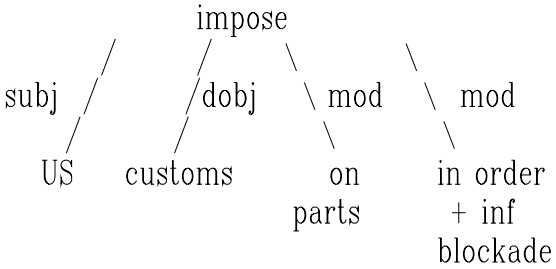
SL input (Japanese):
US ga ... wo fusegu tame ni buhin ni kanzei wo kakeru



simlarities (with probabilities):

5.988	(meishi) ni zeikin no kakeru	impose tax on (noun)
3.077	(meishi) no saibin ni kakeru	take (noun) to court
2.717	(meishi) no made ni kakeru	hang (noun) in window
2.554	(meishi) no sutoobu ni kakeru	put (noun) on stove





TL output (English):

US imposes tax on parts in order to blockade...

Connectionist approaches

Spreading activation: Modification Deciding Network (Matsushita)

example of positive (co-operative) links:

1) single phrase modifying a number of verb phrases simultaneously:
Kare wa hon o kai, sore o yonda
He book buy it read
'He bought a book and read it'
– *kare* modifies both *kai* and *yonda*

examples of negative (exclusive) links:

2) one word cannot have two different meanings in same sentence:
Watashi wa 1-nensei no eigo o motte iru
I freshmen English take charge of
'I teach freshmen English'

motte means either 'take charge of' or 'have'
here it can only be 'take charge of'

3) modifications should not intersect:
Watashi wa kare ga kinoo sakyokushita kyoku o kiita
I he yesterday compose ong listened
'I listened to the song he composed yesterday'

the modification of *kiita* by *kare* and of *sakkyokushita*
by *watashi* would violate the non-intersection condition.

examples of control rules:

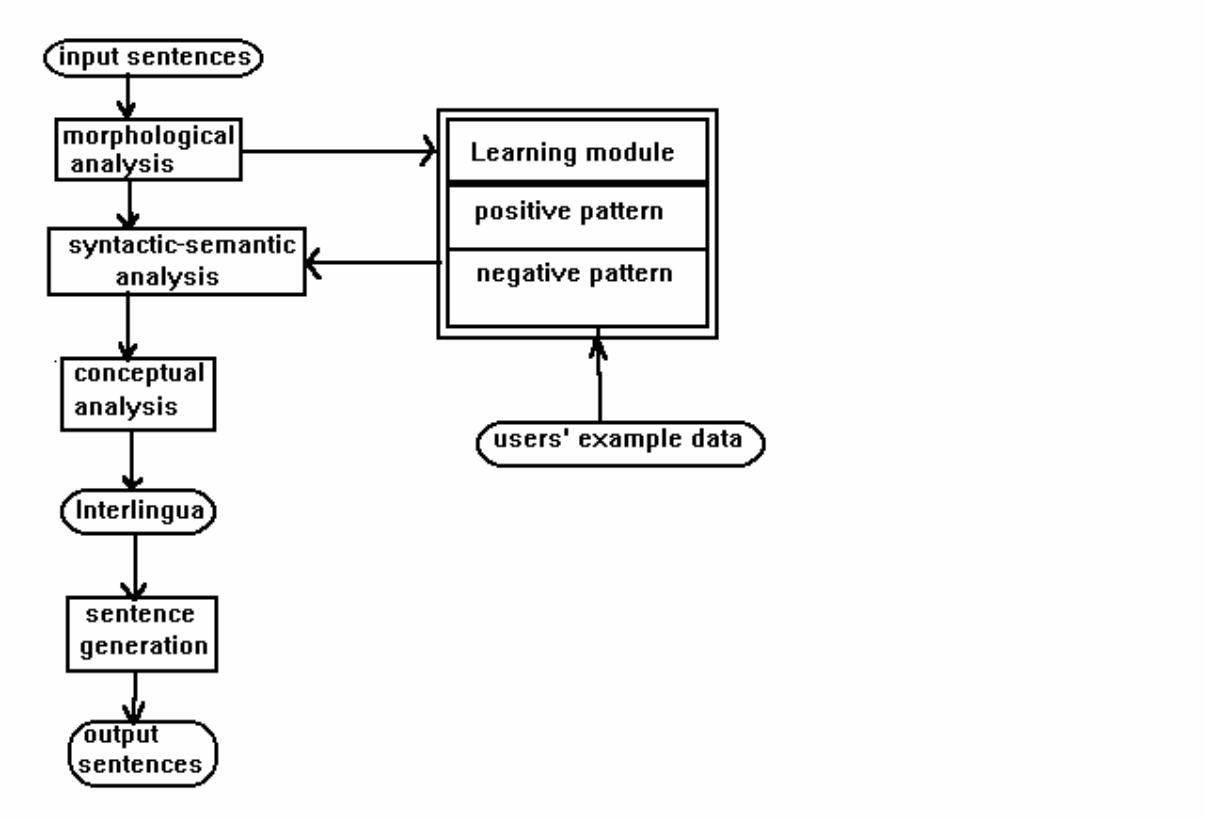
4) obligatory case is given precedence to optional case

5) modifications close to verbs are given precedence
to modifications more distant

6) modifications with modifier closely related semantically
to verb are preferred

Learning systems:

Model - NEC



Corpora as sources of information

text corpora:

- **LDC (Linguistic Data Consortium)**
- **EAGLES (Expert Advisory Group on Language Engineering Standards)**

sublanguage or domain-specific systems

lexical/knowledge databases:

- **UNITRAN**
- **Carnegie-Mellon systems**
- **ULTRA, Pangloss**
- **LMT**
- **Electronic Dictionary Research**

Bilingual text databases (aligned):

- **- for example-based systems**
- **- for translator's workstations**
- **AT&T**
- **ACQUILEX**
- **CWARC (Canadian Workplace Automation Research Center)**

Direct use of statistical information

- **PIVOT (NEC)**
- **ArchTran**

Generation

- **stylistic improvement**
- **discourse features**
- **dialogue translation**
- **illocutionary acts**

example-based methods

multilingual generation (e.g. RAREAS)

dialogue-based MT
(translation by monolinguals not knowing target language)

UMIST
Brussels (Babel-2)
Grenoble (LIDIA)
Kuala Lumpur (Malaysia)

Controlled, domain- and user-specific MT

Controlled input MT systems
- Xerox (Systran)
- Smart Corporation
- Perkins Engines (Weidner)
- CATALYST (Carnegie-Mellon for Caterpillar)

Domain-specific and sublanguage MT
- Meteo, CRITTER, ELU
- Pangloss, CATALYST
- ATR speech translation
- VERBMOBIL

User-specific and custom-built MT systems
- Winger
- Le Routier
- Volmac Lingware Services
- TRADEX
- CSK (ARGO system)
- HESS (Hangul-English Support System)

Translator Work Stations

- **multilingual word processing**
- **optical character recognition, electronic receipt and transmission of texts**
- **terminology management software**
- **automated access to dictionaries, terminology databanks and other information sources (on-line, remote access, CD-ROM, local network, etc.)**
- **concordance software**
- **storage of and access to existing translations (for later (partial) reuse or revision)**
- **access to example translations [aligned bilingual text corpora]**
- **access to automatic translation facilities (individual words; phrases; sentence by sentence; full text)**
- **'pre-translation' facilities**

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examples:

Canadian Workplace Automation Research Center
Carnegie-Mellon Centre for Machine Translation
TWB (Translator's Workbench): [METAL]
IBM workstation TranslationManager/2: [LMT]
English-Malay translation workstation: [JEMAH]

Pre-translation

English original:

Momentary loads can occur repeatedly during the duty cycle but are of short duration, not exceeding 1 min. at any occurrence. When several momentary loads occur within the same 1 min. period and a discrete sequence cannot be established, the load shall be assumed to be the sum of all momentary loads occurring within that minute.

French pre-translation:

charges_momentanées peuvent occur de_façon_ répétée pendant le cycle_opératoire mais sont de courte durée, not exceeding 1 min at any ccurrence. Lorsque several charges_momentanées occur within le même 1 min période et une discrete séquence ne_peut_pas être établi, la charge doit être assumed to être la somme de all charges_ momentanées occurring within that minute.

The global view

Commercial systems since 1988:

- **Globalink**
- **PC-Translator**
- **Tovna**
- **DP/Translator**
- **Toltran**
- **Translate (Finalsoft Corporation)**
- **XLT (Socatra)**
- **AppTek**
- **Hypertrans**
- **Lexitrans**
- **Language Assistant (Microtac)**

- **RMT/EJ (Ricoh)**
- **DuetQt (Sharp)**
- **STAR (Catena), LogoVista E to J**
  (Language Engineering Corporation)
- **EZ JapaneseWriter**
- **Meltran (Mitsubishi)**

Worldwide activity:

mainly:

United States, Canada
Western Europe
Japan

also:

Malaysia (e.g. JEMAH)
Thailand
China (mainland and Taiwan)
India
Korea (HESS, KSHALT, MATES, etc.)
Eastern Europe (AMPAR, ETAP-2, PARS)

The five eras of MT history

[1] 1947-1954:

- **Weaver's memorandum (July 1949)**
- **Bar-Hillel at MIT (1951-52)**
- **word for word translation (Booth, Richens, Reifler)**
- **statistical methods (Kaplan, RAND)**
- **first MT conference (MIT, 1952)**

[2] 1954-1966:

- **IBM-Georgetown demonstration (Jan 1954)**
- **direct translation ("first generation")**
- **syntactic analysis (MIT, ATN)**
- **conceptual interlingua (CLRU)**
- **Georgetown systems installed (1963, 1964)**

[3] 1966-76:

- **ALPAC report (1966)**
- **indirect approach ('interlingua' CETA, LRC)**
- **rule-based formalisms**
- **sublanguage (Meteo 1976)**
- **Systran at USAF (1970) and at CEC (1976)**

[4] 1976-89:

- **transfer "second generation" (Ariane, Eurotra, Mu)**
- **multinational, multilingual projects (Eurotra, CICC)**
- **linguistics-based interlingua (DLT, Rosetta)**
- **knowledge-based interlingua (CMU)**
- **operational systems (Systran, Meteo, PAHO, CSK)**
- **controlled input (Xerox, Smart)**
- **commercial systems (Logos, Weidner, ATLAS, PENSEE, PIVOT, HICATS, ASTRANSAC, DUET, METAL, Tovna, etc.)**
- **PC systems (PC-Translator, Globalink)**

[5] 1989-

Developments since late 1980s

MT Summit conferences (1987, 1989, 1991, 1993)
International Association for Machine Translation (1991)
US government hearings (1990), JTEC report (1992)

statistics-based IBM Candide (1989)
example-based MT (1989)
constraint-based/lexicalist tendencies in rule-based MT systems for monolingual use (Babel-R, LIDIA, UMIST)
spoken language (ATR 1986, VERMOBIL 1992)
lexicon acquisition (two conferences 1993)

end of European "second generation" projects (Ariane, Eurotra, DLT, Rosetta) and of Eastern European projects after 1989/90 political changes
start of new multilingual European project (Eurolang)
operational implementation of knowledge-based MT (Pangloss, CATALYST)
integration of MT/MAT in documentation systems (e.g. Xerox DocuTran, Krupp Industrietechnik)
user-specific custom-built systems (e.g. TRADEX, Volmac, Winger, etc.)
generation from non-textual sources
evaluation: methodology, benchmarks, etc.

MT chronology

	oper. systems	research	other
1945			
46			
47			Weaver letter
48			
49			Weaver memo
1950			
51			
52			
53			
54		IBM-GU demo	
1955			
56			
57			
58			
59			
1960	Mark II (IBM)		
61			
62			
63			
64	Georgetown		
1965			
66		ALPAC	
67			
68			
69			
1970			
71	Systran	GETA, LRC, TAUM	
72			
73			
74			
1975	Meteo		
76	CEC Systran	Stanford, KBMT	
77			
78		Eurotra	
79			
1980			
81	Weidner		
82	LOGOS	DLT, Rosetta, CMU	
83			
84	Fujitsu ATLAS	EBMT, Unification	
1985	PC-Translator		
86	NEC PIVOT		
87	Hitachi HICATS	ATR	
88	METAL, Sharp Duet, Tovna, Globalink		
89		IBM Candide	
1990			
91	Trados	Eurolang	
92			
93			

"Third generation" systems ?

- rule base less abstract than that of the 'indirect' models
- syntactic analysis restricted to surface constituency and dependency relations (roles and cases); single monostratal representation (unification/constraint-based analysis)
- semantic analysis limited mainly to identification of sentence and clause roles (agents, patients, etc.)
- broad-brush disambiguation by simple semantic features (human, animal, etc.)
- lexical information derived primarily from standard dictionary sources ('crude' syntactic categories and semantic features)
- lexical/structural transfer rules (constraint-based) operating on monostratal ('shallow') representations

- example translations (aligned bilingual corpora)
- statistical data about lexical collocations and vocabulary frequencies (monolingual)
- probablilities of lexical transfer (bilingual)
- domain-specific knowledge bases (both linguistic and subject knowledge)
- feedback ('learning') for grammar/lexicon improvement (connectionist ?)
- greater emphasis on discourse and text stylistic aspects
- integration into documentation processing and publishing systems (as in translator's workstations)

Possible precursors of the "third generation"

SHALT (IBM Japan), with five types of knowledge sources:

- **grammar rules**
- **concept definitions**
- **mapping rules**
- **conceptual paraphrasing rules**
- **corpus of example sentences**

ArchTran (Taiwan)

- **language model (inductively derived)**
- **corpus as data source**
- **statistical translation scores (lexical, syntactic, semantic)**
- **probabilistic transfer**
- **feedback to adjust parameters for specific users**

Transfer-Driven MT (ATR, Japan)

- **thesaurus coding for distance measurement**
- **string level transfer:**
  sochira -> _this_ (desu), _you_ (okura), _it_ (miru)
  e.g. _sochira ni tsutaeru -> you convey_
  [okura (send) <-> tsutaeru (convey)]
- **pattern level transfer:**
  X onegaishimasu -> please.../may I...
- **grammar level transfer:**
  [grammatical category sequence]
- **example database:**
  e.g. Japanese N_1 _no_ N_2

fee for the conference	**not: *fee of the conference*,**
conference in Tokyo	**not: *conference of Tokyo***
week's holiday	**not: *holiday of a week***
hotel reservation	**not: *reservation of hotel***

MT and users

Multilingual/multinational corporations
Translation agencies/services
- **post-edited, pre-edited, controlled input**
- **single source text and multiple target languages**
- **partial retranslation of revised texts**

occasional non-professional translator.
- **bilingual non-translators (PC-based systems)**
- **monolingual users knowing only the source language (UMIST, Babel-R, LIDIA)**
- **monolingual users knowing only the target language (mainframe/batch systems, PC-based systems)**

research implications:
- **adoption of realistic and realizable aims**
- **recognition of usefulness of the less than perfect**
- **definition of user environments**
- **no attempt to 'mimic' the human translator**
- **user/developer collaboration**
- **user/researcher collaboration**
- **evaluation of systems, benchmarks, standards of performance**