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AN ANNOTATED BIBLIOGRAPHY OF PUBLICATIONS ON DEPENDENCY THEORY

David G. Hays

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David G. Hays

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PREFACE

The books and papers listed here have in common a concern with the notion that syntax is best described by specifying word-to-word connections, generally called "dependencies," rather than by segmentations of sentences. Some of the works listed contribute to the development of a formal dependency theory in linguistics. Others apply the growing theory to the description of natural languages and to the design of computer systems for machine translation, information retrieval, and other purposes. A few of the papers cited criticize and reject the dependency notion.

The bibliography presented here was constructed from the resources of the RAND linguistic research project, which are extensive but by no means complete. Even within the material available to us, some items have been omitted; in particular, papers on applications in which dependency grammar played only a minor role were omitted. Suggestions for additional entries, as well as comments on the annotations, will be welcomed and used in a possible future revision and enlargement of the bibliography.

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AN ANNOTATED BIBLIOGRAPHY OF PUBLICATIONS ON DEPENDENCY THEORY

1. Early Works

1. THE PRINCIPLES OF GRAMMAR
Solomon Barrett, Jr.
Albany, 1848; revised edition, Metcalfe & Co., Cambridge, 1857.
This author copyrighted a system of grammatical diagramming in which the subject is written on the trunk of a tree, the predicate on a large branch, and modifiers on twigs and leaves. (Cited by E. R. Gammon in 2.13.)

2. A PRACTICAL GRAMMAR
Stephen W. Clark
New York, 1863.
According to this author's scheme, copyrighted in 1847, each word is written in a lozenge, with adjacency of lozenges indicating connection of words. He used the same scheme in Clark's Brief Grammar, 1876. (Cited by E. R. Gammon in 2.13.)

3. HIGHER LESSON IN ENGLISH
Alonzo Reed and Brainerd Kellogg
New York, 1877 and 1898.
The scheme set forth here and later widely adopted places subject and predicate on a horizontal line with modifiers descending. (Cited by E. R. Gammon in 2.13.)

4. SKETCH OF A STRUCTURAL SYNTAX
Lucien Tesnière
Esquisse d'une syntaxe structurale, Librairie C. Klincksieck, Paris, 1953.
This pamphlet is not the first publication in which Tesnière used the notions of dependency theory, but it is the first abstract treatment of the theory. Reviews: Howard B. Garey, Language, vol. 30, no. 4 (Oct.-Dec. 1954), pp. 512-513. Paul L. Garvin, Word, vol. 11, no. 2 (Aug. 1955), pp. 271-272. B. Pottier, Revista Portuguesa de Filologia, vol. 7, no. 1-2 (1956), pp. 441-444.

5. ELEMENTS OF STRUCTURAL SYNTAX
Lucien Tesnière
Eléments de syntaxe structurale, Librairie C. Klincksieck, Paris, 1959.
Tesnière presents dependency theory and discusses many details of French grammar, with an extensive treatment of "translation," i.e., change of syntactic class by means of function words. He touches on the use of dependency theory in comparative and stylistic studies. Reviews: R. H. Robins, Archivum Linguisticum, vol. 13, no. 1 (1961), pp. 78-89. H. Wissemann, Indogermanische Forschungen, vol. 66, no. 2, (June 1961), pp. 176-185. G. Gougenheim, Le Francais moderne, vol. 28, no. 2 (April 1960), pp. 142-147. J. Vergote, Orbis, vol. 9, no. 2 (1960), pp. 477-494. E. Benveniste, Bulletin de la Societe de Linguistique de Paris, vol. 55, no. 2 (1960), pp. 20-23. R. F. Mikush, Voprosy Zazykoznaniya, vol. 9, no. 5 (Sept.-Oct. 1960), pp. 125-140.

2. Formal Analyses

1. ELEMENTS FOR A GENERAL GRAMMAR OF PROJECTIVE LANGUAGES
Y. Lecerf and P. Ihm
Eléments pour une grammaire générale des langues projectives, EUR 210.f, Presses Académiques Européennes, Brussels, September 1963.
Originally issued as an internal report in April 1960, this paper defines the word-order rule known as "projectivity:" If word A does not depend directly or indirectly on words B, C, then A does not occur between B and C. German separable prefixes are examined, and the consequences of projectivity for parsing algorithms are stated.

2. ON A THEORY OF G-ORDERING
P. Ihm and Y. Lecerf
"Zu einer Theorie der G-Ordnungen," GRISA Report No. 2, EURATOM, Brussels, May 1960, pp. 12-15. Trans. in JPRS 10367, 11 October 1961, pp. 8-12.
An axiomatic basis for dependency diagramming is given. Projectivity is here characterized by the coherence, i.e., the noninterruption by extraneous elements, of the subtree headed by any node.

3. ELEMENTARY ALGEBRAIC ANALYSIS OF THE LECERF-IHM CRITERION
P. Camion
"Analyse algébrique élémentaire du critère de Lecerf-Ihm," GRISA Report No. 3, EURATOM, Brussels, July 1960, pp. 3-7. Trans. in JPRS 10380, 4 October 1961, pp. 2-5.
The author proves a property of trees and examines the amount of freedom of word order left by the axiom of projectivity.

4. GROUPING AND DEPENDENCY THEORIES
David G. Hays
In H. P. Edmundson, ed., Proceedings of the National Symposium on Machine Translation, Prentice-Hall, Englewood Cliffs, New Jersey, 1961, pp. 258-266.

Published in February 1960 as a RAND paper, this report compares immediate-constituent theory (phrase-structure, or IC-theory) and dependency theory. IC-theory is based on a topology of grouping, whereas dependency theory uses a topology of trees, each minimal syntactic unit occupying a node in the tree. A concept of correspondence between the two kinds of structures is defined, and the two topologies are compared.

5. AN ALGEBRAIC REPRESENTATION OF THE STRUCTURE OF SENTENCES IN DIVERSE NATURAL LANGUAGES
Yves Lecerf
"Une représentation algébrique de la structure des phrases dans diverses langues naturelles," Comptes rendus des seances de l' Academie des Sciences, vol. 252 (1961), pp. 232-234.

First certain algebraic composition laws are described for arbitrary elements. These elements can be called, tentatively, words, syntagmas, etc., and the resultant structure can be described as a G-syntax. Passing to the case of natural languages, it is shown how certain apparent contradictions met by various linguistic doctrines are removed if it is recognized that the assembly of items (called words by grammarians) into the chains that they call syntagmas, then into larger syntagmas, and finally into sentences, happens within the framework of a G-syntax. --Author

6. DEPENDENCY SYSTEMS AND PHRASE STRUCTURE SYSTEMS
Haim Gaifman
P-2315, The RAND Corporation, Santa Monica, California, May 1961.

The formalism of dependency theory was first published here, together with proofs (i) that the RAND SSD routine (3.5) is adequate for recognition of sentences produced by the formalism; (ii) that dependency and phrase structure are weakly equivalent, since every language that has a finite grammar of one kind has a finite grammar of the other kind as well; and (iii) that the two theories are almost strongly equivalent, in the sense that all but a specified subclass of phrase-structure grammars correspond to dependency grammars, characterizing the same languages and assigning corresponding structures to their sentences.

7. ON MODELS OF SYNTAX FOR MACHINE TRANSLATION
S. Ya. Fitialov
"O Modelirovanii Sintaksisa dlya Mashinnogo Perevoda," Doklady na Konferentsii po Obrabotke Informatsii, Mashinnomu Perevodu, i Avtomaticheskomu Chteniyu Teksta, Institute of Scientific Information, Academy of Sciences, Moscow, 1961. Trans. in JPRS 13197, 28 March 1962.

Phrase-structure grammar is introduced, then dependency. A projective graph is called "configurational." Some representations of dependency grammars are given: (i) list of word pairs. (ii) List of valence symbols and symbol pairs. (iii) The same, with order noted. (iv) The same, with obligatory valences. The difficulty of handling relative pronouns is noted, and translation procedures are sketched.

8. THE CODING OF WORDS FOR AN ALGORITHM FOR SYNTACTIC ANALYSIS
Yu. S. Martem'yanov
In Doklady na Konferentsii po Obrabotke Informatsii, Mashinnomu Perevodu i Avtomaticheskomu Chteniyu Teksta, Institute of Scientific Information, Academy of Sciences, Moscow, 1961. Trans. in JPRS 13321, 4 April 1962.

Word classes ADr, ADl, AG, PGr, and PGl are defined, where A=active, P=passive, D=depend, G=govern, r=right, l=left. An active governor sweeps up passive dependents. A parsing routine is discussed in part, including the effect of English inflections on word class, but omitting several late stages that are expected to handle many difficult problems. A subsequent semantic analysis is mentioned in passing.

9. SYNTACTICAL INDICATORS FOR WORDS AND SYNTACTICAL ANALYSIS OF CLAUSES
Yu. S. Martem'yanov
"Sintaksicheskie Priznaki Slova i Sintaksicheskij Analiz Predlozheniya," Mashinnyj Perevod, Trudy Instituta TM i VT AN SSSR, vol. 2 (1961), pp. 261-279. Trans. in JPRS 13543, 24 April 1962, pp. 315-337.

Very similar to #8 above.

10. THE MODELLING OF SYNTAX IN STRUCTURAL LINGUISTICS
S. Ya. Fitialov
"O Modelirovanii Sintaksisa v Strukturnoj Lingvistike," in S. K. Shaumyan, ed., Problemy Strukturnoj Lingvistiki, Izdatel'stvo AN SSSR, Moscow, 1962, pp. 100-114.

There are two types of linguistic description--"external" or semantic, and "internal" or grammatical. The internal syntactic description or formal syntax of a language is a calculus generating a set of strings of symbols--the set of correct sentences of the language described. The valency calculus based on the conception of the relation of dependence between words in a sentence is one of the most natural kinds of syntactic calculus. Different types of the val-

ency calculus are considered as a possible basis for the construction of formal models for grammars of languages. The connection between valency calculus and "phrase-structure" calculus is discussed.--Author

11. AN AXIOMATIC APPROACH TO PREFIX LANGUAGES
Saul Gorn
In International Computation Centre, ed., Symbolic Languages in Data Processing, Gordon and Breach, New York, 1962.

A prefix language is a set of strings over a stratified alphabet such that if P belongs to stratum n and A_1, A_2, ..., A_n belong to the language, then $PA_1A_2 \ldots A_n$ belongs to it. Gorn derives various properties of this class of languages and chooses eight of them as axioms for a formal characterization. He notes that some of these axioms can be omitted, broadening the class without losing applicability. Dependency diagrams are used as one mode of representation.

12. SOME CHARACTERISTICS OF CORRECT SYNTACTIC STRUCTURE
L. N. Iordanskaya
"O Nekotorykh Svojstvakh Pravil'noj Sintaksicheskoj Strukturv," Voprosy Yazyknaniya, vol. 12, no. 4 (July-August 1963), pp. 102-112.
Trans. in JPRS 22415, 23 December 1963, pp. 62-81.

The correct structure of a sentence is assumed to be intuitively determinable. General principles are stated: Each word depends on one word, each clause on one clause and one word in it. Each clause has one independent (key) element. No element depends on itself. A predicative relation always includes the key element. A syntagma is a type of relation, specifying types of governor and dependent. An active valence predicts when the dependent is found. A correct structure satisfies the general principles; each pair of linked elements corresponds to a syntagma listed for the language, with a relation given for that syntagma; punctuation rules are satisfied; the structure is saturated, or else no saturated structure is allowable. Instances where two links are incompatible or inseparable are given.

13. ON REPRESENTING SYNTACTIC STRUCTURES
E. R. Gammon
Language, vol. 39, no. 3 (July-September 1963), pp. 369-397.

A concept of degree of syntactic relatedness, conjectured to have psychological correlates, is introduced and linked to IC theory by assigning distances from constituents to constitutes; but the head of an endocentric construction is assumed to be closer to the whole than is the attribute. Many examples are given, and some 19th-century diagramming schemes are compared (see 1.1, 1.2, 1.3). Diameter and dimensionality are suggested as measures, along with depth, of syntactic complexity.

14. DEPENDENCY THEORY: A FORMALISM AND SOME OBSERVATIONS
David G. Hays
Language, vol. 40, no. 4 (October-December 1964), in press.

Dependency grammars characterize the class of context-free languages, assigning to each sentence of a characterized language a tree structure with minimal syntactic units at the nodes. Both production and recognition procedures are given. Either transformational or stratified linguistic systems can be constructed on the basis of dependency theory; more attention is given to the latter possibility. Semantic and psychological considerations are cited as motivating specific features of the theory, but they are no more necessary as justifications for this theory than for others.

15. ON THE EQUIVALENCE OF MODELS OF LANGUAGE USED IN THE FIELDS OF MECHANICAL TRANSLATION AND INFORMATION RETRIEVAL
Maurice Gross
Information Storage and Retrieval, vol. 2, no. 1 (April 1964), pp. 43-57.

The theory of language characterization by phrase-structure grammars is sketched and several grammatical models are shown or stated to be equivalent to it. Pushdown automata are given for predictive and dependency parsing. Recursive unsolvability theorems for ambiguity and translatability of context-free languages are quoted and discussed. Examples are given in support of the use of transformations in grammar.

3. Parsing Procedures

1. AN INTERMEDIARY LANGUAGE MODEL FOR MACHINE TRANSLATION
I. A. Mel'chuk
Voprosy Yazyknaniya, vol. 7, no. 3 (May-June 1958), p. 149.

This is a report of a lecture to the Scientific Council of the Institute of Linguistics. The model consisted of analysis, translation, and synthesis. A parsing program to recognize configurations in text was the key element of the analysis program.

2. THE USE OF MACHINES IN THE CONSTRUCTION OF A GRAMMAR AND COMPUTER PROGRAM FOR STRUCTURAL ANALYSIS
K. E. Harper and D. G. Hays
In Information Processing, UNESCO, Paris, 1960, pp. 188-194.

The cyclic research process is briefly described, including mention of the use of structural concordances in identification of new syntactic classes. The RAND sentence-structure determination routine, based on precedence and dependency theory, is outlined.

3. AUTOMATIC ANALYSIS
Y. Lecerf
"Analyse automatique," in Enseignement Préparatoire aux Techniques de la Documentation Automatique, Euratom, Brussels, 1960, pp. 179-245.

The "conflict" program tests each item against the adjoining, already constructed phrase and either subsumes it as an additional dependent or makes it the governor of a new, extended phrase. The result is a chameleon, looking like both a phrase-structure diagram and a dependency diagram. Lecerf discusses sentence diagramming from the point of view of economy in addressing, i.e., ease of locating information during analysis of a text.

4. THE EXPERIMENT OF FEBRUARY 1960
Eric Morlet
"Expérience de Février 1960," in Enseignement Préparatoire aux Techniques de la Documentation Automatique, Euratom, Brussels, 1960, pp. 246-253.

Flowcharts and description of a syntactic recognition program for the IBM 650 are given.

5. STUDIES IN MACHINE TRANSLATION--10: RUSSIAN SENTENCE-STRUCTURE DETERMINATION
D. G. Hays and T. W. Ziehe
RM-2538, The RAND Corporation, Santa Monica, California, April 1960

This program was designed to be relatively simple and easy to transfer from one problem (i.e., input language) to another. Dependency theory is sketched, and the isolation of word-order rules of precedence from all other grammatical rules is explained. Agreement tests are made using a table, with certain complexities to save space. Resultant grammatical types are the altered descriptions assigned to units when dependency connections are made. The special cases of conjunctions (which the program could handle), of ellipsis (for which a subroutine was to be written), and of relative clauses (which could be handled) are outlined in part. Punctuation and idiom recognition are mentioned. The routine consists of 2400 instruction words, running at about 6[illegible] occurrences per minute on the IBM 704. Problems of structure revision--i.e., of backtracking when a partially completed structure is found to contain an error--are considered.

6. A COMMENTARY ON THE RAND SENTENCE STRUCTURE DETERMINATION PROGRAM
A. F. Parker-Rhodes
ML 134, Cambridge Language Research Unit, Cambridge, England, no date.

The RAND program of RM-2538 (3.5) is compared with the author's. The CLRU method of testing agreement is said to be more economical, but the theories are considered similar. "The rapid convergence in the number of grammatical possibilities...as one ascends the structural hierarchy of the sentence" is considered a universal of language, unrecognized by RAND.

7. THE CONFLICT PROGRAM AND THE CONFLICT MODEL
Y. Lecerf
"Programme des Conflits, Modèle des Conflits," La Traduction Automatique, vol. 1, no. 4 (October 1960), pp. 11-20, and vol. 1, no. 5 (December 1960), pp. 17-36. Trans. in JPRS 10367, 11 October 1962, pp. 13-37.

The parsing program described here produces a phrase-structure diagram together with a dependency diagram; Lecerf considers the two equally valid. He conceives of parsing with a sequence of filters, each rejecting some structures and passing the remainder to the next. The parser itself compares one word of a sentence with its neighbor and extends the domain of one to include the other; this process is repeated until the domain of one word includes those of all other words in the sentence. The dependency graph is read from the final result, the phrase-structure graph from the sequence of domains established during parsing. Projectivity is discussed at length in this paper.

8. AN ALGORITHM FOR TRANSLATING FROM THE ENGLISH LANGUAGE INTO RUSSIAN
T. N. Moloshnaya
Problemy Kibernetiki, no. 3 (1960), pp. 209-272. Trans. in JPRS 6492, 29 December 1960, pp. 41-123.

A dictionary of all 1026 stems in a book by Bellman on differential equations was made. 45 grammatical classes were set up for English, 34 for Russian. Morphological analysis is followed by tests of linear context to reduce homonymy. Parsing is based on a list of configurations deduced from Fries's grammar; adjacent words are tested, subordinates deleted, etc.; the possible configurations in the grammar are applied in order. The English configurations are translated, then the stems, then inflections are added and the sentence ordered by Kulagina's rules. The problem is given in extensive detail.

9. BASIC PRINCIPLES AND TECHNICAL VARIATIONS IN SENTENCE-STRUCTURE DETERMINATION
David G. Hays
In Colin Cherry, ed., Information Theory, Butterworths, Washington, 1961, pp. 367-376.

Basic principles of the RAND method of sentence-structure determination include the isolation of grammatical detail from the structure of the computer program and postulation of a certain word-order rule, the rule of projectivity, that is realized in the program. Technical variations control the order of establishment of connections, the format of the grammar used in testing agreement, and other matters.

10. INTERMEDIATE CONSTITUENTS--THEIR APPLICATION TO AUTOMATIC ANALYSIS
J. Verheyden
EUR 332.f, Presses Académiques Européennes, Brussels, October 1963.

This paper was first published as an internal report in August 1961. Tesnière does not specify a dependency relation between translatives (e.g. prepositions) and words associated with them. Bailly's concept of determination makes prepositions depend on their objects. The author proposes that in parsing all connections with determiner preceding be made before any with determiner following. French allows some permutations of the dependents of a governor, but preceding dependents (except with governing verb) are usually fixed. The author's parsing sequence avoids some temporary ambiguities, e.g., "de la ferme" can govern a prepositional phrase, "de ferme" cannot.

11. CONDITIONAL RELAXATION OF THE PROJECTIVITY HYPOTHESIS
Lydia Hirschberg
"Le Relâchement Conditionnel de l'Hypothèse de Projectivité," in Discussions sur l'Hypothèse de Projectivité, CETIS Report No. 35, Euratom, Ispra, Italy, October 1961.

When parsing is blocked and a subtree exists headed by a unit that demands a governor, remove that subtree and continue. When a tree for the sentence is otherwise complete, look for the governor in the subtree headed by the nearest preceding node. Many examples are given. There are also fixed nonprojective combinations in many languages. An annex classifies French dependency types by value. The highest value obtains when governor and dependent require one another; the lowest, when neither calls specifically for the other.

12. AUTOMATION OF SYNTACTIC ANALYSIS
A. Sestier
"L'Automatisation de l'Analyse Syntaxique," Note No. 13, Centre d'Etudes pour la Traduction Automatique, Paris, 19 October 1961.

The author describes the vexations that await anyone who uses only "handmade" analyses as a control on a model for natural language. He describes a system of automatic syntactic analysis, limited to the nominal group, that obtains the graphs of Chomsky and Hays, using hypotheses of Lecerf, Hays, and Yngve. He notes the limitations of such a system, said to operate by "priority sweeps," but he stresses that it is an excellent research instrument for linguists who wish to deepen their studies of syntactic and semantic structure in natural languages.--Author

13. PRINCIPLES OF SYNTACTIC ANALYSIS OF TATAR SENTENCES
F. Drejzin and R. Rashitov
"Printsip Sintaksicheskogo Analiza Tatarskoj Frazy," Mashinnyj Perevod, Trudy Instituta TM i VT AN SSSR, vol. 2 (1961), pp. 294-303. Trans. in JPRS 13543, 24 April 1962, pp. 355-365.

The sentence is cut into sentence modifier, subject modifier, subject, predicate modifier, and predicate. Analysis of dependencies in each section follows.

14. AN ALGORITHM FOR SYNTACTICAL ANALYSIS OF LANGUAGE TEXTS--GENERAL PRINCIPLES AND SOME RESULTS
I. A. Mel'chuk
"Ob Algoritme Sintaksicheskogo Analiza Yazykovykh Tekstov (Obshchie Printsipy i Nekotory Itogi)," Mashinny Perevod i Prikladnaya Lingvistika, No. 7 (1962) pp. 45-87. Trans. in JPRS 19919, 28 June 1963, pp. 35-74.

A dependency parser is outlined. The units of syntactic analysis are "content combinations," i.e., syntagmas (governor and dependent), phraseological combinations, etc., given in the form of configurations, each giving a pair of objects to be sought, a search rule, conditions, actions, etc. These are listed in a syntactic dictionary. The algorithm that uses this list consists of 67 standard (Kulagina) operators. The Russian configuration list has 263 lines. About 250 auxiliary operators are used. A flowchart and configuration list are given.

15. AUTOMATIC SENTENCE DIAGRAMMING
Warren Plath
In 1961 International Conference on Machine Translation of Languages and Applied Language Analysis, H. M. Stationery Office, London, 1962, pp. 175-193.

Commentary on tree structure and parenthetic grouping, with a program for printing sentences with known structures, indicating tree structure by indentation.

16. INTRINSIC ADDRESSING IN AUTOMATIC TRANSLATION
Y. Lecerf
In 1961 International Conference on Machine Translation of Languages and Applied Language Analysis, H. M. Stationery Office, London, 1962, pp. 283-316. French version: L'Addressage Intrinsèque en Traduction Automatique, EUR 123.f, Presses Académiques Européennes, Brussels, December 1962.

For parsing with multiple grammar codes, one plan is to form all selections of one code per item and parse each code string; since many selections would exist for long sentences, a sequence of prefilters, rejecting some selections by local contexts, would be useful. Parsing in general can be reduced to the same problem by assigning multiple syntactic role codes to words. But for an automaton to refer to linear context breeds redundancy; a reference system (e.g., dependency or phrase structure) allows use of other rules during testing of context for applicability of a given rule.

17. OBTAINING ALL ADMISSIBLE VARIANTS IN SYNTACTIC ANALYSIS OF TEXT BY MEANS OF A COMPUTER
G. S. Slutsker
"Poluchenie vsekh Dopustimykh Variantov Sintaksicheskogo Analiza Teksta pri Pomoshchi Mashiny," Problemy Kibernetiki, No. 10 (1963), pp. 215-225.

Assume a grammar that specifies what pairs of words can be connected as governor and dependent. To find all projective parsing of a sentence, first set up a square matrix with $w_{ij} = 1$ if the grammar allows word i to depend on word j. A parsing of the sentence can be specified by a matrix with a single nonzero element in each row, chosen among those with $w_{ij} = 1$. Projectivity can be interpreted in terms of incompatibilities in the matrix; all elements incompatible with unit elements unique in their rows can be erased. Then, by a backtrack procedure, all parsings can be found.

18. A HEURISTIC PARSING PROCEDURE FOR A LANGUAGE LEARNING PROGRAM
Robert K. Lindsay
Information Processing Report No. 12, The University of Texas, Austin, 28 May 1964.

The procedure accepts natural language sentences and produces for each a form of analysis called a "labeled dependency tree." The formal grammar on which the procedure is based differs from the "phrase structure" formalism of Chomsky, and the analysis procedure attempts to discover the single most probably analysis rather than all analyses of ambiguous sentences. Included are discussions of the syntax-meaning distinction, the special problems of simulation, and the need to handle a general class of inputs, and the need for analysis procedures which are to be self-organizing. The paper describes a computer program for analysis of sentences and reports an experiment with the program.--Author

4. Synthesis Procedures

1. SYNTHESIS OF THE SIMPLE RUSSIAN SENTENCE
Z. M. Volotskaya and A. L. Shumilina
"K Voprosu o Sinteze Russkogo Prostogo Predlozheniya," in Lingvisticheskie Issledovaniya po Machinnomu Perevodu, Reports of the Information Mechanization and Automation Department, No. 2, Izdatel'stvo VINITI, Moscow, 1961, pp. 166-168. Trans. in JPRS 13173, 27 March 1962, pp. 228-230.

Information about a word's governor determines its form. The order of governor and dependent being given for each configuration, the order of the sentence can be computed, except that mutual order of dependents of a single node is considered a problem worth study.

2. RULES FOR GENERATING SENTENCES IN A STANDARDIZED LANGUAGE OF GEOMETRY
E. V. Paducheva
Doklady na Konferentsii po Obrabotke Informatsii, Mashinnomu Perevodu i Avtomaticheskomu Chteniyu Teksta, Institute of Scientific Information, Academy of Sciences, Moscow, 1961.

The structures of simple sentences are represented by dependency diagrams; complex sentences are handled with IC rules; and transformations are applied. To construct a sentence, a basic rule is chosen first, attributes are added by insertion of simple sentences, lexical items are selected, quantifiers and referential distinguishers added, transformations applied to simplify and clarify the sentence, and morphological agreements and word order imposed.

3. THE CONSTRUCTION OF SENTENCES IN INDEPENDENT SYNTHESIS OF RUSSIAN TEXT MATTER
T. M. Nikolaeva
"Postroenie Predlozhenij pri Nezavisimom Sintez Russkogo Teksta," Mashinny Perevod, Trudy Instituta TM i VT AN SSSR, vol. 2 (1961), pp. 314-322. Trans. in JPRS 13543, 24 April 1962, pp. 376-386.

Given a dependency structure with type of relation indicated for each connection, the program determines word order and inflection.

4. AN ALGORITHM FOR ORDERING WORDS IN A SENTENCE IN INDEPENDENT RUSSIAN SYNTHESIS
K. I. Babitskij
"Algoritm Rasstanovki Slov vo Fraze pri Nezavisimom Russkom Sinteze," Mashinnyj Perevod, Trudy Instituta TM i VT AN SSSR, vol. 2 (1961), pp. 323-337. Trans. in JPRS 13543, 24 April 1962, pp. 387-412.

The algorithm orders nodes in a dependency tree, given for each node whether it is to be placed before or after its governor. Two dependents falling on the same side of the same governor are ordered arbitrarily.

5. A METHOD OF SYNTHESIZING SENTENCES IN MT ON THE BASIS OF SYNTAGMATIC ANALYSIS
Ch. A. Khoar
"Ob Odnom Sposobe Osushchestvleniya Sinteza Predlozheniya pri MP na Osnove Sintagmaticheskogo Analiza," Mashinnyj Perevod, i Prikladnaya Lingvistika, No. 6 (1961), pp. 80-88. Trans. in JPRS 13790, 18 May 1962, pp. 49-53.

Given a dependency structure, with types of connections marked, and the rule of projectivity, the problem is to order the words. Indices are used to show closeness of each dependent to its governor, and whether it should precede or follow. A procedure is given.

5. Natural Languages

5.1. Miscellaneous

1. SCRUTINY AND EXPLOITATION OF A LINGUISTIC SAMPLE (PRELIMINARY REPORT)
Paul Braffort and Peter Ihm
Dépouillement et Exploitation d'un Echantillon Linguistique (Rapport Préliminaire), GRISA Report No. 7, Euratom, Ispra, Italy, October 1960. Trans. in JPRS 10721, 26 October 1961.

A collection of 131 translations of the Pater noster, prepared in 1787 by Abbe Don Lorenzo Hervas, S.J., was used. The first three Latin clauses ("Pater noster qui es in coelis, sanctificetur nomen tuum, adveniat regnum tuum") were segmented into words, except "qui es" and "in coelis." Seven binary variables were defined by relative location of governors and dependents. Correlations were computed and factor analysis performed. A 2-dimensional array was obtained. The second variable differentiates languages of India from the rest.

2. AN ALGORITHM FOR ANALYSIS OF THE ENGLISH LANGUAGE (FOR TRANSLATION BY MEANS OF AN INTERMEDIATE LANGUAGE)
E. V. Paducheva
"Ob Algoritme Analiza Anglijskogo Yazyka (Dlya Perevoda cherez Yazyk-posrednik)," in Lingvisticheskie Issledovaniya po Mashinnomu Perevodu, Reports of the Information Mechanization and Automation Department, No. 2, Izdatel'stvo VINITI, Moscow, 1961, pp. 210-227. Trans. in JPRS 13173, 27 March 1962, pp. 281-304.

Function words are tied to inflected words; the full units are then cut into morphemes. Meanings are: main (root morphemes), complementary (affix morphemes), or syntactic (relationships between words). English is examined from this viewpoint, and a list of types of governor-dependent pairs is given. A parser, written with Kulagina's operators, is sketched.

3. CERTAIN PROBLEMS IN AUTOMATIC SYNTACTIC ANALYSIS OF A CZECH SCIENTIFIC-TECHNICAL TEXT
N. A. Pashchenko
Nauchno-Teknicheskaya Informatsiya, No. 9 (1963), pp. 38-43. Trans. in JPRS 22415, 23 December 1963, pp. 35-61.

Czech words were grouped in traditional major classes; a great many features were also coded. Governor-dependent pairs were listed and parsing attempted (with Tseytin's program) on the Ural 1. 650 words were processed in 10 hours, with most sentences getting 2 to 8 structures (some as many as 14, 35, 52, and 192). Rules to avoid incompatible dependents for a governing occurrence were written, and a classification of prepositional phrases by kind of weak government was made. A new trial was proposed.

5.2. Russian

1. ON THE RUSSIAN FREQUENCY DICTIONARY BASED ON MATERIAL FROM MATHEMATICS TEXTS
Z. M. Volotskaya, I. N. Shelimova, A. L. Shumilina, I. A. Mel'chuk, and T. N. Moloshnaya
In L. R. Zinder, ed., Voprosy Statistiki Rechi, Leningrad State University, Leningrad, 1958, pp. 93-99. Trans. in JPRS 6543, 12 January 1961, pp. 86-91.

Data on occurrence of inflections, syntagmas, etc., as well as of words, was wanted. Each syntagma in 60,000 words was written on a card; results for nouns in a third of the text are given. The authors were planning to extend their text to about a million words.

2. THE PROBLEM OF GOVERNMENT IN THE RUSSIAN LANGUAGE
S. Nurkhanov
Vestnik Akademii Nauk Kazakhskoj SSR, No. 2 (1960), pp. 85-91. Trans. in JPRS 6505, 5 January 1961, pp. 4-13.

In strong government, the case of the dependent (and choice of preposition, if any) depends on the identity of the governor. A strongly governed unit is identifiable even if remote from its governor; does not need extralinguistic clues for interpretation; is not associated with a whole sentence. Strongly governed units influence the meaning of their governors more heavily.

3. STUDIES IN MACHINE TRANSLATION--8: MANUAL FOR POSTEDITING RUSSIAN TEXT
H. P. Edmundson, K. E. Harper, D. G. Hays, and B. J. Scott
Mechanical Translation, vol. 6 (November 1961), pp. 63-71.

Instructions for (i) choice of English equivalents, (ii) marking of English inflections, insertions, etc., and (iii) indication of dependency structure, all relative to a specific worksheet format and coding scheme. Includes some semantic and morphological suggestions about dependency analysis.

4. TWO OPERATORS FOR PROCESSING WORD COMBINATIONS WITH "STRONG GOVERNMENT" (FOR AUTOMATIC SYNTACTIC ANALYSIS)
L. N. Iordanskaya
Dva Operatora Obrabotki Slovosocetanij s "Sil'nym Upravleniem" (Dlya Avtomaticheskogo Sintaksicheskogo Analiza), Predvaritel'nye Publikatsii, Division of Structural and Applied Linguistics, Linguistics Institute, Academy of Sciences, Moscow, 1961. Trans. in JPRS 12441, 13 February 1962.

The operators are programs to test whether one word (usually a verb) can govern another (usually a noun or prepositional phrase), and if so in what relation. Three object types are distinguished, and 129 "models" are listed. For example, prosit' can govern a first object of any of four kinds: accusative, genitive, o with prepositional, or infinitive; as second object, it can govern accusative (but not if first object is accusative or genitive) or u with genitive (but not if first object is an o-phrase). The models were established by reanalysis of Daum and Shenck's material.

5. TWO OPERATORS FOR DETERMINING AGREEMENT (FOR AUTOMATIC SYNTACTIC ANALYSIS)
I. A. Mel'chuk
Dva Operatora Ustanovleniya Sootvetstviya (Dlya Avtomaticheskogo Analiza), Predvaritel'nye Publikatsii, Division of Structural and Applied Linguistics, Linguistics Institute, Academy of Sciences, Moscow, 1961. Trans. by D. V. Mohr, RM-3190, The RAND Corporation, Santa Monica, California, June 1962.

These operators are computer programs (algorithms are given) for testing (i) grammatical agreement of a long-form adjective with a noun, and (ii) correspondence of the case of a substantive with the government requirement of a preposition, both in Russian. They are offered as models for the treatment of similar problems in any inflected language. They amount to complex table searches.

6. STRUCTURE OF THE ALGORITHM FOR GRAMMATICAL ANALYSIS (FOR MT FROM THE RUSSIAN LANGUAGE)
T. M. Nikolaeva
"Struktura Algoritma Grammaticheskogo Analiza (Pri MP s Russkogo Yazyka)," Mashinnyj Perevod i Prikladnaya Lingvistika, No. 5 (1961), pp. 27-44. Trans. in JPRS 13761, 16 May 1962, pp. 28-56.

A recognition routine identifies units of input text with units of (i) an output language, (ii) an output language grammar, (iii) an input language grammar, or (iv) a universal grammar. The present routine is type (iii). First a description of each single word is obtained, then contextual information is used if needed. The routine consists of many subroutines, each working on a grammatical category. Eventually grammatical connections are found and classified into eight types.

7. DESCRIPTION OF RUSSIAN SYNTAGMAS
E. V. Paducheva and A. L. Shumilina
"Opisanie Sintagm Russkogo Yazyka (V Svyazi s Postroeniem Algoritma Mashinnogo Perevoda)," Voprosy Yazykoznaniya, vol. 10, no. 4 (July-August 1961), pp. 105-115. Trans. in JPRS 10429, 11 October 1961.

A syntagma is a class of word combinations with common syntactic function. The paper lists syntagmas with subordinating functions, based on mathematics text. The concepts of dependency, function, and syntactic characteristic are examined. Agreement requirements for each function are to be given formal statement; simplification of these statements is discussed. When narrower requirements are imposed, each syntagma gives rise to several configurations.

8. SYNTAGMAS OF THE RUSSIAN LANGUAGE
E. V. Paducheva and A. L. Shumilina
"Sintagmy Russkogo Yazyka," in Lingvisticheskie Issledovaniya po Mashinnomu Perevodu, Reports of the Information Mechanization and Automation Department, No. 2, Izdatel'stvo VINITI, Moscow, 1961, pp. 89-113.
Trans. in JPRS 13173, 27 March 1962, pp. 120-150

This is almost the same paper as #7, but contains a list of syntactic indicators (morphological features, function words) and a list of words governing various kinds of dependents.

9. IDENTIFICATION OF CONFIGURATIONS IN THE RUSSIAN SENTENCE
G. S. Tsejtin and L. N. Zasorina
Doklady na Konferentsii po Obrabotke Informatsii, Mashinnomu Perevodu i Avtomaticheskomu Chteniyu Teksta, Moscow, 1961. Trans. in JPRS 10576, 19 October 1961, pp. 30-41.

A configuration is a combination of a governing word and its dependents. Active valence is the potential power of a word to combine with its dependents; passive valence is vice versa. A conjunction depends on the following word, which then governs coordinate elements. Relative pronouns, etc., have double passive valence. The parsing program assumes projectivity and gets one structure; the algorithm is presented. A machine test was planned.

10. SUGGESTIONS FOR MODIFICATION OF LECERF THEORY OF PROJECTIVITY AND OF HIS STEMMAS, FOR THE PURPOSE OF THEIR APPLICATION TO "NON-PROJECTIVE" RUSSIAN SENTENCES
Irina Lynch
Discussions sur l'Hypothèse de Projectivité, CETIS Report No. 35, Euratom, Ispra, October 1961.

Russian is not entirely projective; but failures are limited to single clauses. Some techniques for translation of non-projective sentences are suggested.

11. CONNECTABILITY CALCULATIONS, SYNTACTIC FUNCTIONS, AND RUSSIAN SYNTAX
David G. Hays
Mechanical Translation, vol. 8, no. 1 (August 1964), pp. 32-51.

Code matching is an alternative to table-lookup in tests of grammatical agreement. This plan requires elaborate descriptions of individual items (e.g., the words in a dictionary) but it avoids the use of large tables or complex routines for the tests. Development of the technique also leads to some clarification of the linguistic concepts of functions, exocentrism, and homography. A format for the description of Russian forms and a program for testing connectability by matching are described. Nine functions are recognized: Subjective; first, second, and third complementary; first, second, and third auxiliary; modifying; and predicative. These are the dominative functions; another program still had to be written for the coordinative functions: coordination, apposition, etc.

5.3. French

1. DEPENDENCY CONNECTIONS AND SEMANTIC CLASSIFICATIONS
J. Buydens-Ruvinschii
Liens de Dépendance Grammaticale et Classification Sémantique, CETIS Report No. 38, Euratom, Ispra, November 1961.

The strength of a dependency connection varies as governor, dependent, or both demand (vs. permit) the connection. Dependents are classified by semantic role, a pattern of roles being definitive of a class of governors. Some verb classes are listed for French, with examples.

2. COLLECTION OF STEMMAS
Emilie Scheffer
Recueil de stemmas, EUR 220.f, Presses Académiques Européennes, Brussels, 1963.

A collection of dependency diagrams for French sentences. A rule of order for the construction of connections is presented, and problems raised by interpolated phrases and by conjunctions are exemplified.

3. PUNCTUATION
Lydia Hirschberg
Les Ponctuations, Université Libre de Bruxelles, Brussels, 24 April 1963.

This paper, the text of a lecture delivered to the Seminar on Quantitative Linguistics, Université de Paris, covers most of the material in #4.

4. PUNCTUATION AND AUTOMATIC SYNTACTIC ANALYSIS
Lydia Hirschberg
Ponctuations et Analyse Syntaxique Automatique, EUR 1813.f, Presses Académiques Européennes, Brussels, 1964.

Punctuation marks differ in separatory strength. If $aS_1 \ldots S_n b$ is a string, a and b marks of punctuation, S_1 through S_n syntagmas not dependent on each other (and any marks between a and b have lower strength), then all of $S_1 \ldots S_n$ are members of a single syntagma, and none depend on a governor across the stronger mark unless some do across the weaker. A mark is used either for ellipsis or for change of word order; it has the syntactic value of the associated construction. For adjacent marks, strength and value vary inversely.

5. COORDINATED STRUCTURES IN THE MECHANICAL ANALYSIS OF FRENCH
Lydia Hirschberg
Abstract in program of the 1964 Annual Meeting, Association for Machine Translation and Computational Linguistics.

For our purpose it is useful to define coordinated structures (CS) so as to reduce the occurrence of non-tree structures to cases defined as well as possible. Our definition is more restrictive than the classical one as far as structures are concerned, and leads to a somewhat different choice of words considered as conjunctions of coordination (CC). We consider as CS sequences of common governors of the same dependent, sequences of dependents of similar structure attached to the same governor, or combinations of such configurations when they are in addition tagged by CCs and when they respect a set of laws which are necessary conditions of CS. We exclude sequences of syntagms which are syntactically independent even if they are separated by CCs.--Author

6. Discourse Analysis

1. POINTS COMMON TO AUTOMATIC TRANSLATION AND AUTOMATIC DOCUMENTATION
J. Iung
"Points communs entre les problèmes posés par la traduction automatique et la documentation automatique," in Enseignement préparatoire aux techniques de la documentation automatique, Euratom, Brussels, 1960, pp. 282-307.

This paper is an extended treatment of the CLRU and RAND methods of translation. Harper and Hays's example sentence is given in four languages, with structural diagrams showing the similarities among them. Grammatic structure and semantic structure are compared.

2. THE MANIPULATION OF TREES IN INFORMATION RETRIEVAL
Gerard Salton
Sec. II in Gerard Salton, ed., Information Storage and Retrieval, Scientific Report ISR-1, The Computation Laboratory of Harvard University, Cambridge, Massachusetts, 30 November 1961.

The tree organization of classification schemes such as the LC and UDC is expounded. Dependency structures for sentences are introduced, and alterations (separation of conjoint constructions, specification of antecedents, putting together of noun phrases) are described. Semantic identification of grammatic relations is discussed. Storage of trees in computer memory is shown with various schemes. Some computer programs needed in a retrieval system are presented.

3. A CLASS OF REFERENCE-PROVIDING INFORMATION RETREIVAL SYSTEMS
Arthur Anger
Section III in Gerard Salton, ed., Information Storage and Retrieval, Scientific Report ISR-1, The Computation Laboratory of Harvard University, Cambridge, Massachusetts, 30 November 1961.

Euratom's proposals for a retrieval system, using dependency grammar and a graph of concept nodes and semantic-relation links, is reviewed. The determination of relevance is considered.

4. CO-OCCURRENCE AND DEPENDENCY LOGIC FOR ANSWERING ENGLISH QUESTIONS
Robert F. Simmons, Sheldon Klein, and Keren McConlogue
SP-1155, System Development Corporation, Santa Monica, California, 3 April 1963.

The authors include as dependencies the relation of pronoun to antecedent and that between two occurrences of the same noun. Subject, copula, and complement are linked by two-way dependencies. Questions and putative answers from a file are put through dependency analysis; an answer is required to contain the same dependency links among content words as does the question, but dependency must be regarded as transitive in many instances.

5. SYNTACTIC DEPENDENCY AND THE DETERMINATION OF MEANING IN WRITTEN ENGLISH
Sheldon Klein
In H. P. Luhn, ed., Automation and Scientific Communication, American Documentation Institute, Washington, D.C., 1963, pp. 11-12.

The use of a transitive dependency model of English makes it possible under certain conditions to determine if the meaning of one text is included in the meaning of the other. The principles involved facilitate the design of both a question-answering system and an automatic paraphrasing system.--Author

6. SYNTACTIC DEPENDENCE AND THE COMPUTER GENERATION OF COHERENT DISCOURSE
Sheldon Klein and Robert F. Simmons
Mechanical Translation, vol. 7, no. 2 (August 1963), pp. 50-61.

Dependency as these authors define it is transitive except: not across verbs other than be, not across prepositions other than of, not across subordinating conjunctions. The sentence production routine expands leftmost elements in a phrase-structure tree, selecting lexical items as preterminals appear. Each lexical choice must satisfy dependency criteria from a previously selected list.

7. SOME PATTERNS OBSERVED IN THE CONTEXTUAL SPECIALIZATION OF WORD SENSES
John C. Olney
Information Storage and Retrieval, vol. 2, no. 2 (July 1964), pp. 79-101.

A criterion is developed for marking contextually dependent sentences, i.e., those which cannot be interpreted accurately in isolation. A procedure for expanding sentences to make them independent is described; this procedure retains the original syntactic dependency structure. The environments of words to which dependents must be added are studied for regularities to be used in computer programs for identification and reduction of contextual dependence.

8. DESCRIPTION OF A PLAN FOR ANALYSIS OF SCIENTIFIC TEXT
A. Leroy
Description d'un projet d'analyse de textes scientifiques, EUR 583.f, vols. I and II, Presses Académiques Européennes, Brussels, February 1964.

Translation of text into semantic graphs is described, beginning with the Cocke-Lecerf parser. Semantic agreement in new text is tested by searching the information file for identical, synonymous, or hierarchically related combinations. An example is discussed, step by step, in detail. Sec. II deals with identification of repeated referents in text, which is to be aided by tests of semantic agreement, and by search for conjunction and parallel constructions.

9. AUTOMATIC PARAPHRASING IN ESSAY FORMAT
Sheldon Klein
SP-1602, System Development Corporation, Santa Monica, California, 21 July 1964.

An operating program accepts as input an essay of up to 300 words in length, and yields as output an essay-type paraphrase that is a nonredundant summary of the content of the source text. The components of the system include a phrase structure and dependency parser, a routine for establishing dependency links across sentences, a program for generating coherent sentence paraphrases randomly with respect to order and repetition of source text subject matter, a control system for determining the logical sequence of the paraphrase sentences, and a routine for inserting pronouns.
--Author

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