A Short Annotated Bibliography of Research in Natural Language Generation

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These notes provide some pointers to further reading in a number of topic areas within natural language generation. The list is by no means exhaustive, but should provide sufficient leads to get you started.

Overview Material

Good general overviews of work in natural language generation can be found in McDonald [1987], McKeown and Swartout [1988], and Kempen [1989]. Mann *et al* [1982] provide an interesting snapshot of the field at one point in time, although with no technical detail. For recent views of what distinguishes NLG from NLP more generally, see [Mann 1987a; Joshi 1987c].

Seminal Systems

The most well known NLG systems have typically been constructed as parts of PhD theses. In many cases, the thesis has subsequently been published as a book, or is described more briefly at a higher level in a more accessible publication.

Davey's PROTEUS is described in Davey [1972], subsequently published as Davey [1978]. Some aspects of the program are highlighted in Davey and Longuet-Higgins [1978].

McDonald's MUMBLE is described in McDonald [1980a]. The general approach to generation taken in this system is also described in McDonald [1981a, 1983a, 1983b]. The lasting influence of McDonald's program is demonstrated in McDonald and Meteer [1988]: this describes a number of generation systems which incorporate MUMBLE. Metee's SPOKESMAN system [Meteer 1989] is a text planning system which uses MUMBLE as a tactical component.

Appelt's KAMP is described in Appelt [1982], subsequently published as Appelt [1985a] (although, unlike the former, the latter incorporates Appelt's work on TELEGRAM). An early summary of Appelt's approach appears as [Appelt 1980].

McKeown's TEXT is described in McKeown [1982b], subsequently published as McKeown [1985]; an overview of her system is provided in [McKeown 1982a].

What To Say versus How To Say It

The distinction between *what to say* and *how to say it* in the context of language generation is generally attributed to Thompson [1977]. Appelt's criticism of it (in Appelt [1982, 1985a]) makes use of Reddy's [1979] discussion of the *conduit metaphor*; Danlos [1984, 1987a, 1987b] and Hovy [1985] also argue against the distinction. A more recent approach to the problem can be found in Meteer [1990].

Tactical Generation

The earliest published work on the use of ATNs for generation is that of Simmons and Slocum [1972]; see also [Slocum 1975, 1978]. More advanced work in this area was carried out by Shapiro [1975, 1979, 1982].

Systemic grammar [Halliday 1973, 1976, 1985; Berry 1975, 1977; Kress 1976] was first used in a generation framework by Davey [1978]. The most sophisticated and well-known implementation of a systemic grammar is NIGEL, developed at ISI: see [Matthiessen 1981, 1984, 1987; Mann 1983a; Matthiessen 1984]. This has been used as a linguistic component for the PENMAN text generation system [Mann 1983b]. The mechanism used to make choices within the grammar is called *inquiry semantics*: see [Mann 1983c].

Functional unification grammar was introduced by Kay [1979, 1984]. Its first reported use in a natural language generation system was in the context of McKeown's TEXT [Bossie 1982], although its most well known instantiation is Appelt's TELEGRAM [Appelt 1983a, 1983b, 1983c]. Ritchie [1986] discusses the computational comnplexity of functional unification grammar. A number of researchers have begun to bring together work in unification grammar and work in systemic grammar: see Matthiesson and Kasper [1987] and Mellish [1988a]. Other recent work on functional unification grammar includes [McKeown and Paris 1987]. Patten [1988a] presents an approach that conflates planning and systemic choice; the same work has led to the beginnings of a formal model of systemic grammar [Patten and Ritchie 1987]. Patten [1988b] and Patten and Stoops [1990] have gone on to explore the possibilities for compiling the interface between the text planning process and the realization process in this approach.

The relevance of the tree-adjoining grammar (TAG) formalism [Joshi 1983, 1986; Joshi and Zwicky 1983; Joshi and Vijay-Shankar 1985] to natural language generation was noted by its originator [Joshi 1987b], and the formalism has since been used by McDonald and Pustejovsky [1985b] for generation work; see also Huettner, Vaughan, and McDonald [1987]. Joshi [1987a] shows how TAG can handle word-order variation in the context of generation. McCoy *et al.* [1990] describe an experiment in integrating systemic grammar and tree-adjoining grammar.

Other linguistic theories have been used in generation. For work using generalized phrase structure grammar [Gazdar *et al* 1985], see [Busemann 1987; Busemann and Hauenschild 1988]; for work in lexical functional grammar [Kaplan and Bresnan 1982], see [Block 1986, 1987; Wedekind 1988]; for work in unification categorial grammar [Zeevat *et al* 1987; Calder *et al* 1988], see [Calder *et al* 1989].

A strand of work which is relatively unknown outside of Continental Europe looks at generation in the context of Simon Dik's Functional Grammar [Dik 1978, 1980]; see [Dik 1987].

For recent work in bidirectionality (i.e., the use of the same grammar for both generation and parsing), see Appelt [1987a], Jacobs [1988]. Block [1987] suggests some problems in this area. For a more radical approach, see [Shieber 1988a, 1988b].

NLG as Psycholinguistic Modelling

Work in psycholinguistics can offer suggestions about the nature of the human language generation process; these can be used as a basis for psychological models of language generation, but are also useful as a source of ideas for models which are not intended to be psychologically real.

See the work of Bernardo [1977] on the cognitive relevance of the sentence, and Taylor [1969], Butterworth [1975], MacNeilage [1973], Danks [1977], and Lindsley [1975, 1976] on the size of planning units in language production. Work on speech errors can give important clues to how human language generation works: see Fromkin [1973, 1988], Garrett and Kean [1981], Harley [1984, 1987], van Wijk and Kempen [1987].

Kempen and Hoenkamp's original work in *incremental procedural grammar*, a psycholinguistic model, is reported in [Kempen and Hoenkamp 1982, 1987]; more recently, this has led to an approach called *segment grammar* [Kempen 1987; De Smedt and Kempen 1987, 1988; De Smedt 1990].

McDonald's claims for the psycholinguistic reality of his model are described in McDonald [1980b].

Speech Acts

A great deal of work in natural language generation is founded, either implicitly or explicitly, on speech act theory (see, for example, Austin [1962] and Searle [1969]). Within computational linguistics, work in this area was first suggested by Bruce [1975a] and further developed by Allen, Perrault, Cohen and Levesque [Cohen 1978; Perrault and Allen 1978; Allen and Perrault 1978; Cohen and Perrault 1979; Perrault and Allen 1980; Cohen and Levesque 1980; Cohen 1981; Allen 1983]. Some of the more recent work on speech acts has looked closely at reference [Cohen 1981, 1984a, 1984b]. Appelt's original work [Appelt 1982, 1985] has led him onto other aspects of reasoning about speech acts [Appelt and Konolige 1988].

Much of the above work takes the view that deciding what to say is essentially a kind of planning in the AI sense. For discussion of this view, see Hobbs [1980]; Jacobs [1988] provides a dissenting view. Hovy [1985, 1988a] discusses planning in the context of generation.

Discourse Generation

Some early work in the generation of discourse is described in [Mann and Moore 1979, 1982]; see also [Weiner 1980].

McKeown's use of discourse strategies is detailed in [McKeown 1982b, 1985]. In [McKeown 1983c], she addresses the use of recursion in generating using discourse strategies. McKeown's

approach has been adopted and extended in other work: see [Paris 1985; Paris and McKeown 1987]. McKeown's original work on using focus [McKeown 1983a] to guide discourse generation is extended in [Derr and McKeown 1984]. McKeown [1979, 1983b] has explored the use of information structure in deciding how to paraphrase a question.

Mann [1981, 1982] compares two approaches to discourse generation; see also his PENMAN system [Mann 1983b]. Mann's Rhetorical Structure Theory is described in a number of papers and technical reports [Mann and Thompson 1983, 1986, 1987a, 1987b; Mann 1984, 1987b].

Mellish [1988b] and Dale [1988a, 1988b] discuss the generation of natural language texts from plans.

Of course, different researchers have chosen different subject matters for the texts they generate. On the generation living space descriptions, see [Sibun, Huettner and McDonald 1988]. For work that describes street scenes, see [Novak 1986, 1987a, 1987b]. For the generation of stock market reports, see [Kukich 1983].

Houghton [Houghton 1986; Houghton and Isard 1987] describes a dialogue system based on dialogue games, which has its roots in earlier work by Power [1974, 1979].

Some work has looked at creating polished prose: see, for example, McDonald and Pustejovsky [1985a]. Kukich's work [Kukich 1983, 1988] looks at report generation. The problem of revising a piece of generated text is discussed in [Vaughan and McDonald 1986; Meteer 1988]; see also Gabriel [1988].

Sibun [1990] considers the generation of text that does not appear to have the kind of structuring suggested by approaches such as RST; Mooney *et al.* [1990] suggest a more elaborate model for higher levels of structure in text. Rambow [1990] introduces the notion of domain communication knowledge as a distinct knowledge source in generating text.

Generating Referring Expressions and Object Descriptions

For an overview of various aspects of reference from a linguistic point of view, see Lyons [1977]. For particular theories, see Frege [1982], Russell [1902, 1919], Ogden and Richards [1949], Strawson [1950], Quine [1960], Davidson [1967], and Searle [1969, 1976]. On the referential/attributive distinction, see Donnellan [1966], Charniak [1976] and Kronfeld [1986].

On the use of discourse models to provide a source of referents in natural language processing, see Sidner [1979], Karttunen [1976], Johnson-Laird and Garnham [1980], Webber [1983, 1988].

For various approaches within the linguistics literature to pronominalization, see Lasnik [1976], Kantor [1977], Partee [1978], Bosch [1983], and Reinhart [1976, 1981, 1983]. In computational linguistics, pronominalization tends to be discussed in terms of a notion of *focus*: the most well-known work in this area is that of Sidner [1979, 1981] and Webber [1979]; Carter [1987] describes a recent extension of Sidner's work, and Grosz, Joshi and Weinstein [1983] describe an alternative that relies on a notion of *centering*. Busemann [1984] and Pignatoro [1988] discuss a computational approach to topic and focus in the context of language generation; McKeown [1983a] and McCoy and Cheng [1988] discuss how focus can be used to constrain what a generation system talks about.

See Hirst [1981b] for an excellent survey of the range of different types of anaphoric expressions; this is summarised in Hirst [1981a]. Other interesting and useful surveys of anaphora can be found in Halliday and Hasan [1976], Webber [1979, Chapter 2] and Carter [1987, Chapter 2].

For theories of definiteness and indefiniteness, see [Searle 1969; Donnellan 1977; Hawkins 1978; Clark and Marshall 1981; Prince 1981; Heim 1982, 1983; Lewis 1983]. Kramsky [1972] provides a wonderful cross-linguistic study of definiteness.

Appelt's earlier work on various aspects of planning noun phrase referring expressions [Appelt 1983b, 1985b, 1985c] has been carried further in collaboration with Kronfeld [Appelt and Kronfeld 1987, 1988; Appelt 1987b]. This is based on Kronfeld's own work on reference [Kronfeld 1985, 1986, 1988a, 1988b, 1988c, 1988d], much of which addresses the referential/attributive distinction.

McDonald's approach to subsequent reference is summarised in McDonald [1978]. See [Dale 1988b, 1989] for more recent work in this area. Both Dale [1988b, 1989] and Novak [1987a, 1987b] consider the problems of generating referring expressions in dynamically changing environments. Reiter [1990b] considers the problems of undesirable conversational implicatures in building object descriptions. Gundel, Hedberg and Zacharski [1988] discuss the generation of demonstrative expressions.

Ortony [1978] points out some psycholinguistic constraints that apply to the generation of referring expressions; other psycholinguistic findings of relevance can be found in Schriefers and Pechmann [1987].

Much recent work on discourse structure makes claims about the effects of a discourse's structure on the forms of reference that can be used: in particular, see [Grosz 1977; Grosz and Sidner 1985, 1986; Fox 1984, 1987]. Dale [1988a] observes some problems with these claims. Many other researchers have suggested ways of partitioning the space of possible referents: see [Reichman 1978, 1981, 1985; Linde 1979; Grimes 1982; Polanyi and Scha 1984; Polanyi 1985, 1986]. Other related work outside of computational linguistics includes [Karttunen 1976; Kamp 1981; Fauconnier 1985]; these approaches are broadly compatible in that they view structural concerns as important in restricting the context of interpretation of referring expressions. For a more psychological perspective, see Sanford and Garrod [1981], Reichgelt [1986] and Chafe [1977, 1979].

On the integration of natural language generation and non-linguistic modes of reference, see [Kobsa *et al* 1986; Reithinger 1987; Schmauks and Reithinger 1988].

Knowledge Representation for Language Generation

This has become an increasingly important theme in NLG work. Early work by Chester [1976] was concerned with the generation of surface sentences from input logical forms. McDonald [1980a] deliberately constructed his generator in such a way that it could be ported to different underlying knowledge representation formalisms. More recent work has focussed on the question directly: see [McCoy 1982].

Much of the interest in this area comes is derived from the need to have expert systems explain

themselves adequately. Considerable work has been carried out in this area at the University of Southern California's Information Sciences Institute: see [Swartout 1983a, 1983b; McKeown and Swartout 1988; Paris 1988; Moore and Swartout 1989]. See also Cawsey [1988, 1989]. Suthers [1989] provides a survey of material in this area.

Some early work in natural language generation used Schank's Conceptual Dependency networks [Schank 1972] as an input representation; in particular, see [Schank *et al.* 1973; Goldman 1975]. Related work, using input representations which have their origins in Schank's work, continues: see Adorni [1987] and Ishizaki [1988]. Boyer and Lapalme [1985] describe work in the generation of sentences from semantic networks.

Knowledge representations used by back-end systems may not provide what a generation front-end requires; see McCoy [1982] and Sondheimer and Nebel [1986] for approaches to this problem.

The Lexicon and Lexical Choice

Some early work by Goldman [1974, 1975] looked at the problem of choosing between different words. Interest in this area then lay dormant for a while, but has grown again in recent years. One approach to the issue of connecting a generator's lexical knowledge to the underlying system is addressed in McDonald [1981b]. Cumming [1986] surveys the lexica used in a number of generation systems. For recent work on lexical selection, see [Pustejovsky and Nirenburg 1987; Marcus 1987; Nirenburg and Nirenburg 1988; Matthiessen 1988, Reiter 1990a]. Ward [1988] describes a connectionist approach; Hovy [1988b] describes the use of a phrasal lexicon [Becker 1975] in generation.

Taking the User into Account

Another recent research topic has been the use of hearer modelling in generation. The problem of what to include and what to omit in a generated text is addressed in Conklin and McDonald [1982] and in Cook, Lehnert, and McDonald [1984]; see also [Fornell 1984]. One approach has been to anticipate the hearer's understanding of a generated response to see if it is successful: see [Busemann 1984, Jameson and Wahlster 1982, Jameson 1983].

The distinction between user models and discourse models has been discussed by Finin and Kass [1987].

Hovy's work [Hovy 1987] looks at pragmatic aspects of generation, and in particular, how a system might produce different outputs depending upon who the hearer is. McCoy's work [McCoy 1984, 1985, 1986, 1987] focuses on correcting users' misconceptions concerning the objects modelled by a computer system. See also [Paris 1985].

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