Generative models for parallel processes*

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A brief introduction to four areas of theoretical research in computer science and bibliographies for these areas are presented. A common factor in each of these areas is one of parallelism and the study of its effects.

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1. Introduction

The notion of a parallel process has become, in recent years, one of the central notions in computer science. The reasons for this interest are two-fold. Firstly, in computer technology (both hardware and software) there has been an increasing trend towards finding 'parallel' solutions to implementation problems. Secondly, since theoretical computer science mirrors the 'real world' it has reflected this interest by investigating models of parallel processes. It is instructive to notice that the same basic notion of a parallel process enters the field of theoretical computer science from distinct motivational backgrounds. Thus, for example, there are areas of theoretical computer science, stimulated by biology, linguistics, picture processing, etc. interested in grasping the notion of parallel processes.

Because of a joint interest in generative models (or rewriting systems) for parallel processes, the authors decided to hold a workshop in this specific area. The aim of the workshop was:

1. To survey this relatively new area in formal language theory, and
2. To present current research work.

The present paper is an outgrowth of this workshop. Its purpose is:

1. To briefly introduce the research areas represented at the workshop, and
2. To provide a bibliography of these areas.

We hope that this will provide an impetus for readers outside these areas to enter one of them and also help them to do so by means of the bibliographies. In the following section each area is briefly introduced. Further each talk in the area is mentioned and it is accompanied by bibliographic references which lead the uninitiated reader into the specific topic.

2. Developmental systems

Developmental systems were introduced for the description of the development of filamental organisms, i.e. essentially one-dimensional sequences of cells. It is well known that a living cell can be considered as a finite automaton, hence the development of multi-cellular organisms can be described by growing arrays of finite automata. Each configuration of such an array is a momentary description of the organism, while the whole life of the organism is described by a sequence of such configurations. When only one-dimensional arrays of finite automata are considered (corresponding to filamental organisms), the formalism and end results of formal language theory are applicable.

A typical developmental system has the following components:

(*a*) a finite set of symbols, the alphabet,
(*b*) a starting string (or a set of them), the axiom, and
(*c*) a finite set of productions which give the strings by which a symbol may be replaced.

In every step of a derivation all symbols in a string must be simultaneously replaced according to the productions. The set of productions that may be applied to a certain symbol may be dependent on the context of the symbol and/or on the choice of productions that are being applied to other symbols in the string at the present time or at previous times. Note that a basic difference between developmental systems and the traditional Von Neumann type cellular automaton lies in the fact that growth and shrinkage can take place at any point in the array, not only at the ends.

From the biological point of view development systems have provided a useful theoretical framework within which the nature of cellular behaviour in development can be discussed, computed and compared. Their study has also provided a number of biologically interesting results.

From the formal language theory point of view developmental systems have provided an alternative to the, now, standard Chomsky framework for defining languages. As a result of this different approach, the families of languages which are defined by developmental systems are rather different from the more traditional families that have been studied. The novelty of this approach is also reflected by the fact that most standard techniques of formal language theory were found unapplicable to developmental systems and a set of new techniques had to be devised. The introductory papers for this area are: Lindenmayer (1968a, 1968b) and Lindenmayer and Rozenberg (1972).

The following talks were given in this area:

1. G. Rozenberg and K. P. Lee, 'Towards a mathematical theory of developmental systems' (Rozenberg and Doucet, 1971; Rozenberg, 1972b; Rozenberg, 1972c).
2. G. Herman, 'Some biological motivation, justification and feedback of developmental system theory' (Lindenmayer, 1968a, b; Herman 1972; Baker and Herman, 1972).
3. A Salomaa, 'Growth functions of developmental systems' (Paz and Salomaa, 1972; Salomaa 1973a; Szilard, 1972).
4. K. Culik II and J. Opatrny, 'Macro OL systems' (Culik, 1973; Culik and Opatrny, 1973).
5. A. Walker, 'A theorem about adult OL languages' (Herman and Walker, 1973).
6. A. Lindenmayer, 'The biological motivation for developmental system theory' (Lindenmayer, 1968a, b, 1971a).

3. Adjunct and tree-adjunct languages

In natural language the constituents of sentences are formed in two distinct ways:

(*a*) endocentric—there is a part of the constituent which is

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clearly the head; the rest of the constituent is built up around this head,

e.g. in 'new books from the library', 'books' is the head, and

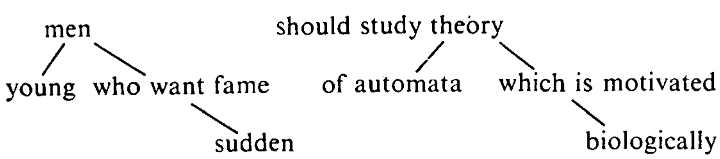
(*b*) exocentric—no part of the constituent can be said to be a head,

e.g. in 'who will represent us', it is unclear which part is the head.

In the following all remarks refer to endocentric constituents.

The traditional approach to the syntactic description of natural language is by the use of phrase structure grammars. However there are difficulties with this approach, for example, (i) it is difficult to characterise the head (or centre) of a constituent in a phrase structure grammar, (ii) the unlimited hierarchical structure that can be introduced in a phrase structure grammar often leads to awkward structural descriptions, and (iii) the relational and categorical aspects are both subsumed under the 'rewriting rule' and this makes statements concerning the relational aspects (and therefore the verification of particular restrictions) unnecessarily complex in a phrase structure grammar. These comments motivate the consideration of a new class of grammars, the string adjunct grammars. The concept of an adjunct can be seen by example:

'young men who want sudden fame should study theory of automata which is biologically motivated' can be broken down as follows:



The centre or kernel sentence is, 'men should study theory', and examples of adjuncts are: 'young' is a left adjunct of 'men', 'sudden' is right adjunct of 'want' in 'who want fame', which is itself a right adjunct of 'men' in the kernel sentence.

The basic references for this area are Joshi, Kosaraju and Yamada (1972a, 1972b).

The following talks were given:

1. A. K. Joshi, 'Adjunct languages' (Joshi, Kosaraju and Yamada, 1972a, b; Hart, 1972).

2. L. S. Levy, 'Tree adjunct languages' (Levy, 1971; Levy, 1973; Joshi, Levy and Takahashi, 1972).

4. Array and web grammars

One obvious approach to picture description and generation is to find a picture's basic constituents and the way they are connected. Thus, a large variety of generative formalisms (essentially generalising the one-dimensional phrase structure grammar approach to the description of strings to two-dimensions) can be found in the area. Since a picture does not ordinarily have a natural description as a string of sub-pictures, phrase structure grammars as such are not a natural tool for picture generation or analysis. In general, a (discrete, e.g. digital) picture is an array of elements having given colours or gray levels. A grammar for a language whose 'sentences' are such pictures would have to have rules which rewrite arrays as arrays. Such rewriting for the whole picture can basically be done in a sequential or parallel fashion. The most efficient approach is some mixture of these two ways of rewriting. This represents a well-known compromise in picture processing between purely sequential methods which are too slow for large arrays and purely parallel methods which require too much hardware for large arrays.

It is clear that the underlying structural unit of a picture is not restricted to being an array. In fact, often it is a labelled graph (or a web) which is the basic building block (Rosenfeld, 1970; Milgram and Rosenfeld, 1970; Pfaltz, 1972).

The following talk was presented:

1. A. Rosenfeld, 'Array and web grammars—picture-processing motivated automata theory' (Rosenfeld, 1973; Rosenfeld and Milgram, 1972a).

5. Restricted parallel languages

In the development of a filamental organism the 'amount' of parallelism that can occur at any time in the developmental process is unbounded. Contrariwise in a multi-processor environment the 'amount' of parallelism is strictly bounded by the number of processors available. Just as developmental systems have been introduced to study the effects of the addition of unbounded parallelism in rewriting systems, so n-parallel grammars have been introduced to study the effects of the addition of restricted parallelism in rewriting systems. This area is related to an earlier and more general investigation by Ibarra. However, n-parallel grammars retain the essence of parallelism while removing the structural constraints inherent in the simple matrix grammars of Ibarra. (Ibarra, 1970; Rosebrugh and Wood, 1972c; Wood 1973a).

One talk was given in this area:

1. D. Wood, 'n-parallel finite state generators' (Wood, 1973a, b).

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Book review

Documentation Manual, by J. van Duyn, 1972; 158 pages. (*Auerbach*, £2·00.)

The title of this book describes its content exactly. The author presents a proposed set of documentation standards and gives examples of their use. The material is presented as a documentation manual split into six sections, each section containing the proposed standards for that section of the manual with a specimen chapter from an actual documentation manual. The sections are: General Systems; File and Input/Output Specifications; Programming Specifications; Clerical Procedures; Audit Control Description; Operator's Instructions.

The examples used are from live systems but unfortunately each section considers a different system so one does not get a total picture of how the standards would operate in practice. This fact also decreases the book's value as a case study for teachers.

Despite what is said in the introduction the standards are heavily biased to batch-oriented data processing applications and the user contemplating a real time system will find little here to help him; this bias is particularly noticeable in the section on audit controls. The whole book is permeated with a feeling of DOS and OS/MVT.

The layout adopted makes for easy access to information, as indeed this modular approach to documentation should, unfortunately the examples do not always match the proposed standards with sections missing without comment and the indexing scheme going awry in places (notably Section 2). As to the proposed standards my major arguments are with: a lack of any points being made on security aspects, a much too computer oriented general user section, a lack of cross referencing to interacting systems (for maintenance ease), programming style and the use of comments are given only a passing mention with the only program listing presented (albeit a short COBOL program) having not a single NOTE, and the general feeling of mid 1960's data processing one gets when considering these standards.

The manager installing documentation standards could well look at this book as it contains much useful detail but I would suggest a better base on which to construct standards would be the NCC Systems Documentation and Programming Standards (Documentation) Manuals.

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