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Editorial Note

Regrettably this is the last issue of *Questiones Informatica* to appear in its current format. There are a number of reasons for terminating the production of *QI* in printed form. Firstly, the cost of publication has tripled over the last couple of years. Secondly, the interest in the journal has dwindled to the point where one may question the need for a South Arican publication on the more academic aspects of computing: the readership has not expanded but, more seriously, despite many appeals no contributions are submitted. At present I have only one paper in the pipeline. It appears that the only supply of papers comes from the two-yearly Computer Science Symposium, and this is not sufficient to justify the expense of publishing *QI* in its present form.

Nevertheless, both the Computer Society and the Institute of Computer Scientists feel that a vehicle for publishing the results of research in the field of information technology is required for this country. We propose to continue *QI* in a format similar to that used by *Questions Informatica.* In other words we shall use a photo-reproduction process and a printed cover to continue the publication of *QI*, but at greatly reduced costs. This puts the onus of delivering reproducible copy of the authors, but relieves the printers from the problems experienced with unusual symbols, diagrams, computer printouts, etc.

The journal will continue to accept only papers which have been referred. In fact, we shall try to satisfy all the requirements for being regarded as a publication acceptable under the rules for obtaining university subsidies. It is also intended to guarantee quick publication, say not more than three months after acceptance of a paper. However, the journal can only continue to exist if it receives enough contributions of sufficiently high standard.

Again, I would like to appeal to all engaged in research and development in computer related areas, to consider publishing your results in *QI.*

Finally, it is my pleasure to thank Dick White, of Thomson Publications, for all he has done to produce this journal in its current form.

G WIECHERS,
Editor

On a Generalisation of Cayley Diagrams

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Abstract

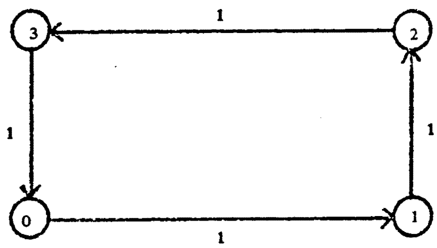
A technique for partially representing binary group operations by sets of binary relations was devised by Cayley. This technique can be generalised to permit the representation of arbitrary sets of n-ary relations ($n \geq 2$) by sets of binary relations without loss of information. Such binary representations have associated diagrams. A simple practical application is partially described.

1. Cayley diagrams

By a binary system we understand a pair $\langle A, R \rangle$ where R is some (usually finite) set of binary relations on A. Every binary system can be displayed diagrammatically by plotting members of the underlying set as vertices and inserting an arrow from a to b iff $\langle a,b \rangle$ belongs to a member of R. Binary systems in which R is a singleton correspond to digraphs or graphs according as the relation is irreflexive, or irreflexive and symmetric, respectively.

The Cayley diagram of a group (see [1] and [2] for a survey of applications) is the diagram of a digraph $\langle A, \{R\} \rangle$ where A is the underlying set of the group and $R \leq A \times A$ is obtained from the group operation in the fashion exemplified below.

Consider the cyclic group of integers modulo 4. Its Cayley diagram is



where each arrow represents addition by the generating element 1. The group operation may be viewed as a ternary relation, where we write $\langle x,y,z \rangle$ if $x + y = z$. The triples

$\langle 0,1,1 \rangle$ $\langle 1,1,2 \rangle$ $\langle 2,1,3 \rangle$ $\langle 3,1,0 \rangle$

have been displayed via a binary relation R consisting of the pairs

$\langle 0,1 \rangle$ $\langle 1,2 \rangle$ $\langle 2,3 \rangle$ $\langle 3,0 \rangle$.

No information is lost because the generator is used to label the arrows.

It is possible to display the entire operation using the general principle that there is a bijection between n-ary relations $R \leq A^n$ ($n \geq 2$) and functions $F : A^{n-2} \to P(A \times A)$, where P denotes powerset. Given $R \leq A^n$ one simply defines the corresponding F by, for each $f \in A^{n-2}$, $F(f) = \{\langle x,y \rangle \mid \langle x,f(0),f(1),\ldots,f(n-3),y \rangle \in R\}$. Conversely, it is clear how R may be recovered from F.

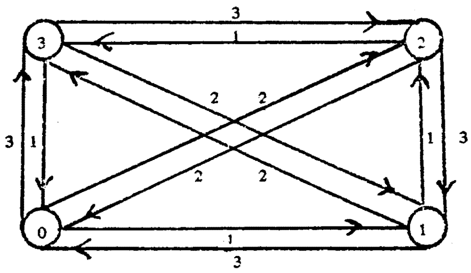
2. Nebulas

By a nebula we understand a pair $N = \langle A,F \rangle$ where A is a set and F is a function which correlates with every element i of its domain a function $F(i) : A^{n_i-2} \to P(A \times A)$ for some corresponding $n_i \geq 2$.

Nebulas can, like binary systems, be displayed by plotting members of the underlying set as vertices, while arrows and labels are inserted in accordance with the convention that if for some $i \in \text{dom } F$ and some $j \in \text{dom } F(i)$, $\langle x,y \rangle \in F(i)(j)$ then an arrow is inserted from x to y and labelled with i;j. All relevant labels may be attached to a single arrow from x to y in order to avoid the occurrence of multiple arrows. Nebula diagrams were introduced and combinatoric aspects investigated in [3]. More recently explication, development and computer implementation of basic nebula theoretic modelling techniques, with applications in the field of education, have been presented in [4], [5] and [6].

Examples:

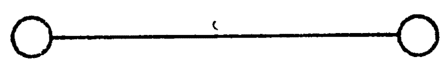
2.1 Z modulo 4 gives rise to a nebula $\langle A,F \rangle$ with $A = \{0,1,2,3\}$, dom $F = \{0\}$ and $F(0) : A \to P(A \times A)$ defined by $F(0)(y) = \{\langle x,z \rangle \mid x + y = z\}$ for each $y \in A$.
The corresponding diagram may be viewed as a completion of the Cayley diagram:



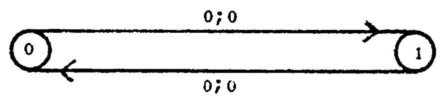
Since dom F is a singleton, it suffices to write y instead of i;y.

2.2 Associated with a lattice $\langle A,\wedge,\vee \rangle$ there is a nebula $\langle A,F \rangle$ where dom $F = \{0,1\}$, $F(0) : A \to P(A \times A)$ is defined by $F(0)(y) = \{\langle x,z \rangle \mid x \wedge y = z\}$ and $F(1) : A \to P(A \times A)$ is defined by $F(1)(y) = \{\langle x,z \rangle \mid x \vee y = z\}$.

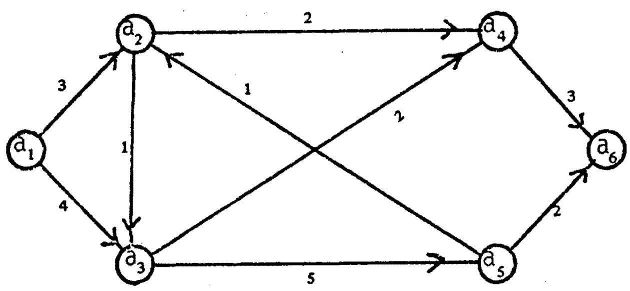
2.3 A graph $\langle V,E \rangle$ suggests a nebula $\langle A,F \rangle$ with $A = V$, dom $F = \{0\}$, and $F(0) : A^0 \to P(A \times A)$ defined by $F(0)(0) = \{\langle x,z \rangle \mid x \text{ and } z \text{ are adjacent}\}$.
For instance, the graph with diagram



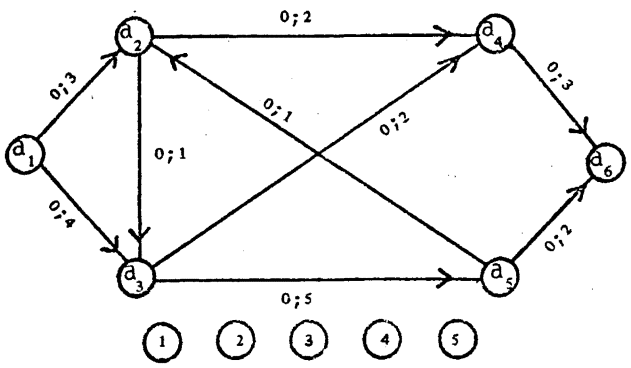
corresponds to a nebula $\langle A,F \rangle$ having $A = \{0,1\}$, $F(0)(0) = \{\langle 0,1 \rangle, \langle 1,0 \rangle\}$ and diagram



2.4 Consider a weighted digraph $\langle V,E,w\rangle$ with vertex set $V = \{a_1,\ldots,a_6\}$, edge set $E = \{\langle a_1,a_2\rangle, \langle a_1,a_3\rangle, \langle a_2,a_3\rangle, \langle a_2,a_4\rangle, \langle a_3,a_4\rangle, \langle a_3,a_5\rangle, \langle a_4,a_6\rangle, \langle a_5,a_2\rangle, \langle a_5,a_6\rangle\}$, weighting function $w : E \to \{1,\ldots,5\}$, and diagram



The corresponding nebula $\langle A,F\rangle$ has $A = V \cup \operatorname{ran} w$, $\operatorname{dom} F = \{0\}$, and $F(0) : A \to P(A \times A)$ is defined by
$F(0)(y) = \{\langle x,z\rangle \mid w(\langle x,z\rangle) = y\}$ for $y \in \operatorname{ran} w$
$\varnothing$ otherwise.
The nebula diagram is



which differs from the diagram of the digraph only in the five extra (isolated) vertices which represent the weights.

3. An application

Consider the problem of student advice in connection with registration for a university degree. Assume that a degree consists of course units selected from topics a, b, c and d. Assume further that only two forms of restriction need be applied in order to ensure adequate control of curricula, namely prerequisite and parallel conditions. By a prerequisite condition for a course unit x we mean a list of course units each of which must be completed before x can be read. By a parallel condition for x we mean a list of course units which are not prerequisites for x but which must be completed as a necessary part of any degree in which x is read. Given course units may have several alternative registration conditions. The table gives a coded version of these conditions taken from part of an actual situation, where a_0 is a dummy course unit representing an entrance qualification for topic a.

Course unit	prerequisite	parallel
a_1	a_0	
a_2	a_0	a_1,c_0,c_1
a_3	a_0	a_1,a_2
a_4	a_3	
a_5	a_0	
a_6	a_0,c_1	a_5,c_2 or a_5,b_o or a_5,d_1 or d_0,c_2 or d_0,b_0 or d_0,d_1
a_7	a_0,c_1	
a_8	a_6	c_2 or b_1 or b_2
a_9	a_7	a_8,c_3 or a_8,b_1 or a_8,d_2 or c_3
a_{10}	a_4	c_3 or b_1
	a_3,d_0	c_3' or b_1
a_{11}	a_2	
a_{12}	a_4,a_5,a_6	c_3 or b_1 or d_2
a_{13}	a_4,a_5,a_6	a_{12},c_3 or a_{12},b_1 or a_{12},d_2

The prerequisite and parallel relationships can be represented by n-tuples of the form $\langle a_i,x_0,\ldots,x_k, y_0,\ldots,y_m,a_j\rangle$ where $a_i,x_0,\ldots,x_k$ is a list of prerequisites for a_j and $y_o,\ldots,y_m$ is a list of parallels for a_j.

The relevant nebula is $\langle A,F\rangle$ where $A = \{a_0,\ldots,a_{13},b_0,\ldots,b_2,c_0,\ldots,c_3,d_o,\ldots,d_2\}$, $\operatorname{dom} F = \{\langle 0,0\rangle, \langle 0,1\rangle, \langle 0,2\rangle, \langle 0,3\rangle, \langle 1,0\rangle, \langle 1,1\rangle, \langle 1,2\rangle, \langle 2,1\rangle, \langle 2,2\rangle\}$, and $F(i)$ is defined below. Note that dom F has been selected so as to show the number of prerequisites and parallels, respectively, which remain after the outer co-ordinates of an n-tuple $\langle a_i,x_0,\ldots,x_k,y_0,\ldots,y_m,a_j\rangle$ are suppressed.

Let $F(\langle 0,0\rangle) = F_{00} : A^0 \to P(A \times A)$ be defined by
$F_{00}(0) = \{\langle a_0,a_1\rangle, \langle a_3,a_4\rangle, \langle a_0,a_5\rangle, \langle a_2,a_{11}\rangle\}$
where we write F_{xy} for $F(\langle x,y\rangle)$.

$F_{01} : A \to P(A \times A)$ is defined by
$F_{01}(x) = \{\langle a_6,a_8\rangle\}$ if $x = c_2$
$= \{\langle a_6,a_8\rangle, \langle a_4,a_{10}\rangle\}$ if $x = b_1$
$= \{\langle a_6,a_8\rangle\}$ if $x = b_2$
$= \{\langle a_7,a_9\rangle, \langle a_4,a_{10}\rangle\}$ if $x = c_3$
$= \varnothing$ otherwise

$F_{02} : A^2 \to P(A \times A)$ is defined by
$F_{02}(\langle x_1,x_2\rangle) = \{\langle a_0,a_3\rangle\}$ if $\langle x_1,x_2\rangle = \langle a_1,a_2\rangle$
$= \{\langle a_7,a_9\rangle\}$ if $\langle x_1,x_2\rangle = \langle a_8,c_3\rangle$
$= \{\langle a_7,a_9\rangle\{$ if $\langle x_1,x_2\rangle = \langle a_8,b_1\rangle$
$= \{\langle a_7,a_9\rangle\}$ if $\langle x_1,x_2\rangle = \langle a_8,d_2\rangle$
$= \varnothing$ otherwise

$F_{03} : A^3 \to P(A \times A)$ is defined by
$F_{03}(\langle x_1,x_2,x_3\rangle) = \{\langle a_0,a_2\rangle\}$ if $\langle x_1,x_2,x_3\rangle = \langle a_1,c_0,c_1\rangle$
$= \varnothing$ otherwise

$F_{10} : A \to P(A \times A)$ is defined by
$F_{10}(x) = \{\langle a_0,a_7\rangle\}$ if $x = c_1$
$= \varnothing$ otherwise

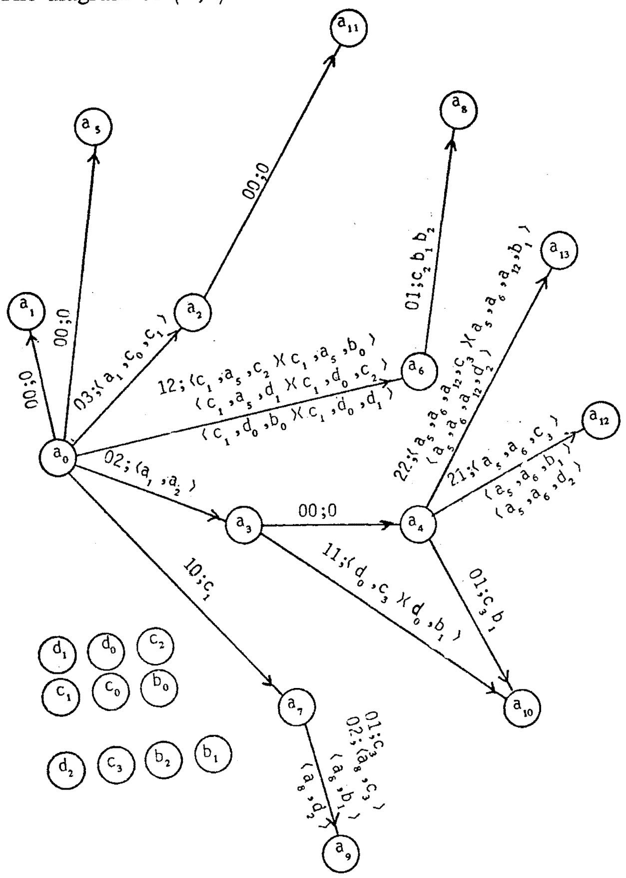
$F_{11} : A^2 \to P(A \times A)$ is defined by
$F_{11}(\langle x_1,x_2\rangle) = \{\langle a_3,a_{10}\rangle\}$ if $\langle x_1,x_2\rangle = \langle d_0,c_3\rangle$
or $\langle d_o,b_1\rangle$
$= \varnothing$ otherwise

$F_{12} : A^3 \to P(A \times A)$ is defined by
$F_{12}(\langle x_1,x_2,x_3\rangle) = \{\langle a_0,a_6\rangle\}$ if $\langle x_1,x_2,x_3\rangle = \langle c_1,a_5,c_2\rangle$
or $\langle c_1,a_5,b_0\rangle$
or $\langle c_1,a_5,d_1\rangle$
or $\langle c_1,d_0,c_2\rangle$
or $\langle c_1,d_0,b_0\rangle$
or $\langle c_1,d_0,d_1\rangle$
$= \varnothing$ otherwise

$F_{21} : A^3 \to P(A \times A)$ is defined by
$F_{21}(\langle x_1,x_2,x_3\rangle) = \{\langle a_4,a_{12}\rangle\}$ if $\langle x_1,x_2,x_3\rangle = \langle a_5,a_6,c_3\rangle$
or $\langle a_5,a_6,b_1\rangle$
or $\langle a_5,a_6,d_2\rangle$
$= \varnothing$ otherwise.

Finally, $F_{22} : A^4 \to P(A \times A)$ is defined by
$F_{22}(\langle x_1,x_2,x_3,x_4\rangle) = \{\langle a_4,a_{13}\rangle\}$ if
$\langle x_1,x_2,x_3,x_4\rangle = \langle a_5,a_6,a_{12},c_3\rangle$
or $\langle a_5,a_6,a_{12},b_1\rangle$
or $\langle a_5,a_6,a_{12},d_2\rangle$
$= \varnothing$ otherwise.

The diagram of ⟨A,F⟩ is



Consider the initial registration of a student who wishes to read a_9. How must he plan his degree curriculum? He needs to know which choices of course units lead to a_9. This information can be provided by one or more nebula diagrams. The appropriate nebulas are produced by forming cascades in ⟨A,F⟩ as described below.

Some preliminary definitions are required.

By a weak subnebula of a nebula ⟨D,K⟩ we understand a nebula ⟨B,G⟩ such that $B \leq D$, dom G = dom K and, for each $i \in$ dom G, each $j \in B^{n_i-2}$,

$$G(i)(j) \leq K(i)(j).$$

By a reduct of ⟨D,K⟩ we understand a nebula ⟨B,G⟩ such that B = D, dom G ≤ dom K and, for each $i \in$ dom G,

$$G(i) = K(i).$$

By a weak subreduct of ⟨D,K⟩ we mean a nebula ⟨B,G⟩ which is a weak subnebula of a reduct of ⟨D,K⟩. It is straightforward to show that ⟨B,G⟩ can also be seen as a reduct of a weak subnebula of ⟨D,K⟩.

A cascade in a nebula ⟨D,K⟩ is a sequence of weak subreducts $\langle B_i,G_i\rangle$ of ⟨D,K⟩ such that if i < j then $\langle B_i,G_i\rangle$ is a weak subreduct of $\langle B_j,G_j\rangle$.

For any family $\{\langle B_i,G_i\rangle \mid i \in I\}$ of weak subreducts of a nebula ⟨D,K⟩ the supremum is the weak subreduct $\langle vB_i,vG_i\rangle$ of ⟨D,K⟩ defined by:

$vB_i = \bigcup_{i \in I} B_i$, dom $vG_i = \bigcup_{i \in I}$ dom G_i and, for each $k \in$ dom vG_i, each $j \in (vB_i)^{n_k-2}$, $(vG_i)(k)(j) = \bigcup_{i \in I} R_i$

where $R_i = G_i(k)(j)$ if $k \in$ dom G_i and $j \in$ dom $G_i(k)$
$= \varnothing$ otherwise.

Given any nebula ⟨D,K⟩, the reverse adjacency function $\Gamma^{-1} : D \to P(D)$ is defined by, for each $d \in D$, $\Gamma^{-1}(d) = \{b \mid$ for some $i \in$ dom K, some $j \in$ dom K(i), $\langle b,d\rangle \in K(i)(j)\} \cup \{d\}$.

Given a nebula ⟨D,K⟩, the reverse context-function $\tau^{-1} : D \to P(D)$ is defined by, for each $d \in D$, $\tau^{-1}(d) = \{b \mid$ for some $i \in$ dom K, some $j \in$ dom K(i) and some $c \in D$, $\langle c,d\rangle \in K(i)(j)$ and $b \in$ ran $j\}$.

In order to illustrate the formation of cascades, we return to the nebula ⟨A,F⟩ and define the sequence $\{\langle B_i,G_i\rangle \mid i \in \omega\}$ as follows.

$B_0 = \{a_9\}$ and $G_0 = \varnothing$,
$B_{i+1} = \Gamma^{-1}(B_i) \cup \tau^{-1}(B_i)$, dom G_{i+1} = dom F and, for each $k \in$ dom G_{i+1},
$G_{i+1}(k) : (B_{i+1})^{n_k-2} \to P(B_{i+1} \times B_{i+1})$ is defined by
$G_{i+1}(k)(j) = F(k)(j) \cap (B_{i+1} \times B_i)$.

For i > 4, $\langle B_i,G_i\rangle = \langle B_4,G_4\rangle = \langle vB_i,vG_i\rangle$. In particular,
$B_4 = \{a_0,a_5,a_6,a_7,a_8,a_9,b_0,b_1,b_2,c_1,c_2,c_3,d_0,d_1,d_2\}$, and
$(G_4)_{00}(0) = \{\langle a_0,a_5\rangle\}$.

$(G_4)_{01}(x) = \{\langle a_6,a_8\rangle\}$ if $x = c_2$
$= \{\langle a_6,a_8\rangle\}$ if $x = b_1$
$= \{\langle a_6,a_8\rangle\}$ if $x = b_2$
$= \{\langle a_7,a_9\rangle\}$ if $x = c_3$
$= \varnothing$ otherwise.

$(G_4)_{02}(\langle x_1,x_2\rangle) = \{\langle a_7,a_9\rangle\}$ if $\langle x_1,x_2\rangle = \langle a_8,c_3\rangle$
$= \{\langle a_7,a_9\rangle\}$ if $\langle x_1,x_2\rangle = \langle a_8,b_1\rangle$
$= \{\langle a_7,a_9\rangle\}$ if $\langle x_1,x_2\rangle = \langle a_8,d_2\rangle$
$= \varnothing$ otherwise.

$(G_4)_{03}(\langle x_1,x_2,x_3\rangle) = \varnothing$ for all $\langle x_1,x_2,x_3\rangle \in B_4 \times B_4 \times B_4$.

$(G_4)_{10}(x) = \{\langle a_0,a_7\rangle\}$ if $x = c_1$
$= \varnothing$ otherwise.

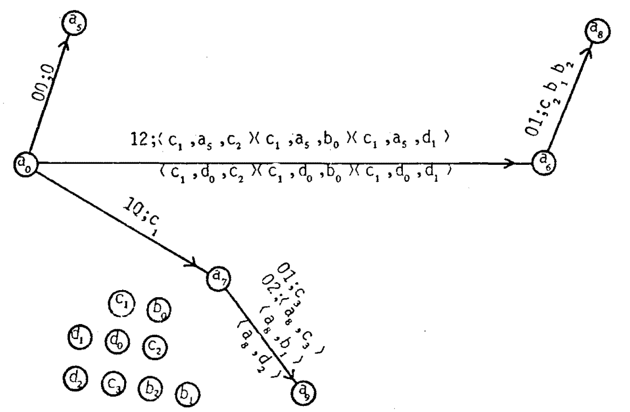
$(G_4)_{11}(\langle x_1,x_2\rangle) = \varnothing$ for all $\langle x_1,x_2\rangle \in B_4 \times B_4$.

$(G_4)_{12}(\langle x_1,x_2,x_3\rangle) = \{\langle a_0,a_6\rangle\}$ if $\langle x_1,x_2,x_3\rangle = \langle c_1,a_5,c_2\rangle$
or $\langle c_1,a_5,b_0\rangle$
or $\langle c_1,a_5,d_1\rangle$
or $\langle c_1,d_0,c_2\rangle$
or $\langle c_1,d_0,b_0\rangle$
or $\langle c_1,d_0,d_1\rangle$
$= \varnothing$ otherwise.

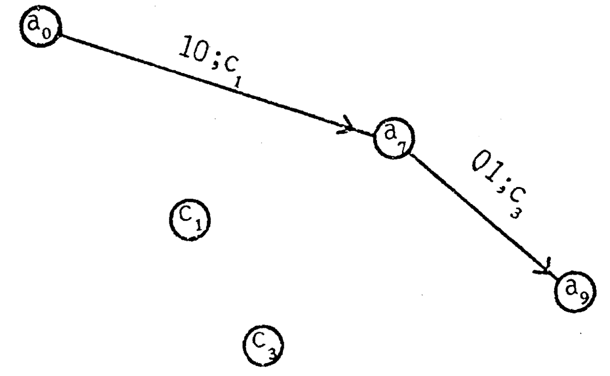
$(G_4)_{21}(\langle x_1,x_2,x_3\rangle) = \varnothing$ for all $\langle x_1,x_2,x_3\rangle \in B_4 \times B_4 \times B_4$.

$(G_4)_{22}(\langle x_1,x_2,x_3,x_4\rangle) = \varnothing$ for all $\langle x_1,x_2,x_3,x_4\rangle \in B_4 \times B_4 \times B_4 \times B_4$.

The diagram of $\langle vB_i,vG_i\rangle$ is



The diagram dispalys the various lists of prerequisites and parallels which lead to a_9. Each particular choice can be provided for the student in the form of a diagram produced by defining more limited cascades in either $\langle vB_i,vG_i\rangle$ or ⟨A,F⟩. Two examples are



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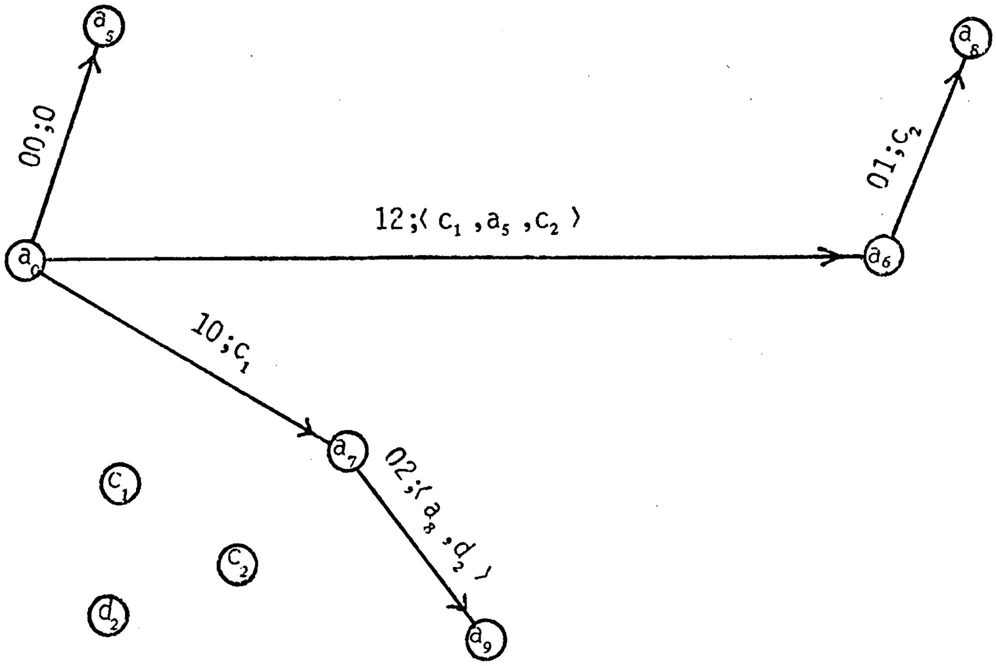

References

[1] Bollobás., *Graph Theory: An Introductory Course,* Springer (1979).

[2] Schupp P.E., *Groups and Graphs: Groups acting on Trees, Ends and Cancellation Diagrams,* p.205-214. The Mathematical Intelligencer, vol.1,(1978).

[3] van Rooyen H.O., *Binary Networks in Graph Theory,* Ph.D. Thesis, University of South Africa, Pretoria, South Africa (1977).

[4] van Rooyen H.O., *Mengers Theorem in a Nebula,* Proc, 2nd S.A. computer symp (1981).

[5] Weiermans D.J., *Private Communication,* University of South Africa, Pretoria, South Africa (1982).

[6] Wolvaardt D,E., *Development of Nebula Theory with Application to Syllabus Databases,* Ph. D Thesis, University of South Africa, Pretoria, South Africa (1982).

* In this paper $\leq$ is used to denote "less than or equal to", "Subnebula of", or "subset of", depending on the context.

New reading

***Mathematical Foundations of Programming* by Frank S Beckman. Published by Addison-Wesley, Reading, Massachusetts, 1980. 443 pages, exercises, chapter references, index.**

THE phrase 'mathematical maturity' is used to describe a way of thinking that is required not only of computer scientists but also of programmers, not only of systems analysts, but also of managers of programming projects and thus also of dp managers. Very few people would like to attempt a definition of this desirable quality, but one may indicate a relatively painless way of acquiring it: Peruse the book under review.

In its breadth of coverage (with one omission noted below), in the topics dealt with, in the way all topics are related to actual or potential computing practice, the book contributes to the acquisition of the vitally important quality of mathematical maturity and also a quality that can only be termed algorithmic maturity. In other words, this book contributes to the appreciation of what can but also of what cannot be computed, and the various ways in which a computation may be characterised, realised, criticised, and analysed.

The author covers the area variously known as 'theory of computation' or 'meta-theory of computing', in a descriptive, almost intuitive, but mathematically sound fashion. The topics covered include: The concept 'effective'; functions and sets; recursive functions; computability and its limitations; automata and languages; and computational complexity.

In every chapter the author introduces the main topics by examples (so necessary for the development of the 'feel' for a subject) and then progresses through mathematical descriptions to applications. In the process many sidelines are touched upon which in textbooks are mentioned but then tantalisingly ignored. This is thus a book not only to be read but to be dipped into.

The practitioner in computing will find the book worth reading, not only to acquire the aforementioned maturity, but also to gain a background knowledge of the many developments in progress all over the world which go by the name 'fifth generation'. It is rather unfortunate, however, that the predicate logic receives but scant attention in the book since the Japanese fifth-generation R and D is based on Prolog-programming in logic. The research thrust in America, by the MCC, is to be based on a Lisp foundation and various aspects of this functional style are covered in the book.

For students taking a formal course at honours level in one or more topics covered by the author, the book should be recommended reading in order to put their field of study in perspective. For honours students not taking such topics, the book should be required reading.

STEF W POSTMA

Notes for Contributors

The purpose of this Journal will be to publish original papers in any field of computing. Papers submitted may be research articles, review articles, exploratory articles of general interest to readers of the Journal. The preferred languages of the Journal will be the congress languages of IFIP although papers in other languages will not be precluded.

Manuscripts should be submitted in triplicate to: Prof. G. Wiechers at:

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References

References should be listed at the end of the manuscript in alphabetical order of author's name, and cited in the text by number in square brackets. Journal references should be arranged thus:

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2. BÖHM, C. and JACOPINI, G. (1966). Flow Diagrams, Turing Machines and Languages with only Two Formation Rules, *Comm. ACM,* **9**, 366-371.
3. GINSBURG, S. (1966). *Mathematical Theory of context-free Languages,* McGraw Hill, New York.

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A section of "Letters to the Editor" (each limited to about 500 words) will provide a forum for discussion of recent problems.

Hierdie notas is ook in Afrikaans verkrygbaar.

Quaestiones Informaticae

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