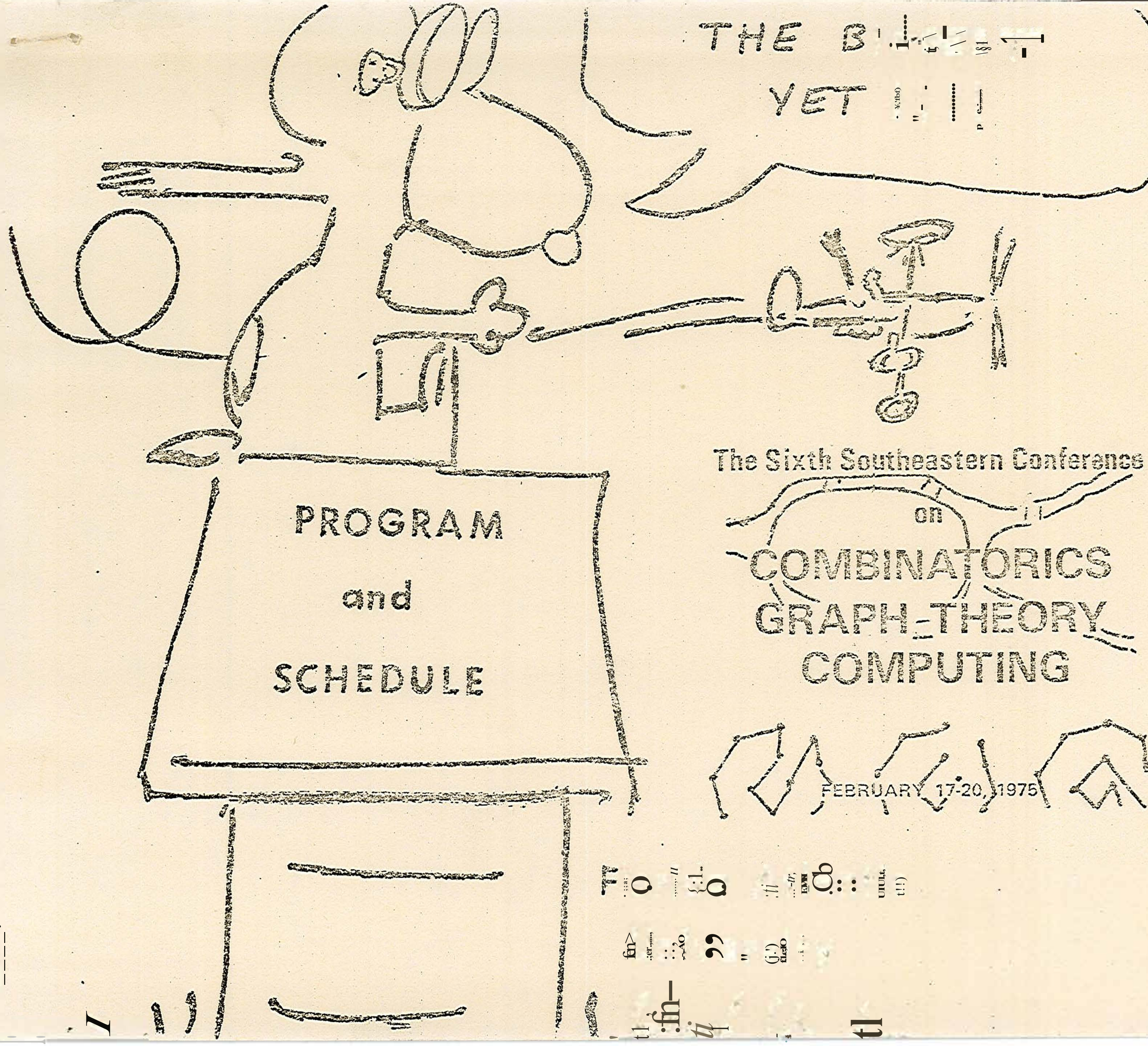

The Sixth Southeastern Conference on COMBINATORICS GRAPH THEORY COMPUTING

FEBRUARY 17-20, 1975

GCR is the Gold Coast Room.
Room 207 is entered from the second floor lounge of the University Center.
Coffee available in the other half of the Gold Coast Room.

POOLSIDE COCKTAIL PAR'IYfor Conference participants at HOLIDAY INN-LAKESIDE 6PM, Monday, February 17, 1975

CONFERENCE BANQUET at 7:30PM at the HOLIDAY INN-LAKESIDE in the Baroness and Marquis Rooms, Tuesday, February 18, 1975
(Drinks will be available in the Baroness Room from 6:30.)

	MOND/1.Y		Tl.lESD/1.Y		WEDNESDAY		THURSDAY	
	GCR	207	GCR	207	GCR	207	GCR	207
8:30	**Registration (from 8AM)**		Mesner 18	Cook 20	Alpern 36	Vanstone 69	Chung 59	
9:00	Opening **remarks** **Welcome by V.P. K, Michels**		Mathon 19	Klerlein 21	Alspach 37	Murty 70	Graham 60	
9:30	**KARP**		SHULT		WILSON		ERDOS	
10:30	COFFEE		INSTANT COFFEE		INSTANT COFFEE		INSTANT COFFEE	
10:40			Pless 22	Chungphasian 26	Mills 73	Hartnell 42	Mullins 61	Cot 65
11:00	Hedetniemi 1	Brown 4	Stockmeyer 23	Chen 27	Chang 39	Schmidt 43	Worrell 62	Collens 66
11:20	Chein 2	Shapiro 5	Berman 24	Welch 28	Kramer 40	Geldmacher 44	Hulme 63	Dirksen 67
11:40	Habib 3	Alter 6	Levinson 25	Slater 29	Di Paola 41	Cadogan 45	Jackson 64	
12:00	LUNCH		LUNCH		LUNCH			
1:30	**KARP**		SHULT		WILSON			
2:40	Owings 7	Young 12	Anderson 30	Hansen 33	Danhof 46	Levow 52		
3:00	Hemminger 8	Kes:iler 13	Schtlnheim 31	Ducasse 34	Schellenberg 47	Albertson 53		
3:20	Matula 9	Fredrtcksen 14	Wolfe 32	Butler 35	Baker 48	Simmons 54		
3:40	Day 10	Dillon 15		Thomassen 72	Gibbons 49	Whitehead 55		
4:00	Hoffman 11	Dulmage 16			Stein 50	Bondy 56		
4:20	Hadlock 68	Ismail 17			Payne 51	Burr 57		
4:40	Kainen 71					Duke 58		

MONDAY, February 17, Professor Richard M. Karo will speak on "The Computational Complexity of Some Graph-Theoretic Problems.•

TUESDAY, February 18, Professor Ernest E. Shult will speak on "Some Combinatorial Problems in Finite Group Theory,•

WEDNESDAY, February 19, Professor Richard M. Wilson will speak on "t-Designs and Linear Algebra.•

THURSDAY, February 20, Professor Paul Erdos will speak on "Extremal Problems in Graph Theory and Combinatorial Analysis,•

AUTHOR INDEX TO. ABSTR/\CTS

NOTES:
Schedule lists paper by presenters.
Paper 38 will not be presented.
Papers beyond i73 (if a. y) are not on index or schedule; see abstract for time and place.

· CD Some Linear Algorithms for recs

S. Mitchell
S. Hcc:ctnicr.1i
S. Goodmai\

University of Virginia
Charlottesville, Va. 22901

-· Let Tn be an arbi rary tree with n vertices. We present algorithms which solve a variety of problems on Tn in time that is linear inn. In particular, these algorithms find the Hamiltonian completion number, tho domination numl>er, a maximum b-matching, and point and line covering numbers.

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O;,tilr.:ilRer.istc, /IJlocation For implc wu tiaJ. Pr.,<!r.uns

G, O!i\TI . ;P .l PTI ,G .rl'TnLIA

1•'eused Grap!1 TI,eo(ry to stt>:ly t',c foJ.J01••jn nrol•)t•M:4'in<1 nu, jMn)c-Mc-:-.ttio:-. of a siJ:lple s e:ucntial !":-O,:ra:afjc. on)v constitutc6 hv .irit."MCt:ica) st.:itc-r>cn::s),.•hi,:', r.tlnimizcs trc tctal nmh: r of rc-r.ist.c-rsto 1,c 11scd.

Let 1r re a ;,ot r.:-cursive sC'ciu ;,cc *of* .irit',,<'ticaJ.stnt.-1'C':it.s= 1 G•fX,U) t1lt"2cirn,it clir.rap!1 :is,oc:atcd as follodnp,: X is tl-c set of v:ifal,Jcs an-1 f ,v)e U jf there is a statcn.-nt x= f (••• ,Y, ...) fo TT • /In ir-mkinc-ntatic-nor if is a J.ir,c;:rorder (X,?:) c=.atibk i:it.hG. A r"!!istcr alloc:iti n cf rx,r.) is n im)'<> o.r Y in fl,?, ... ,r,} suc.'ithat: (i) IS°(S)I =Isl, 1•herc lx/ <Hx)=0} :(ii) I[()>)\ \"/ ,'.'"CIC !'-1x/d(x)-=0 / ;(:.ii) b(x)•r.>()().>.-/y,xz;y = > V z :(x,z) U ?°GV. 11,e cor.:;,.itation of 1.;i,,,Ω such t":it : pJc;,c:;)=m;r\b fx) I) :.s N'uiva .ent to .those of t!-.ecJIror..atic nlt!1l-erof nul interval r.r:ip>,.1>/\fln'f',d,'rst.n1,.tcvlnP ,,Hic:ipnt algorith:l for this last prorkM.'3v usinr. F111I's results 1—cnrovc,1 th;,t ti-e nroi-,ern of ca:;,uting g such th:it r.(G)=r.1tnr (G,"{,)) is a ;,olvncr..ia! co!111,)etc nro'-Jcrr. . Y:inaHv ""<' cbtaine.1 S— res·Jlts for particular p,raphs.

(fff) · so:-:z ru:su:,::s ABOUT TIIB MrnIMAL CARDINAL (p (G)) OF A PATII SZT rn A G!1APH G a (X, U) CARRYING OUT A PARTITION OF X, AND THE NU?{E:C:R OF JUM:!"S (S (G)) HI ACIRCUIT GRA?H::J.

M. H 6"TIR •
G. IAl-i.BERT

U1HVERS!T2 PARIS. VI
INSTITUT 1>E PROGRJJ·U·JATIIDN

·In :a graph G a (X , U) , S (G) is the m!.nimum c:f the ardir.al of a set of arcs Vc:X:" snch that G1 (X, UvV) is an ac:trct:it graph and verifies p (GI) c r

We study t?le relation b<?tween:;:, (G) and S (G) , g!ve some decomposition theorems i order to compute those invariants i11 so::ie special clas:; o graphs.

This work follows M. Cfil.IM: , G. CiiATY last year con:fc-re:ice paper , ai:d would not have exist without s. HBDET!H:EMI , S. GCO MA.. study about tte ¥.amilto l= Co pletion Problem.

@ Behrend's thcore for sequences containing no k-clerncnt arithmetic p ogression of a certain type. '1'.(;.Brown, Si:non Fraser University.

Let k and n be positive integers, and let d(n,k) be the maxi-.:.." cen ity in {0,1,2,kn-1} of a set.containing no arithmetic progression of % cer s \ol'ith fi!'.'st term a = :E a k1. anO cor..0:1 d'iff-ercnce d = 1: &: k , ,..,-here 0 ai .k-1, C i = 0 or 1, ai:d C i = 1 ""ai = 0. Such an arit:-,::'!ctic proc;ression is called a k-dia9on.11. Thus d(n,k) = ;c::!;-.J, where.;:,, is a subset c: [0,k") which has largest cardinal while not containing a:-.y k-diac;onal. (Note t:"lat k integers form a k-diagonal if and only if their k-ary r«prescntations C'1.n be ;,ut ir.to the rows of a matrix **in** such a ay that eac colu.: o=th& atrix reaCi s iron top to botto , is either i i i ... **i** , for so=e i dcpc Ci g c t e colt= , :or 0 1 2 ... k-1. For exa. ple, {2,5,8} is a 3-diac;onal which contains ::o 2-diagonal.) Setting Sk = lim d(,k), we show that L Bk is either 0 or 1. (At present the only known values of Sk are 1 - B2 = 0. It' is also tr\!e that 81 !: 62 =: ••• =:Bk =: ••• =: 1.)

@) Catalan and "Total Informa tioi1" Ni.::nbers

Louis Shapiro, Howard U:,iversity

Let C = {1, 2, 5, 14, 42, ···) denote the Catalan nu bers. We prove th followin g pro?ositions

(A) $\sum_{0 \le k \le n} (-2)^k \binom{n}{k} C_{n-k} = \begin{cases} 0 & n \text{ odd} \\ C_{n/2} & n \text{ even} \end{cases}$

(B) $\sum_{0 \le k \le n} 2^{n-2k} \binom{n}{2k} C_k = C_{n+1}$ (Touchard, 1924)

A short, natural proof is given of ooch i cn:ies an as an pplication we can show that two interpretations of :J:e sequer.ce 1, 1, 2, 4, 9, 21, 51, ··· , the "total infroma::cn nu. bers", cc,ii'1cicle.

@ . RE IARKS A."D RESULTS RELATED TO Ti-IE MCRGAN WARD CONJtCTu"RZ

Rona}d Alter
University of Kencucky

A secon d order linear recurrence s. a. 1. r.) is a sequence {an} of integeri: satisfying an+2 = Man+1 - Nan where H and N arc fixed integers and at least.:0n a_n is nonzero. Morgan ard conjectured that in every nor.degenerate s. o. 1. r. no integer can occur ;:;ore th.:,."\ five tines. This pa?er is c.,ncerr.ed Yith the proble;:; of characterizing those integers in a s. o. 1. r. which occ r ore cha."\ once.

.0)

TREES WITH FULL SUBTREES

Steve Clark, inf., James Spriggs

Dept. of .ath., U. of Maryland, College Park, MD 20742

Let $n2$, for n a nonnegative integer, be the full bin.i.ry tree with n+1 levels; i.e. 2^{n} branches. In this note we derive a fo=ula. for the largest number F(m,n) of braac!-ies a subtree of $n2$ can have yet not contain a subtree ho::ieo.r.orphic to m2. We find F(m, n) = I:'11:5 (J), Our search for this bound was inspired by a stat ment of S. Shelah who ..:cd that a certain related function G(m,n) was bounded by n& m^{lai}, for some functio g. We shall prove F(n-.,n) = G(m,n). Thus our theorc:w shows that C(:n, n) is never greater than n:u and, for fixed m, m>l, is asymptotic to n-1 / (m-1) !.

Ⓡ

On the Automorphism Group of a Line Graph

Robert L. J!em:ainger

Van.derbilt University

A !la.I ar.d short proof is given to a theor.:m of Sabiclussi asserting that, .rt.th fo r xceptional cases, the group of auto orphisms of a connected gr;i.ph is iso.:icrphic to the group of auto:norphisms oi its line graph. This proof easily extends to give the corresponding .results for pseudographs =d **dipseudographs.**

(j)

<u>k-B1cc ks ar.d U1trab1ocks in Graphs,</u> DAVID \./. MATULA, <u>Souti1ern Methodist</u> Univers_i_!r. For k;:l , a <u>k-block</u> is a maximal k--poir.t conrected subgraph of a graph. b1ock for any k ,hich does not contain a (k!-1)-'.llock is ter:r.ed an <u>ultrabloc:<.</u> Although both k-blocks and ultrablocks can extensively ave.lap, it is sholln cnar-thair total number n a given graph is moderate. Specifically, the total number cf ultr&blccks in appoint graph G where the largest point connectivity of any subgraph of G is -r is given by $\frac{1}{4}$(p-1+1)/2J for an p>T>2. A similar result is presented fork-blocks.

.!2.)

<u>The Char·c:cterization of Certa n Sets of Graphs Using il Generalized Closure Oocntion,</u> \·1!LLIA;-1 H. - DAY, <u>Sc uth2rr. i1:thodist University.</u> - Jardine and Sibson[1] invt:stigated <u>flat cluster r.iethcds</u> and characterized them in terms of certain sets cf graphs called <u>ind'.cator familias.</u> In this paper I characterize indicdtor fa;nn ics in tems of certain closure operations defined on a set of gn::,hs. This is a special case of a ore general result in which r characterize certai sub-sets of lattice elements in terms of closure operntions defined or. a comple e lattice •

1Nicho1as Jardine and Robin Sibson, Mathematical <u>Taxonomy.</u> Jvhn ki1ey & Sons Ltd. (19m-:------

Ⓡ

Routing fer Solid aste Collection

Frank o. Hadlock and <u>Frederic% !toffman,</u> Florie.a Atla:-.tic u .:.v rsi..ty

T11is is a preliminary r port on the dcvelop ent of a libr =Y cf routed block patterns for both-sides-of-the-street solid w3ste co!l c-tio11. The routed patterns arc to be Ltsed as the basi for a o ula= D>f>: oacl1 to routing. The procedure involves several al oric s, so c ttdig11tforward, uth r3 of c,:rrc t research intc ast. Bloc ?dt: s ctrc gcncrutcd. Patterns not. c:o:1forming to pos i;:)le st.-:cc potte:-r.s 1rc rejected, as are isomo! phs under "routing-.inv.J.ria:;t'' t:-a:-isfvrrr,.::-tion . In addition, pc:1ttcrns which can be routcC as u:1ions of :;iw?ler patterns {t osc with bridg s) re eliminated. ·he routing p=cc ss ai s to minirnize distar\ce, eliminate unnecessary U-turns, an , given t ese constraints, to minimize turns. We shall discucs scme of che algo-rithms used, as well as some properties of the sraphs involved.

This research is being carried out und r a grant frora the ?AU-Y!U Joint Ccr.te: for Enviror -ncr.tal and Urban :>roblc:i:s.

@

1·.:1,,"(:\0P) -:;:r:::;I(;,!S 0—.:'P/.Ir.:E ?0'.'/:S:1 ErDEY. · Ai:D ASSOCH::'"D .r.) ::; ll'.- 1\c c.; C 110,:1t: and <u>li • .£'. Yo"L .!'1 -;Ci-</u> :; U!11.V. O:.i: !I.Y•, Grc.c . s"'2iioo}.

1\ <u>i. :-:..:G: od·;)c i....</u> i.l o;i the finite set E in 2 :1 ::o i.t i : ·.-:-:'1ic;-the 1::y9c -:-:).L8.410;:0 -"-1 ha::3 t 1- s2.:.!e c2.rcJ.ir ;:1li."by k. :le c2. c1: :_i::: c: .:-1)'. """Oci c-li r- {"J:"" i c21lef ...1-:-i.;..,,(,....o-!' r- :—;,:"\c>... ...v,c0r ..L.-,f,., 01. 01 o 1 1;1C j.C 1,,0 c... -a-JZ..1,.. :;le vv...c."'U_..:;-..;.:....1< r.'.acr-oicl ct::si::ns or _r;rLw po':1cr i:r.uc;: incluc.0 the !=:o:;: i"J:1i ce p-;:c-jccti 1c coof.'! ::i-c bu: arc :.:o::-e G:?r..0:.c 1 .

:Evc:r.y rar_ : 3 ::iatro.-:.c. de sicn ,ith ind :c a princ por:er is, e si:: 11-**tially, either (i) a** (J. + q + q2t°,1 + q, 1) - 31:BD; o::.· (ii) a (1 -, q2t-+ 1, 1 + q, 1) - EIED; or (i.ii) a c=-01.!p d.ivisitle c.es::.o: r,itn A-= 1 a,,.d 1 + q^{2t} + 1 [TOU.PS,_ ec.ch o:f s.i.zc p^{s} (p^{s}, 11 <".:-:C: block sisc 1 + n.

'ih f'jr.-:—> -'.••,o-J."'rou o-:...cloc-i.r.,. •c- J:::a;;s e:•:j_st, tr.e:r C-ei z cp 1.e..1 C11.::JCS 0 a r.ru.cn. 1 ;er !:;Cr.-::.c 01 3BDts, :,it:1 !,> C::.:-:cto:.s o:" fo ::1: v:.1+q-+q^{n}, $n2$ + ... + $q^{r.r}$, k -;:.1 q, > ...1, \'('1 = q J.S 2.. pe1O p,:,;-;er, r-li ,a { mocl 2 and. ni-1 .-::ni fo:- i =-1, 2, ... !.'..

The e::i tZ!ncc of -c·.mc (iii) desi.-. s is a.:—iu... sclvcd u1..o";J.. :.1. Ir. su:.'!m2...ry, ei.."'8:y i:-2J1.1:,3 :12.t.roid-C. s.i.c:;:1of ::,:..:r.:c :9c.:•. e::-i:::t-;::-::*is* ua2.;.:ootn a <u>ne"1"'f'ect r.a:-::roid des5</u> (a : atrvit. i ,:-;:lic:1 the .:.1.2..-:—c:: each gi-ve:r. :.' 1 :1a,1e t:le sa:-.ia ca:rdil1alit:, . Simila:: results f'.:. ld for c11 ra."'1lm i:1ighcr t:ila..'13 •

@ LEXICOG.RA?HIC C0!1!'C3ITIOHS AND dcBRUIJN SEQUENCES

Harold F:cc:dricksen, I,-wJ.r.o-Kessler
IDA-CRD, Princeton, N. J.

Let n be a positive intei;er. A composition of n is **a k-tuple of positive integers** $a_1 \ldots$ **ak such that** al + ••• + ak = n. A co,Jposition al •• ·'\ is a lexicog,·aphic co::iposition if fo::- every cyclic permutatic,n " of (1, ... ,kl there exists an integer j, ·1 j _$k, such t:iat al = a,r(i} for 1 < j and aj > $a_{r(j)}$.

Let GF(2) denote the f:!.e:td consisting of two eleme:1.ts and let V_m de:1.ote the m <li en!:>ional vector space over GF(2). A deBruijn sequence of orde::- m, is a sequence [xi] of lengtll 2^m, xi , GF(2), such that every element o V_m appears as xk,xk+i' ..., xk+m-l for some k with the subscripts taken modulo 2^m.

I—i this paper the authors ive an algorithr.. 1"or gen-erating a cowplcte list of t. e lexi ographic compositions of n, a d then use this list in an algorithm to generate a c.eBr..iij:1. sequer.<:e of ordar n + 1•

@ Five Sum-Free Sets

Hd.rold Fredricksen, IDA-CRD, :::>rinceton, N. J.•

A su:n-:·rce se':: S 1s a collection of integers ,:hich satisfies the ccndl tion that if 1, j ϵ S then i + j t S (i, j not necessarily distinct). A proble:n.of Schur is to place the int<:>gers 1,2, ... , k into k SUJ1l-free sets with mk <'.S large es possible. Schur ;;hewed th.:it e. K! is an upper bound for mk.. For k 1, 2, 3 extremal solutions e.re easy to find by hand, viz. mk = 1, 4, 13 in the three, respe tive cases. Via e. co:np,.1ter backtrack search naur..ert sho·,,ed ff_4 = 41;.

By a cons true tivc tecilnique, Schui lo:,·er bour.ds $:n_k$ by showing k+1 3::ik+ 1. Both upper and lower 'cou:.cs have 1:>:eeni:npro·,ed. 'i'hc up;:,e:- bound co (e-1/2)k! by Whj_tehead and t-he :Lvwer bound to $(89)^{n/4}$ by Abbott and l-lcser. 'l'he latter 1;:akes :u:e of Ba.umert•s ialution ;o the k 4 case.

·The author gives a pl cement of· he int.e crs 1-138 into five su. -f:-ee s cs usincs 3 °bec:'ed-\ B. backt!"t..ck siri.ilar to 3awr.c:-t ts. T'nis ir.-,;,roves the lower bcund slightly to $(277)^{n/5}$. ?he nur.iber 5 would sec to be rr.uch larger t:ian 136.

@ ELEKF.:NTARY :-J.ADP.HARD DIFFERENCE SETS

J. F. Dillon.

Departrr.ent of Defense
Fort George G. Meade, XD 20755

R. L. }leFarland and J. A. Maiorana have independently constructe:l a large family of <li.f.ference sets in the elementary 2.beli.:in 2-gr:-oups of sqL:.are order; w. call t'nese- difference se:s F,\J-tlLY AL F/tl-'iLLY,\i:includes the difference sets studied earlier 'Jy l'. Kes:wa Hcnon, R. J. Turyn, et al. We have ,:eccntly give:1 a "p.:i.rtial spread" construction, a s;,ecial case of -which takes c!le follol,ing "cyclocomic" form.

THEOREM. Let Cc be the grot.:o ?f $(2^m+1)^{th}$ powrs i:1 t:ie finite field K:GF(22m). Then the t.:mion of 2^r,- co sets cf Co cons::ituces differer.cc et the addir:ive group K.

In chis paper ,,.e consirler a very special family of ciffer1lnce sets which are given by this theorem and which ara closely related to n interesting pair of error-corr cting codes We shew that these new difference sets are not eqt.:ivalent to any in F.-"-'IILY M. We obtain this result and others on inequivale.nce by er.:.?loying c rtain affine invariants which we develop here and which are useful _in the more general stt.:dy of Boolean functio::is.

@ A 1:'O LJT..A ?OR COc,"><"TING TI-IR..'1"E-LINE

1A'fIN' RECT.11.'-:GLES

I'.. L. :).11.-:eae
G. E. I-'M"-2ster

Mat.hs:atics arrl Ccn:puter Scie.—:ce Depa..'"tme."lt

&an.don Univ sity

An r by n rectanqul..c.::> array is cc.ZZed a_Lc.-;ia rcctc.ngZe if *aZt tha intagcrs 7, 2; ....., n appaar in ecch rU, cnd f f r Cis ir:.c= ,-f;eg#"'s occur. in aach c:olunn:.. In this pap0r, ye p;:;,eSant a py,cof of an e:::pZicit fomiAZa (I'Z=g} 19t;1) for ev Zuctir.g -ike r:Lkhar-* of three b!^{f}n La.tin rectangZas. Fsing ."/'UZti-prea ise in tager c.ritmu:itic, a tabZ.e is aonst:"Ucted giving the number of rectangles for r. ·40.

@ A DCRANG!:MENT P.I.03LEM

Rich3rd Askey, I,io1.:ra:I Is mull, Thanaa Ismail

!Matile:';')a:.Jcs Research Center, University of Wisconsin,. Madison, Wisco sL,

The classical derangement pro':-lem may be described as follows. !i k-people leave U-,eir **hats,** one per **person,** at a chi?ck room and the hD!s are returned al random, how many ways can each i:,crson receive oi,ly one hat and it is not his own and what is the probability of this happening. The number is $k! \sum_{j=0}^{k} \frac{(-1)^j}{j!}$ and the probability Is $\sum_{j=0}^{k} \frac{(-1)^j}{j!}$. In a very recent paper Ev:-1 a:id Gillis conside:-.:!d the !ol!ow!ng \;Cnerallzat!on of this problem. In addition to checking hats some paople also check coats, gloves, scarves oc any numb:?r of other items. Each person ·collects the same numbec of Jtc:r,s he checked. 'ine prc.blem is to find the number of ways of doing this so that nobody receives ar.y piece of his own clothing. Using M11cMaho11's Master· ?hecrem, we give a sim;,le proo! to Even ar,d Gillis' result. We also prove that when k peop!-e each check n items the proba!:;!lity thnt no perso" receives ar:y p!Ccc of his own, fer k large and n fixed Is $e^{-n}(1 + O(\frac{1}{k}))$ for $k > 1$ • Toe e:ror. term is $O(\frac{1}{k})$ for $n > 1$ and $O(\frac{1}{(k+1)!})$ for $n = 1$ and both. are best possibl .-

@ A CENSUS OF 3-CLASS ASSOCIATION SCH.E ES

. Dale M. Mesner

Univer:ftY of Nebraska

Lincoln, Nebraska 68508

Let X be a finite set, $|X| = v$. • An m-class association scheme on X is a set $\{R_0, R_1, \ldots, R_m\}$ of symmetric binary relations on , where $R_0 = \{(x,x) | x \in X\}$, each (x,y) is in exactly one of $R_0, \ldots, R_m$, and the following holds for $i,j,k \in \{0,1,2,3\}$: if $(x,y) \in R_i$, then the integer $p^i_{jk} = |\{z \in X | (x,z) \in R_j, (y,z) \in R_k\}|$ is constant (depends only on i,j,k). p^0_{ii} is denoted n_i. 2-cl ss schemes have been exiensively studied. This talk deals with m = 3, descrioing a table of all parameters $v \le 200$, n_i, p^i_{jk} which satisfy the major conditions known to be necessary for the existence of 3-class association schemes. For v < 100 the table includes parameters for about 700 known schemes, 200 impossible, and 200 unknown. For 100·< v < 200 the total is about 2300 and the proportion of unknown schemes is la::-ger. Inspection of the table reveals some new families of potential schemes.

@ 3-class association schemes

Rudolf .Mathen

Deoartrnent of Computer Science

Univcrsi ty of 'l'oron

Necessarv conditions are derivec for the existence of 3-class associ;tion sche es. These results are bnsed on parameter relations, eigenvalue multiplicities anc the Xrei con<litio . Certain parameter coc inations are ruled o t by countin,;i clicrues or cycles incident with a vertex ir. the corresponding grap!1s of associates.

The known-3-class association scheP1es are -::hen classified into union and prodcct sche es, s he es derived from syrr.metric bJ.ock desiqns, projective geo;n€:trie:s· il.:'lc !-loore o.ra)Jhs and as syf!l!Tletric and exceptional sche!'.es. E'or each class the properties of· the schemes e.nd construction tr.ethods are given. Finally, applications are discussed relating association schemes to gr·aphs and .balanced incomplete block designs •

Firs: Order Graph Acceptors

Curtis R. Cook, Oregon State University

In this paper we define acceptors for classes of gra?hs generated by iirst order context-free: graph gra,r.r.::in:. **'T!'':: o::.** Seate acceptor recognizes the sets oi graphs generated by first order graph gra, T-ars ar.d the finite state acceptors recogni=e sets of graphs generated by first ord r graph gra::-.. ars NhosP. productions are sequences o:: rewriting r les. **We show the equ5.valence between the Ce-:er:r.ini.stic and r.cn-C:ete=::i.nist.::.c** acceptors. Finally wa considP.r the closure o:: th sats o:: graphs under various graph operations such as line graph, block graph, clique graph, etc. and the closure under se ·opcra ions.

@ Cha=act izations ?f Line D pscudoz=aphs

J&eph B.•Klerlcin

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In chis ;:>aper we ;>rct:c:s.c a r.cw de:f.:initio:-. o a line ciipscuCoz.·a? •,,:hie:, i.;;.:i:-:.1!. the. old dct:nition. :reflects al.L types of adjac ncies. ·e the;n prcSt:It t\'O ::y;:it:s of ch.:ir ctcrizatio:,;s. Tr.e iirst c'na.racteriz:cs .4.i::c Ci;:>scudcsr.l;:is ::: :cr.=.s i t•o 1wprop r p.:irt!tions oz the v rc x set. The secv j 1& a !or idGc CYcC su!;Gigro? characterization fo= the class ! disra, s wh1c. a=e line Gi,s µGog=a s.

V:era Pless Massachusetts Institute of Technology

22

A Combinatorial and Algebraic Machine Ai<lod· Computation System (CAHAC)

Tre CAMAC system is a new_ flexible, interactive computer system .base<i on Joi-in Cannon's Croup cor.1putcr system.

A group is given to the computer by either generating permutations or generators and relations. The system c�n handle mny groups at once and stores the infonnation computed about the group in a table which is referred to by the name of the group. There arc commands to compute the order of the group, the index of a subgroup, orbits, conjugacy classes, and special subgroups like norr.1alizers and stabilizers. There are also prograrr,s •..:hich compute vector-orbits of *a* pcrr:iutation group. Some major algorithi:::s used tv implement these co=ands will be discussed. A main algc�Lthm used for groups given by generators and relations is the Todd-C,,xeter algo.ithm and an important aliorithm for handling pcr-�utation groups is the Sims algorith�. _The type of problems already **solved by the system will be** given, and future capacilities will be in-dic.ited.

@ On the numocr of S-cycles in a tournacent

David Be"l'an
University of New Orleans

The maxinun number of 3 or 4-cycles that an n·-tournaicent can have is well known. The problem of ma,:i:nizing the nu:uber of S-cycles is more difficult as a S-tournament can have as :nany as ::r.ree S-cyclcs.

In this paper we ccnsic!er the class cf tournaments ;;1th the follow-ir.g prope.-cy (which we call semi-transiti·.ity):

if a•x and a·y, and if x+b+y, then a+b.

Since it is easy to mini�ize the number cf 5-subgraphs havir.g no 5-cycles, and since a semi-transitive 5-tourna�ent can have no :core ::han two S-cycles, the problem reduces to maximizing the nu�ber of 5-sub-graphs with t;;o S-cycles, w:-iic:-i we call Cs's.

The r�gular semi-transitive n-::ourna�en:: :,as $(n^5-ion^3+9n)/1920$ Cs's. We :;ho.„ that any sernitransitive tournament oust "contract" :o a regular tournament, and we compute the nu�ber of c_5•s in any se:ii-transitive tournaffieut in terms of regular ::ourna::ient co which it contracts.

In this way w� establSsh an upper bound for the n=ber of_�5•s which is of the order of n /1920..

@ The Reconstruction Conjecture for Tournaments

Paul K. Stockmeyer
College of l,illio.m and �fory

Tne famous gmph reconstruction conjecture asserts that except for small trivial cases, •every n-point graph is uniquely determined by its n subgraphs on n-1 points, each ob�ained by deleting one point and its incident edges. The corresponding conjecture for tcurnaraents ;,as first considered by Harary and Palmer [c:onatsh. Nath. 71 (1967) 14-23), who verified the cc�jecture for non-strong tour-na,:ients with more th"n 4 points. The truth of the conjecture for strong tournaments was cast into serious doubt by Beineke and Parker [J. Combinatorial Theory 9 (1970) 324-326], ;,ho displayed a pair of 5-point tournaoents with the same collection of subtourn��ents, and three pairs of 6-point counterexamples. (Counterexample pairs on 3 and 4 points were already k,1own.)

An exhaustive co:i:puter search has noc; c.etern,ir:ed that

1) the conjecture is true for 7-point tournaments, and

2) there are exactly two distinct pairs of ccunterexamples among.the 6,880 tourn��ents on 8 points. In both cases, each tour-nament is the converse cf the other, a property noticed by Baineke � d Parker of all c?u:iterexaDples on 4 an� 6 ?Oines.

@

Anr.111C1' Pl1t11:.rity of Csyley uiaC"ra.:nf:: Plrn:lr ?;:::esenta.tions. 01 vira Rs.r,iaport Stras-ser, SUY at Sto:-y Br'Jok,and .Hfn�y _'7,!,,Levir��Rut,;;ers, �ey Er=s·i;ici:, NJ. Let!'� (xl'•.•,xt; r/1,..•,r 0a) � (x; :<·) be the nresentaticn o: a gr0u::,,ar.c. G the Cayle_y dia,cram of t!,e pre,a�ntaticn� If G c.!n be cr.osen p:.ar.er, pcir.t-sy:::-,etric (:d th t:ic ;;,,;;c c-:iuntercloc;.r,,ise succs:s:no:. of ecges a� e�ch \·ertcx), a=; 1-Jcally fi-nite (�it�out �ccu�ul�tion points of v�rt�ccs), P will b� .callee speci.11 pl�n1�. T�e p::cse'1t ��k pi,es !!U speci·�l pL'�:1r -:,rcs£::1.�tinr.� of all groi;.ps posz�ssi:;:J �he::. Co:1di tio�s are irr.posed on the word1 R wf.ic1 c:c nc,ccs�a.ry to :ake ? =(�; ��) s,-:cia2 plan::r.Th�$e nllo� the �ssir;ninL to a of a i;ni�ua ele::-2:,t S_t cf the sy;.:=.et:-ic ;:-�.:? on 2t s,-:1b�ls. Neces:;ary condi ti�n.c; :re i:Jp;se;d 01 the exp0nc:1t set C ul�o. T:r, f�l-lowinc t�ree conditio�s are equivalent (Theorec 1): (1)� i� cf �i.ni�al x-le��th u�-Car auto:corphi$:::s cf the free [TO�p of rar.k t, E\; (2)5_1 is a si::glc c::cl� v: le!;gt�. 2t; (3) P ic sp-�cial plan:::r. (Cor.ciitions (1) SC (2) are reacily �scert:.inn'll e fr;;;:-: tr.e pre,entatio::.) It is shown that S, Ccn!:ists of h.-l di_sjoi::t cycles if a,� or:i.y if Pi:; a�to�or?hic image in Ft of a free �rod�ct of a standard special plc.::�r ;,re-Si'?ntation P' and a free group of rank h. (Theore�: 2.) The values of tr.o •.:,egers, q and r., which cor::;,letely c:.aracterize P' are read off the cet of .,n:cs n (Thecre:. ;.) Po:- giver, t (nudoe= of eene:-at.:,rs) and c (co:-t'"!G.tible n�ber of defi!"li::g releto:-:,), all special planar presentations and their iso�orphy classes are fou.�d.

@ Con$truction of l!amiltonian Graohs With Prescribed Degrees

V. Chung?haisan

Depart=ent of Combinatorics and Optimization, University of Waterloo

A simple graph G is a realization of a sequence • (dl, •• ,d_o) of nonnegative integers if the degrees œ the vertices vl, ... ,vn of G are dl, ... ,dn respectively. I: is icro\J't\that. the itavcl-Hoidci thcoret:"I on r alizab:!.lit:y can be avplied co cons:ruct a reali:a:ion of a sequence by uccessively "laying off" vertices. We shall prcsP.nt a layir,g-oH algorith:n for the constru tlon of .a re"lization of ,!! that h.i.s a iltoni"n ·path starting at a specified vertex (if such a realization exists). This algorithm can also Le used to construct a realiz"tion vith a hamiltonian cycle.

@ A NODE-ELIMINATION METHOD FOR FINDING ALL SiliI'IE CYCLES IN A DIRECTED GRAPH

by I-Ngo Chen

Syracuse University & University of Alberta

A method for finding all sir.iple cycles in a di:::-ected graph is presented. The method is based on the idea of node-elimination. To eliminate a node from a graph, we simply join each entering edge to every leaving edge of the node. It is proved that a graph, after eliminating a node from it, wili recein all the simple cycles. The algorithm first transforms node attribute to edge attribute, then proceeds to eliminate nodes from the graph, one by one, until finally only one remains. During the process, simple cycles will appear, gradually, as selfloops of some nodes. Thus, upon the termination of the process, ·all the simple cycles of _the graph can be found. Infonnacion about the graph is stored in a matrix. At the beginning of the process, en entry of the matrix may·store nc edge, or a single edge. After the process starts, an entry rr.ay have to store sequences of edges .. This infornation may be respresented by sequences of symbols where different symbol represents different edge, or they ay be represznted by a finite nuruber through a certain coding scheme. In the first case, variable entry length has to be provided, while in the second case, extra space and time are required for tracing the cycles. Upper bounds for both cases are given;

@ RETRIEVAL IN MULTILIST FILES WITH ORDERED LISTS

James w. Welch and J.W. Graham

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.Multilist files arc widely used for information retrieval with Boolean expressions. Two algorithms, one by Hsiao and Harary and another, called the Trace algorithm, may be used to advantage with such lists_. We present a probabilistic analysis of these two algorithms for several situations. For a r.umber of com on cases, it is shown that the Trace algorithm is more efficient.

® Leaves of Trees

Peter J. Slater

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Washing ton,· D.C. 20234

If v is a vertex of degree at least three in a tree T and at least one branch at v is a path, then the subgraph of T consisting of the union of all such branch paths at v is called a leaf of T. Given a collection of two or .:iore le:r,es there arc infinitely many tr.ees wi::h that leaf struccure. As a function cf the nu ber of leaves, the nu= er of nonho::ico,::iorphic trees with given leaf structure grows exponentially. Certain par=ecers, such as the nucber of ecges it is r.ecessary to add to T to produce a 2-connected graph, are the s=e for all such trees, and simple formu as may be given for them.

@

SEQ,UE,,CDlGS CF CERT.U:·: DIHEDRAL GROUPS

S. A. Ancie:-so:1
AriJona State University

Su?pose G is a finite group of order n. A sequencing of G 1s an ordering e, a.1, a2, •••, an-l of the ele:::cnts of G such that the partial ?roduc s e, ea1, ea1n2, •.•, ea1a2···an-l are distinct. Sec;uenc1n3s are t..sefu:l: 1n constructlnc; certain types of Latin Squares and in finding certain decompositions of co plete directed graphs. Little f known about sequencin5s of non-Abelian groups and mcst exai:lples known have been found by computer.. I'le **consider a. techc1que for** sequencing certain dihedral groups.

@

SOXE OBSERVATIONS IN FINITE TRANSVERSAL THEO Y

J. Schonheim
University of Calsary and Tel-Aviv University

A kno,,-,, necessary and s fficient condition for a finite family F•{F1,F2, ••• ,F8} **of finite cets, to have 't'-O disjoint: transversals is J -=lF i, J 2.K, k - 1,2, ••• ,a.** Obviously this condition is sufficient for F to have ?ro?ercy B. Attcmpcing to stre gthen this condition by requiring only tw disjoint maxi:::al partial transversal. obtained the surprising result that if & fa. ily F hns two disjoint m .xi al pa:-U;.l l•..ns versal s then it. has also t"o disj-,int tra:-:sversals. This spoils the above·vay to find a st onger condition.

On the ct er hw:d e establish the cond tion IU 3-.F..j k+l to be sufficient fer F to have property B, it is not necessary, but it is best possible, in the •en•e, th.t |0.1Fij| k is.not suffi ient.

Wolfe, Warren
Queen's University, Canada

"Amicable Orthogonal Designs"

32

Orthogonal designs are generalized Hadamard arrays and have been used to construct weighin matrices. Pairs of designs, X, Y where $xy^t = Yx^t$ are particularily useful in generating large designs.

Using Clifford algebras, we have obtained limits on the number of variables which can occur in such a pair, extending the Pullman - Geramita result on sets of anti commuting, orthogonal matrices. We also have results which describe the nature of designs which can occur in such a pair.

@

A Process DccomDosition Thc,orcm. John C. Hansen, Univc:·sity of Nissouri-Rolla - A necessary and sufficient condition for the parallel decon csition of *a* process is given in terms of parti ioning of the state space of that process. A process is definod as a triple (S,f,I) where S is a state space, f is a successor function in that space, and I is a subset of S which defines the initial states of the process.

®

State Granhs anrl the Assir.nment ProhleM for Asynchronous Seo,uential 1-'achines

f:dr,ur nur.asse
1lrool lvn Collere, c.tr.N.Y.

Sequential machines can be classified as heinp either synchronous or <lsvnchrc,nolls. Seouentiill rr.cidrjncs ?.T'.; ca 1] ed svnchrnnous if th ir one ation ii controllerl bv clockinp evices whose outnuts svnchronize sirnals in their c-ircl:its, an:'! clsvr;-chrcnous if thev function without these timinr evices. Asvn-chronous circuits have the advantape o be nr ahlc to utili e basic <lcvicc snecd since it is unnecess rv f r thcm to \-;ait for synchronizinr: nulscs. Unfortunatelv, pua!'antecinr, p-:-one':" oneratik'.'Jl of asvnchronous circuits in the oresence of uneoual t ar:smission delavs of sipnals is a·diffic lt task. Of nirtic-ular il"lnortrlnce in this connection is the wav in which nares are assip.ned to the internal states of the machine. This oaper studies the relationshi? between state p.ranhs of asynchronous sequential machines and some of the standard methods of coding their internal states.

· @

THE BELL POLYNJMIALS A.\'DM<\XIM:.\LGRO\.J'PS OF TilE SFNIGROUP OF rxxmLY STOCHASTIC }.'ATRICES

K Ki-Han Butler
Alabama State Universizy

Let be the set of all n x n doubly stochastic: matrices. Let g(rln) be the set of all maxiEal groups of nn. Let g*( ) be the set of all nonisomorphic: maximal groups of . Let be the nth Bell number. Let Yn be the nth Bell polynomial. Let t(Yn) be the number of te:-ms contained in Yn. The mai."l.results of this paper are as fellows: (i) lg( ) I • x..i,and (ii) lg*(.) I ,. t(Yr).

HAMILTONIAN CIRCUITS, CYCLIC PERMUTATIONS, AND EQUIDISTRIBUTED FINITE ORBITS

Steven Alpern
University of California, Los Angeles

Abstract: Computing a continuous map $T: X \to X$ on a finite word length computer which can distinguish points in X only up to a finite partition $P = \{P_1, \cdots, P_n\}$ of X yields a "discrete" map $\tau: P \to P$. In application, for example, P is a dyadic decomposition of the unit square. P. D. Lax has shown that if X is a compact metric space and T preserves a measure m for which $m(P_i) = 1/n$, then there is a permutation $\tau: P \to P$ that approximates T. This means that the maximal error is small if the diameter of the partition P is small. We show that if X is connected and if either n has a small prime divisor or T has a fixed point, there is a cyclic permutation τ_1 that approximates T in the above sense. If X is a k-dimensional polyhedron, m a k-dimensional measure on X, and T is an m-preserving homeomorphism of X, then there is another m-preserving homeomorphism of X, T_1, that approximates T and has a finite orbit which enters each P_i exactly once. These results are proved by establishing sufficient conditions for Hamiltonian circuits in a class of directed graphs which reflect the adjacency structure of Γ and the action of T on P. Analogous theorems are established for partitions which are "almost" equimeasured and for partitions with arbitrary measure distribution. The above results are sharpened forms of previous results of Oxtoby and Ulam, Kartok and Stepin, and the author.

Recent Progress on Path Numbers of Digraphs

by

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and

Norman J. Pullman
Queen's University
Kingston, Canada

ABSTRACT:

If G is a digraph (a directed graph having no loops or multiple arcs) a path decomposition of G is a family of arc-disjoint, circuit-free paths which partitions the arcs of G. The cardinality of a minimal path decomposition is called the path number of G. Analogous notions for undirected graphs were studied by Erdős; Gallai; Lovász; Harary and Schwenk; and Stanton, Cowan and James.

We will discuss recent results of Chein; Mason; O'Brien and the authors. They concern bounds on the path numbers of various classes of digraphs and the determination of those integers which are path numbers of digraphs in a given class. Several open problems will be presented.

ON THE COVERING OF PAIRS

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Let S be a finite set of n elements. Let $C(n,k,2)$ denote the minimal number of k element subsets of S such that every pair of elements of S is contained in at least one of them. We determine $C(n,k,2)$ for $n < 5k/2$.

For $n \leq 2k$ this was done by R. G. Stanton, J. G. Kalbfleisch, and R. C. Mullin. For $2k < n \leq 7k/3$ we have $C(n,k,2) = 7$ except for the case $7k - 3n = 1$. For $7k/3 < n < 12k/5$ we have $C(n,k,2) = 8$ except for the case $12k - 5n = 1$ with k even. For $12k/5 < n < 5k/2$ we have $C(n,k,2) = 9$.

COVER SEQUENCES AND MAPS

by

Lena Chang
Arthur T. Poe
Temple University, Philadelphia, Pa.

A cover sequence of a finite set S is a finite sequence of subsets of S whose union is S. Let f be a map from TT onto S. If one considers f as a table, then each row can be thought of as a cover sequence of S.

The present work establishes the conditions on a collection of cover sequences of S such that at least one function f can be defined from TT onto S. Relations and applications to the theory of decomposition for automata and to the representative selection problem will be discussed.

SOME t-DESIGNS FOR $t \geq 4$

Earl S. Kramer
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A t-design $(\lambda;t,k,v)$ is a system of sets (called blocks) of size k from a v-set S, such that each t-subset of S is contained in exactly λ blocks of . After selecting a permutation group G acting on S, an m by n matrix A of integers is constructed with the property that a $(\lambda;t,k,v)$ exists with G as an automorphism group iff A has an m by s submatrix M where M has uniform row sums λ. For example, with G = PGL(2,17) and $|S| = v = 18$ 3 by 17 matrix A is searched and $(\lambda;4,8,18)$'s are found for 51 different values of λ (not including complements). A number of other t-designs for t = 4 and 5 will be discussed.

Di Paola, Jane ii,, Florida Atlantic Univ ersity, Totally non-sym etric quasi rouns and combinatorial d signs. A totally non-sy metric quasigroup ::;atisfies (i) ab=ba only if a=b and (ii) (ab)a = b, b = a(ba) Such quasigroups are shown to be idempotent and to have cyclic multiplication (ab=c implies bc=a). The ain results are I. If there exists a totally no -symmetric quasigroup o v elements there exists a balanced incomplete block design with parameters v, v(v-1)/3, **v-1**, 3, 2 and II. There exists a totally non-symmetric q csigroup of ordtr v=6t+1 whenever 6t+1 is a power of a prime.. An e::::ample shows the converse of I. to be false,

ON UNICYCLIC GRAPHS IIAVING TWO DISJOINT t'..AXIM/\LY.ATCHINGS

B.L. Hartnell
Uni¥ersity of Manitoba

We are. interested in obtaining information on thos.? unicyclic graphs rhich possess two disjoint maximal matchings. tn t is paper, we characterize :hose unicyclic graphs in which each of the trees rooted on the circuit cave two disjcint maxilllal matchings, but the graphs themselves do not,

A PARl'ITICU!NG ISOMORPH.ISM AiillRITii?1 FOR DIREX:TED GRAPHS USING THE F MATRIX

L.E. Druffel & D.C. Schmidt,
Vanderbilt University ;
J.E. Simpson, University of Kentucky.

A number of characteristics have been used to define conditions necessary for isomorphism. Traditionally, gcaph isomorphism algorithms attempt to find a permutation of the adjacency matrices of the two graphs. Druffel and Schmidt have reported a partitioning algorithm using necessary conditions based on the distance matrices. The algorithm is effective for a large number of grapns, including some regular graphs. However, using the minimu..il distance matrix for graphs with a maximum distance of two offers no improvement over the use of the adjacency matrix. Kelly has defined a m trix F for which each clc:uit:i aLf$_{1J}$ cfiuc t!i nu c= ::::;afd.;.::= i t.l":::::::::.=:;::-.aph d ed. t-:' re.moval of the vertex pair vi• Vj, Conditions necessary for isomorphism based o:n the F mat.cix are similar to the distance matrix so that the partitiOtting algorithm may be applied using the F watrix. **The algorit."un so applied is practical. for non-regular graphs.**

THE PRODUCT OF INDEPENDENT SETS OF THE VERTEX-INCIDENCE VECTORS OF A LINEAR GRAPH

by R .C. Gelrlm2.chcL and C. S. Liu
Department o.fElcctc ical Engineering
Stevens Institute of Technology

Abst:.a.ct

Given a linear graph G=(x, r) with |X| = n and with reduced ve:::-tex-incidence m;,.trix [A] consisting of row vectors {a.1, a.2, ••• ,a.$_{n-1}$}. Define S as the set of vectors of all possible combinations of th row vectors of [A), i,e.

$$S = \{ s \mid s = \sum_{i=1}^{n-1} c_i a_i \text{ where } c_i = 0 \text{ or } 1 \text{ but not all 0's} \}$$

The following theorem is proved: If [A] is a reduced vertex-incidence matrix oi ann-vert ;c linear graph G and B = {131,B ,... ,j3$_{n[:S}$}and C ={y,,'Y$_2$ •'" .. ,')'$_{-1}$} are sets of independent vectors of . then J[C is nonsii'gclz.:: ar.d!cfet [.BJ[\ | is equal to an integer multi!)le of the nu.-nber of trees of G.

INVERSE V1FFERENT1AL" OPE'RATo·RS OVER GRAPH-LATTICES

Charles C. Cadogan
University of the West Indies

The ge.n.ua.l 601tm 06 a. c.ta.,H 06 -ltivu.se di66e1t-entia..t ope1ta.toll.1;oveJt polynom-<.a.U de6ined on pa.1tt-i.ti.OM 06 po6i.t.lve .lntegeM .11;obta.ined. The coe6{.lc-i.er..u. in the polynom.la.l6 a11.ethe nu.mbeM v6 gene.1;,a.lgll.a.ph6 and the application 06 the ope11.a.tolU> to the.6e polyncm.la.U detv:.m-i.nu a, counting 6e11.lu 001;.mu.lt.lg11.a.ph6 on th 11.upect.i.ve pa.11.t-ltioM. The bMic ,1;,t.'1.u.ctu.11.e, g1:.a.ph-la.ttice, comma.nd1; a, vital 1tole in e,,1;ta.bl-i.1,h-lnge 6-lna.1. 601tm 06 the ope a.toJt.

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Computational Aspects of the Study of Bicek Designs HHing Regular Rcpresen_tations

A. !laartmzns, K. Dar.hof and G. Frank
SOUTHER/I IU.I1101S u:1:vrnsnv

kl aut;;irnorphism a on a (v,b,r,k,;1.) block design Dis.said to c'ict regularly or, if it permutes both the points and blocks in orbits all of the same length n ı > 1). A design admitting a regular automorphism submits to a relatively simple i rese:1tai:io:1.. !n previous work, Baartrnans and Oar.hof have develop<:d ,1ecessary id ·sufficient conditions for a block design tc adr.iit a regular auton1orphism. 1ese ccnditions suggest a series of algorithms which can be used to determine if giv2r, design {kno1m or unkn01m) admHs a regular automorphism of a given order. ı effect, the problem of finding an unkr.own desi9n is replaced by the simpler and ire res:ricted problem of finding a regular representation for the design.

The algorithms {implemented as computer prograrr.s) for carrying out the :>rocess e deso•ibed. Heuristic techniques are needed in several of the algorithms. i-he ·cblems of applying the heuristics--such as chosing an effective state-space rc- ·esentati•Jn, finding a good evaluation function and reducing the number of eq, i\•., !Ot nodes--are discussed.

Vario s r J lts of applying tbe programs to specific design parameters are isted. The results indicate m:W repre!>entations for several desig:1s ;;;;d :he >n-existancc of regular representations fqr other (known and unknown) designs.

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A Computer Construction for Balanced _Orthogonal Matrices

Paul J. Schellenhc,rg
University of Waterloo

A balanced weighing matrix is a square orthogonal matrix of O's , l's and -1's such that the matrix obtain<ld by squarine entries is the incidence matrix of a (v,k,A) configuration. The existence of a (v,k,A) ccnfig'.lration with appropri.:;te parameters does not imply the existeoce of a correspondio balanced weiGhing.matrix as is hown for v = 16, k a 6 and) - 2 • • •

The structure of cyclically gener ted balarlc tl weiching matrices ilas bee:i the object.of sc,veral investigations. Using these properties, a computer search is car.:-ied o:it for balanced weighing matrices corresponding to (v,k,;1.) configurations with small valcr,s for v .

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\'IHS'1'TOU RNM,:ENT

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Department of athematics
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E. H. f,'.core [!,mer. J. r.'iath. 18 (1896) ,290-JOJ J defines a Whist Tournar::ent in v players, Ylh [v] , as an arrangement of v-1 rounds of play such that every player meets every other player once as partner and twice as onnonent, a round being a list of ¼v tables cxhaustim the list of players.A table is a set of fou!' players with. a distinguished partitior. into pairs called tJartners, the other four pai"rs being known as op:,onents. It is shown that Wh [v] exist for all v=c4;,,.except possibly v=1J2, 152, or 264.· without the·distinction between partners a.1d opponents a W:1 -2 is a re oJ.vab:!.e BIBD with k-=4 and A=J•

@)

"S_tcincr Quadruole Syster.is on 16 Sy:nbols"

P.B.Gibbons, R.Mathon, and D.G.Corneil
- University of Toronto

A new rn<>thod for the systematic generation of Steiner quadruple systc;;is·of order vis discussed. This method incorporates a state-space search, where the space of & ates corresponds to the s t of quadruple systems cf order v, and tha operators are bijections which are applied to subsyste1:i,; of a quadruple system. The object of the sear:::h is to obtain all pairwise non-isomorphic designs reachable from a specified start desiga. Formi.:las for tr.e num1 . rs of subsystems in an order-v quad:::-uple system are derived, leading to a classification of the generated designs according· to th-a :1umbers of subsystem!:. th1=y co:-itain.

In particular the method is appljed to the case v=,1€. Properties of the generated set of d2signs are examined, givi.:.g in!o=mation on the derived triple syster.iz, and also on the s :ucture and number of higher order quadruple systems.

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FINDING THE INDEPENDENT SETS OF A MATROID

Lambert S. Joel, Marjorie L. Stein and Christoph Wit:::gall
National Bureau of Standards

Abstract

Axioms for circuits and axioms for independent sets are two equivalent ways of defining matroids. However, all proofs of this fact in the literature rely either on another set of axioms or or. additional concepts such as duality. In a new proof of this 2quivale..,ce, we derive the independence axioms from the circuit axioms by constructing an algorithm for generating the inC:epcn:ent **sets** of .:he matroid from its circuits.

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Skew-Tran6lation Generalized Quadran.;;.J.es

Stanley E. Payne
Miami University
(Ohio)

Abstract: Let G be a group of order s^3 . Let L = {H. lo.::_i ::_s + l} be a collection of subgroups, each of order s, for vfiich HiHj n Hk = {e}, ir i, j, k are distinct. Then the incidence structure! S*. = \1', B, d ;,,ith P = G and 8 = {Higjg ε G, 0 ::_i ::_s + l} is a generalized qi..adrangle of order {s - J., s + 1). Let Ho be a norma.l subgroup of G. '!'hen S* may be constricted about the pivotal family Mo = {l! g lg ε G} to o·ot,air. a skew-translation generalized quadrangle S of order {s, s). In this way all knovn generalized quadran0les of orders {s, s) or {s - l, s + l) raay be obtained. This construction provides a generaliz tion of the kno\l!l ones via coset geometries in a nonabelian group in a manner i.na:ogous to the construction given by Tha.s of translation generalized uaclrangles sing elementary abeli n groups.

@.. Coioring Pln:nar raphs with Five or More Colors II

Roy B. L3'1ow
Florida Atlantic University

At this Conference last year the authoc presented the ccn- ject e that lf G ie a planar grapr., P. iJ a subgraph, n> !', ar,.d O < r < n there i3 a t\:nc!:ion i(H,r.,.c) such that an I'- co:'.or.n of- li extends t:, an n-colori;,g oi C ! .rd only i:': ÷ ex(;noD p .n n-coloring of: ::..13 induced si:bgraph cf C c.,,.- _:.;d:v c: ver:::.cs, v, of G sr..tsfyir.s- c.:,,1.: f(!I, .,::'. Tu on;..cti.!::e wa -he. .verii:!ei. for "sm:--" o clei.. :u=:.:- ...,:.ul;tJ !:o::i the inve&tig.,,ticn of thi3 conjec-.i.::e :.ill :a : : .- -__l!ed. :n pa=ticular, r h2 conjcct·.!!'.e is ;;;;;_ fo.i: - - : •

HDEPENDENCE IATIOS AND TOIGIDAL GRAPHS
by
Hichael (h ID r-tli.QlI, Smth Conei;e and
Joan P. Hutchinson, Dartmouth Colleee

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Supyuse G is a graph with V vertices that embeds on the torus. A set of vertices I is independent in G if no p?ir of vertices in I is adjacent in G. Let ol(G) be the maximum number of vertices in any independent set, and...((G) be d. (G)/V. the 1rrc1enendence ratio. Set U(1) = f;.\(G) : G ecbds en the torus1 and L(1) = limit'i>oints of U(1)} • Thee are essentially only four to oidal graphs w-th ndependa. ratios less than ./'i (A.lbertson "nd liutch:!.nso::!, "T;13 Independence ijf.tio and Genus of a Graph"). Theorel'l. =;(1) C [/

@ A Lowe • Bc, d on the Ctu.'o,natic Number of' a' Sphe_re

Gustavus J. Simmons
Sanda Laboratories
Albuquerque, New Mexico

The chrc.'Tlatic m:mber x(s$_r$) of the three dime:nsional sphere, S$_r$, of radius r is d:?fined to be the :i.east number of sets partitioning the surface of S$_r$ such that no set contains two points at unit chm·dal distance apart. Obvi:msly, x(S) = 1 for r < $\frac{1}{2}$ am! x(S$_i$) = 2. ::lim. 1ons had shci-r.1 that x(S) ?.4 f'or r:::; .fj and had. conjectured that x(Sr) ?.4 for all r > $\frac{1}{2}$, i.e. for o.ll no1- t.rlvial. case!., . The nri1 result of this p::per is a p:-:-cof of this conje:ct.i..e-- .w.ch. at t.l;t: s=.:i ,1de 1'Cnders •.umec-a?s:;ary the specitl a.:-gum,z::ts requir.:id for ....i C.Jo<S L Li<? ...i-1.i.erIn-estigat;.c:.J Ol' tl,c doron.1fc n;bor cf the spIe.-.... _ t .... :) l, ?- r >./.½ '..... _C,SdbC :.1e x(s ,'12> = 4.

@ EARL GI7,r I;UITEHS \D, JR., Un1'-r..1ty of Pittsburgh

Chro!n3t1c "olvrior.:1 1s f'or !)ot11e Cycles

A double eve le is a er2ph with n vertic2s ::-.2 1a n ed&es such t:1at the cdr;c set can be p.:1l t:tlioned into t;-10 disjoint n-scts, ech of wh1c1 is an edge set for an n-cycle on the n vertices of t1e vertex set. R&c.1rrenoc relations for chrot!at1c polyno::,1..ls of s:,ec:ial c12sses of do'.ble cycles are given. These recurre::i.c.,; :i.'(;laticns y1 1:! fast algorithms for cr.,1.1pUng chrol:!::-.tic poly- rol'?;lals for thee spe al clas:::.as. Tcse 2.lg::>rith:ll::. ara r:=late.c. ";, the Oc: :::.x:..rr c?.i; ; ::,:il -;•f'>i.ial cc:aplet eoblna t:>rial 1:-t.cr.. ...

@ 1loloncr:d Colo..:,:ir., s and Grar,h rf. nt11tio1'

J. A. ?0116;•
Ur.iv .,.,Hy _O£ ;;.,. crloo

An und!rected er ph c=n, in i ncral, be ri nted in many ways. Of particular interest are oriantations wh!ch have certain r;pecifi d properties. Theor os of H.E. RoLbina and C. St. ;,A. Nash-Williams, !or example, are ccncerned with the arc conn ctivity f the rP.sulting orientation.

Let G be a graph in which all vortcr. degree h ve the sace parity, and let k be a nonnega ive integer. i.e giv-, a neccs:."l') and eufficient condition for C co have ac orientation ir. which, at each vertex, the !n anJ ?uc Le&recs d ffer by e.Qctly k; and shoJ hc,v thla condition is re .·.:.:d to botl. :irStzach'a tl,eorem OUld tw fouc codur conjedux •

On Graohs of Ramsey Tyoe

S.A. Burr AT&T Long Lines
P. Erdos Hungarian Academy of Science
L. **Lovasz** Eotvos L. University

If F, G, and H are graphs, write F (G, H) to signify that.if the edges of.F are colored d and blue in any fashion, either the red subgraph of f contains a copy of G or the blue subgraph contain3 a copy of H. Various· properties of such graphs F are studied.· For instance, for given G and H, the minimum chromatic number X of any graph F for which F--; {G, H) can be determined, at least in principle. In particular, if F (Kr.„ K_n), "X(E') 2 r (m, n), where r (m, r.) denotes the ordinary Ramsey number. Thus 6(F) r(;:l, n)-1, where 6(F) denctes the maximum degree of F. On the other hand if F is a ;:iiniroal graph for which F-4 (K_{m}, Kn), then S°(F) ± mn, here (F) denotes the minimum degree of F. Ea h of the Qbove re lts is sharp.

OPTIHIIL RE1\RRANGEABLE GRAPHS

F. R. K. Chung
Bell Laboratories
Murray Hill, New Jersey

Let G bee finite graph with vertex set V = MV N. We say that G 1;; rearrangeable if fo:- alJ. choices of distinct vertices i1,12, •..,it in X and J1,J2, •••,jt in N, t::iere exist vertex disjoin_t_paths between i_k and J1, for all k. For exa.,:iple, a corr.plete bipartite graph with the vertex sets M and r: is.rearrangeal::le. However, this graph Will usually have many ore ecges than is necessary for rea::-rangeability.

We determine the minimal.nu."ber of eGges any rearrangeable graph may have for all choices of Mand N. We also discuss generalizations in which V is strictly great r than ML; N anci/or t is boundei by a predej;e=Leci value.

Ramsey Numbers of Families of 2-Complexes

R. A. Duke

Georgia Institute of Technology

In the last few years a great deal of work has been done in what has come to be known as generalized Ramsey theory for graphs. A long !ist of "generalized Ramsey numbers" have alrnady been computed. In the most recent of a series of papers on this subject co-authornd by Frank Harary the area was extended to include generalized Ramsey numbers for pairs of 2-dimensional simplicial 2-complexcs. In that paper Ramsey numbers for several small pure 2-complexes, or plexes, wre computed.

In most of the cases for graphs the critical colorings are fou;-:d among a few rather simple canonical types. The critical colorings found so far for 2-complexes often involve Steiner triple systems or other designs.

In this paper values are obtained for the Ramsey numbers oI certain classes of pairs drawn from the families of 2-cornµlexes described in the paper mentioned above. The techniques used include the utilizatio:1 of know:i values of the Ramsey numbers for graphs as well as various resuits from the study of block designs.

ON SUDCRAPH VIDER INDEPENDENCE DinuES

by
R. L. Grtlhom
Dell LetoraturiC.S
Yummy Hil!. Cw Jersy
E. SzemerCdi
The Hungarian Academy of Sciences
Budapest, Hungary

For finite graphs F and C, let NF(C) denote re number or occurrences of F in G, 1.e.,. the number or subgraphs of C "Which are 1::;or:ior;ihlc to F. If ;; and G ere f&::i.1:!es of graphs, 1t 1s n&tur&l to esk them whether or no the J&-1tt'es N_F(C). FcJ, are linearly independent hen G 1$ restr!.ctet! to <; For exomple, 11"; • (K_1, K?J (here K denotes the complete graph on ; verticeG) and G is the ta--ily o all (finite) filE then of course N_{F_1} (T) - N (T) a 1 tor all T<C. Slightly loos tr1v1"lIY, 1f:; • (Sn: n 1, 2, 3, •••) (where S_n denotes the on n edges) and C 111ga1n1s the family or ell trees then

$$f: (-i)^{n+1} N_{S_n}(T) \cdot 1 \text{ tor all } T<\{.$$

n=

It will be proved that such a linear deper.C ce can occur :t d is t'1r.1te, no FeG has an isolated point and G cont1ns all trees. Thia result has !c>orant applic4t1ons 1n recent voric O: L. tov4 sZ and one of the authors.

• co1mrrnc ALCORITIIXS FOR CONNECTED LABELLED GRAPUS

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D.D. Colol:i.n, R.C. Xullin, and R.G •. Stanton
University of Waterloo

-ABSTRACT. Althouch cethods exist in the literature for the cou::ierat:!.on of connected linear graphs by partition, these generally involve group theoretic expressions which do not lend thC.t:1selves readily o coi::put.i.tional techniques. The authors obtain recursive 11:ethods which are amenable to computation Ly v..rlous formula manipulation techniques.

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FINDING SIMPLE PATHS IN A GRAPH BY **SYMBOLIC** MANIPULATION OF BOOLEAN EQUATIONS*

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Albuquerque, New Mexico

Simple paths in a graph can be determined by the symbolic manipulation of Boolean equations. In this procedure a graph (directed or undirected) is represented by a set of Boolean equaticris--one equation for each node. By a process of substi- tution, an equation is generated hich represents all ti:e simple paths from one node to another. Application of the distributive law to this equation then delivers a disjunctive normal form wherein each term is one of the si ple paths. The Set Equation T ransformation System (SETS), a software package for the symbolic manipulation of any Boolean equations, has been used to carry cut this prccedure for se eral example graphs.

* This work **was** supported by the· United States Atomic Energy Cor.unission.

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A LATI'ICE ALGEBRA FOR FINDING SD'.PLE PATHS AND CUTS IN A GRA.t-""H*

Bernie L. Hu.line
Sandia Laboratories, Albuquerc;.ue,.N. M. 871.15

Ari algorithm for finding sLnple paths in a directed or undirected graph has been given by Fratta and Montanari and a similar algorithm for cuts has been presented by Martelli. Each of these authors has developed a different "regular algebrar, appropriate for the proble:n. In this paper we present an algebra, a.1.wost identical. to Martel.li's, in which both the si.I:lple path and cut algorithms are valid. We show that this algebra is a self-dual distributive lattice. Tnus, we unify the treatment of the simple po.ths and cuts within a. single algebraic structure and find tt.a.t they a:l'e naturally related by the concept of duality.

* n d s work was suppoz:ted by the Unit ed...sts.t. s Atomic Energy Co:mnission

The enumeration of hon:coloorphtcally irreducible labelled graphs

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D.N. Jackson and J.W. Reilly
University of \.,aterloo, Canada

This paper gives the exponential counting series for the nut:.ber of homeomorphically irreducible labelled gra·phs, with and witho:,t cultip:e loops and edges. The series obtained bears a i.trong resembla;ice to t!1e series given by Gilbert for the nur.:ber of gra;:,hs on a specified nlinber of vertices and edges. The derivation involves the application of the Principle of Inclusion and Exclusion together with a decoi7.position o: ::he configur.:.tions involved into multiple-loops and ultiple-edges with edge subdivision. A linear recurrence equation is obtained which pe ts the number of homeo::ior;,hically irreducible simple labelled graph.:; on n vertices to be computed in $O(n^2)$. Tabulati n fo: this case a:id the corresponding connected case are obta.ined for O s n s 20; **(Paper** submitted for publication elsc here.)

Complexity of the Vari:ible-Lcngth Encoding Problem

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Norbert Cot
Department of Electrical Engineering
Stanford University

A prefix code is given. It cor.sist:s of n word,s w, with symbols dr:.wn from an :ilphat;.ct aj. Tc, e:ich letter a_j is associated a cost a_J and to each codeword w_i a probability P_i. Then the cost c_1 of a word equals $\sum_3$ aj and the cost of the code e is such that e = r P . 1. c 1:

The problem is to find the optimal code (minimal cost)., Karp formul:ited this problem in terms of int.?ger pro ramr.iir.g, which 1.eads to a possibly non-polynomial solution. With the following condition, P i = Pk' V1, k, some algorithms are known·requiring O(n log n) steps. Using some structural properties of the probler.i, we recently showed how to only use O(n) steps for a binary alphabet.

In this paper, using some additional theorcr.is, we s!-,ow how to extend the result to a general alphabet. We then analize t;1e i::i- plications to the general problem.

co:1PUTER DECOMPOSITION Cf DIFFERENCE SETS

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R.J. Callens
University of Manitoba

A computer algorithm which tries to divide a differenc set of cardinality n with differences each occurring), ti::ies into two disjoint s®sets A and B of cardinality **k** anc! n-k such that the differences of **A** and the differences of B • together s m to),/2 , will be preserrted.

AUTOMATIC GENERATION OF KEYWORD DETECTION SOFTWARE

R.J. Collens and P.H. Dirksen

University of Manitoba, Winnipeg, Canada

University of Waterloo, Waterloo, Ontario, Canada

The construction of programs for the detection of keywords is common to many computer applications. We describe here a system for the automatic generation of such programs. The resulting keyword detection programs are both reliable and efficient.

Minimum Turn Euler Circuits

Frank O. Hadlock, Florida Atlantic University

Given a block pattern which has been augmented to have only even vertices, a simple algorithm is given which produces a minimum turn Euler circuit. An underlying assumption is that the augmented pattern has no edges of multiplicity > 2. With this assumption, a pattern decomposition is defined for which the number of components increases the number of turns in the minimum turn circuit. A branch and bound matching algorithm is given for matching odd vertices so as to minimize not only the cost of matching them but also the number of components in the augmented pattern.

This research is being carried out under a grant from the FAU-FIU Joint Center for Environmental and Urban Problems.

A CONSTRUCTION FOR BIBDs, RBIBDs AND 3-DESIGNS

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UNIVERSITY OF WATERLOO

S.A. VANSTONE
ST. JEROME'S COLLEGE, UNIVERSITY OF WATERLOO

A construction is given for balanced incomplete block designs (BIBD) resolvable designs (RBIBDs) and 3-designs which makes use of substituting disjoint equicardinal sets from one design for varieties of a second design.

Magic Pair-Wise Balanced Designs

U.R.S. Murty

University of Waterloo

A pair-wise balanced design is said to be <u>k-magic</u> if positive integer weights can be attached to its points so that the sum of weights of points on any line is equal to k. A <u>magic</u> design is one which is k-magic for some k. Some constructions of such designs are presented. The problem of characterizing magic designs which are embeddable in the real plane remains unsettled.

Minimizing Weighted Conflicts

by Paul G. Kainen

Case Western Reserve University

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If, in the exam scheduling problem, the number of exam periods is fixed, one tries to minimize the sum of the weighted conflicts. We examine this situation from two points of view, (1) Every weighted adjacency graph is induced by a bipartite graph and we seek a minimal such bigraph. In terms of the example, what is the minimum number of students needed to produce the weighted adjacencies? (2) If all weights are unity and there are only two colors available, how many conflicts can there be?

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R. Haggkvist and C. Thomassen *)
University of Wcrterloo -

On Cycles in Di graphs

We determine tne minimum degree which guarantees a strong digraph to contain cycles of all lengths and the minimum number of edges guaranteing a hamiltonian digraph to contain cycles of all lengths. As applications of these results we determine for each k the minimum number of edges required t.o insure that a digraph includes a cycle of length k. The corresponding problem for undirected graphs has not been solved completely for k even.

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A NEW BLOCK DESIGN

W. H. Mills

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Princeton, New Jersey 08540

A balanced incomplete block design with $v = 106$, $b = 371$, $r = 21$, $k = 6$, $= 1$ was found by computer. This is apparently the first BIBD ever constructed with $= 1$ and. $v \not\equiv 0, 1 \pmod{k}$, although R. M. Wilson has shown that such designs exist if v is sufficiently large.