=$;NO@J8

3,AX7?%i%8%*%7%F%#K!Kh$k
2hA|@8@.%7%9%F%`$N9=C[$H$=$NJBNs2=

;XF3650w!';3:j>!90 65<x

O@J8Ds=P<T;aL>!'@u@n C#Lo
3X@RHV9f!6124960002-3

1998 G/2 7n13 F|Ds=P

N)L?4[Bg3XM}9)3X8&5f2J
=$;N2]Dx>pJs%7%9%F%`3X@l96

E&MW

K\O@J8GO!$3,AX7?%i%8%*%7%F%#K!$Khk2hA|@8@.%7%9%F%`$N9=C[$H$=$NJBNs2=$K$D$$$F=R$Y$k!%%i%8%*%7%F%#K!$H$O!$J*BNI=LL$r9=@.$9$k%]%j%4%s$r:Y$+$$%Q%C%A$d%(%l%a%s%H$KJ,3d$7!$3F!9$K$D$$$F8w$N=PF~$j$r7W;;$7$F51EY$r5a$a$kJ}K!$G$"$k!%J*BN4V$N8w$NAj8_4X78$r07$&$?$a!$Hs>o$K8=<B46$N9b$$2hA|$r@8@.$G$-$k!%%i%8%*%7%F%#K!$G$O!$%U%)!<%`%U%!%/%?$H8F$Plk%Q%C%A$d%(%l%a%s%H4V$G8w$,E~C#$9$k3d9g$N7W;;$,=EMW$HJk!%0lJ}$G!$%U%)!<%`%U%!%/%?$N7W;;$K!$7W;;;~4VA4BN$N9 3d0J>e$r@j$a!$G|Bg$J;~4V$rMW$9$k!%3,AX7?%i%8%*%7%F%#K!$O!$%]%j%4%s$rH?I|E*$K:YJ,$7!$3,AX:YJ,Cf$N>eAX$ND:E@$N%U%)!<%`%U%!%/%?$rMQ$$$F!$2<AX$N%U%)!<%`%U%!%/%?$r6a;w$9$kJ}K!$G$"$k!%3N3H$G!$2hA|$N<A$r0];}7D$D!$7W;;;~4V$r:o8:$9$k!%$7$+$7!$3,AX7?%i%8%*%7%F%#K!$rMQ$$$F$b7W;;;~4V$,$+$+k?$a!$3,AX7?%i%8%*%7%F%#K!$rJBNs2=$9k3HG!$7W;;;~4V$rC;=L9k!%$^$?!$K\8&5f$G$O!$J,;6%a%b%j7?JBNs7W;;5!!$AP-1000+$rMQ$$$F<B83$r9T$&!%

3,AX7?%i%8%*%7%F%#7W;;8e$N%G!<%?$G$O!$2hA|H7$F=PNO$5lJ$$$N$G!$B>$N<jK!$G%l%s%@%j%s%0$r9T$oJ1lPJi$J$$!%$=$N$?$a!$%7!<%s$N5-=R$+$i2hA|$N=PNO$^GN2hA|@8@.%7%9%F%`$r9=C[$7$?!%$3$l$O!$$3$l$^$G8&5f<<$G$J$5$l$F$-$?%i%8%*%7%F%#K!$NJBNs2=$N%7%9%F%`$N%W%j%W%m%;%C%5It$H%W%l%S%e%"!<It$rN.MQ$7!$3,AX7?%i%8%*%7%F%#7W;;It$H%l%s%@%i!<It$r:n@.$7$?!%

K\8&5fGNJBNs2=$K4X$7FO!$%]%j%4%s$NLL@Q$rMQ$$$F9T$&!$@EE*Ii2YJ,;6$H!$%U%)!<%`%U%!%/%?7W;;Cf$N%l%$$rMQ$$$F9T$&!$F0E*Ii2YJ,;6KD$$$F8!F$$7$?!%@EE*Ii2YJ,;6$G$O!$%]%j%4%s$rLL@Q$NBg$-$$=g$K%=!<%H$7!$$3lr3F%W%m%;%C%5$K3d$jEv$F!$Ii2Y6Q9U$r?^$k!%LL@QNBg-$J%]%j%4%s$[$I!$3,AX$,?<$/Jj!$7W;;NL$,A}$($k$?$aG"$k!%$^$?!$LL@QNBg-$J%]%j%4%s$rJ,3d$7!$3F%W%m%;%C%5$NIi2Y6Q9U$r!$$5iK?^$k!%$3lO!$%]%j%4%s$NLL@QNBg-Jb$N0l$D$G!$>.5JbN0lDN?tG\$+$i?t==G\$N7W;;;~4V$N:9$KJkNG!$$3lrKI0?aG$"$k!%

F0E*Ii2YJ,;6GO!$%W%m%;%C%5$r%0%k!<%W2=$7!$%0%k!<%WFb$GIi2YM=B,$r9T$$!$%]%j%4%s$r3djEvF$k!%$^$?!$Ii2YM=B,$O!$%U%)!<%`%U%!%/%?7W;;Cf$N8r:9$9$k%l%$$rMQ$$$k!%8r:9$9$k%l%$$NK\?t$+$i!$%]%j%4%sCf$K!$J|<M%Q%C%A$+iN8w$,E~C#$9$kNNO0h$H7J$$NNO0h$,4^$^lF$$$k$+$,J,$+$j!$N>J}$NNNO0h$,B8:_$9$k;~!$:YJ,$,7+$jJV5l!$7W;;NL$,A}2C9k!%N>J}$NNNO0h$,B8:_9k%]%j%4%s$,!$0lDN%W%m%;%C%5$K=8Cf$7$J$$$h$&$K!$8r:9$9$k%l%$$NK\?t$rB?$$=g$K%=!<%H$7!$3F%W%m%;%C%5$K3djEvF$k!%

@EE*Ii2YJ,;6GO!$It20$N%7!<%s(%]%j%4%s?t:238)$rMQ$$$?%7%_%e%l!<%7%g%s$N7k2L!$4Bf;HMQ;~$GLs3G\!$16Bf;HMQ;~$GLs8G\$NB.EY8~>e$,4|BT$G$-$k!%

L\<!

?^L\<!

I=L\<!

1 O8aK

%3%s%T%e!<%?Kh$j%G!<%?$r=hM}$7!$2hA|H7$F=PNO$9$k5;=Q!$$"$k$$$O!$2hA|$=NbNr0UL#9kCG(Computer Graphics) $O!$:G6a!$%F%l%SHVAH$d%3%^!<%7%c%k!$1G2h!$$5iK$O0eNE$J$II}9-$$J,Ln$G?tB?$/MxMQ5l$F$$$k!%$=$NCfGb!$2f!9$,@83h9k3<!856u4VCf$NJ*BN$d>p7J$rI=<($9$kLdBj$r07$&3D-CG(3<!85CG) $N8&5f$O!$%3%s%T%e!<%?$N3+H/$KJbD4$r9go;$FHs>o$K@9sHJj!$8=:_$K;jCF$$$k!%3D-CG $r1G$7=P9?aN<jK!H7$F !V1%$%H%l!<%7%s%0K!!W!$$Vi%8%*%7%F%#K!!W!$$V\%j%e!<%`%l%s%@%j%s%0!W[1][2] Ey$,$"$j!$K\8&5fGO%i%8%*%7%F%#K!KD$$$FHj$"$2$k!%

%i%8%*%7%F%#K!$O3H;6H?<MLL$NAj8_H?<MKh$k8z2L$r9MN8$7$F51EY$r7hDj$9kbNG$"$j!$$-oa$F%j%"%k$J2hA|$r@8@.$9k3H,G-!$;kE@$K0MB8$7$J$$8=>]$NI=8=$d2:d+$J51EYJ,I[$NI=8=$KE,$7$F$$$k!%%i%8%*%7%F%#K!GO!$J*BNI=LL$r9=@.9k%]%j%4%s$r:Y$+$$%Q%C%A$d%(%l%a%s%H$KJ,3d7F7W;;9k!%$3$3$G!$%U%)!<%`%U%!%/%?$H8F$P$l$k%Q%C%A(%(%l%a%s%H) 4V$G8w$,E~C#$9$k3d9g$N7W;;$,I,MW$H$J$j!$$3$l$O!$2=E@QJ,$r2r$/$3$H$G5a$a$k$?$a!$2r@OE*$K2r$/$3$H$O6K$a$F:$Fq$G$"$k!%$=$N$?$a!$6a;wCM$r5a$a$kJ}K!$H$7$F!$%X%_%-%e!<%VK!$dH>5eK!!$area-to-area Monte Carlo %U%)!<%`%U%!%/%?Ey$,Ds0F$5l?[3]!%

0lHIE*$J%i%8%*%7%F%#K!$G$O!$%U%)!<%`%U%!%/%?$N7W;;;~4V$,A4;~4V$NBgItJ,$r@j$a$k$N$G9bB.2=$,I,MW$H$J$C$F$/$k!%$=$N5;K!$H$7$F!$3,AX7?%i%8%*%7%F%#K![3] $,Ds0F$5$l$?!%3,AX7?%i%8%*%7%F%#K!$O!$2h<A$N@:EY$r0];}$7$D$D!$9bB.$K2hA|$rF@$k5;K!$G$"$j!$%(%l%a%s%H$N?t$r$=$N$^$^$K$7$F!$Be$o$j$K7W;;$9$k%U%)!<%`%U%!%/%?$N?t$r8:i9N3H,G-$k!%%U%)!<%`%U%!%/%?$O!$%(%l%a%s%H$N?t$NN_>h$G$"$k$N$G!$$3$N?t$r8:>/$5$;$k$?$a$K%(%l%a%s%H$r%0%k!<%W2=$7$F!$%0%k!<%W4V$N%U%)!<%`%U%!%/%?$rMQ$$$F!$8D!9$N%(%l%a%s%H$NA4$FNAHN%U%)!<%`%U%!%/%?$r6a;w$9$k!%$3N3HG!$7W;;%3%9%H$O$+$J$j>/$J$$$bNHJk!%$^$?!$%]%j%4%s$N7A>uKh$j3,AX9=B$$N9=@.rJQ(!$0lHIE*$J%i%8%*%7%F%#K!$N2hA|$HHf3S$r9T$$!$B=?'$N$J$$2hA|$r@8@.$9$k8&5f[4]!A[9] $b9T$olF$$$k!%K\8&5fGO8=:_!$;M3Q7A$N%]%j%4%sN_$r;HMQ$9kN$G3,AX9=B$$O#4J,LZ9=B$$G9=@.9k!%$^$?!$3,AX7?%i%8%*%7%F%#K!$H$N7W;;;~4V$H2hA|$N<A$rHf3S$7!$3,AX7?%i%8%*%7%F%#K!$NM%0L@-$r<B>Z$7!$%U%)!<%`%U%!%/%?7W;;$N%l%$$NK\?t$d3,AX9=B$$r9=@.$9$k$?$a$N%U%)!<%`%U%!%/%?$N:9$NE,1~HO0O$rD4$Y$k!%

$^$?!$%i%8%*%7%F%#CM(%i%8%*%7%F%#7W;;7k2L) $@$1GO2hA|H7$F=PNO$G$-$J$$!%2hA|H7$F=PNO$9k?aK!$%i%8%*%7%F%#CM$rMQ$$$F%l%s%@%j%s%0$r9T$&I,MW$,$"$k!%$3$N%l%s%@%j%s%0$O0lHIE*$KZ-%P%C%U%!K!$d%l%$%H%l!<%7%s%0K!$rMQ$$$F9T$&!%K\8&5f$G$O%l%$%H%l!<%7%s%0K!$rMQ$$$F%l%s%@%j%s%0$r9T$&!%3l$N%a%j%C%H$H7F6@LIH?<MEy$,07$(!$$h$j8=<B46$N9b$$2hA|$r@8@.$G$-$k;v$,5s$2il$k!%$=N?$a!$%7!<%s$N5-=R$+$i2hA|$N=P

NO$^$G$r0l4S$7$?2hA|@8@.%7%9%F%‘$r9=C[9k[17][18] I,MW$,$"$k!%K\%7%9%F%‘$O5-=R%G!<
%?$+$i%7!<%s%G!<%?$XJQ49$9$k%W%j%W%m%;%C%5It!$%7!<%s%G!<%?$rMQ$$$F;kE@%G!<%?$r=P
NO9k%W%l%S%e%"!<It!$%7!<%s%G!<%?$rMQ$$$F3,AX7?%i%8%*%7%F%#7W;;$r9T$$!$%i%8%*%7
%F%#%G!<%?$r=PNO$9$k%i%8%*%7%F%#7W;;It!$5Z$S!$$3l^GKF@$?%G!<%?$rMQ$$$F%l%s%@
%j%s%0$r9T$$!$2hA|$r=PNO9k%l%s%@%j%s%0It$+$i@.$jN)$D!%

3,AX7?%i%8%*%7%F%#K!$rMQ$$$F$bJ#;($J2hA|$r07$&$?$aKO!$$h$j9bB.$K7W;;9kI,MW
@-$,@8$8$k!%$3N?aKMM!9$JJBNs2=<jK!$K$D$$$F8&5f$,9T$olF$$$k!%3lKO!$%U%)!<
%‘%U%!%/%?7W;;$N%X%_%-%e!<%VK!$dH>5eK!$r%a%C%7%e$KJ,3d$7!$JBNs=hM}$r9T$&8&5f[11]
!A[16] $d3F%W%m%;%C%5$r%0%k!<%W2=$7!$%0%k!<%WFb$G%"%$%I%k%W%m%;%C%5$r8+$D$1!$$=$l
$K=hM}$5$;$k8&5fJI$,$"$k[19]!A[28]!%

K\8&5fGO!$9bB.2=$r?^k?aNJBNs2=<jK!H7$F!$%]%j%4%s$NLL@Q$NBg$-$$=gKh$k
@EE*Ii2YJ,;6$H!$%U%)!<%‘%U%!%/%?7W;;Cf$N8r:9H=Dj$rMQ$$$?F0E*Ii2YJ,;6KD$$$F$N<j
K!$rDs0F$9$k!%A0<T$G$O!$%]%j%4%s$NLL@Q$NBg$-$$$bN[$I3,AX$,?<$/$J$k@-<A$KCeL\$7!$
3F%W%m%;%C%5$K%]%j%4%s$NLL@QNBg-$$=g$K3d$jEvFk!%$^$?!$0lEY3d$jEvFr9T$&$H7W
;;$N:G8e$^$G:F3d$jEvFO9Tol$:!$J|<M9k%Q%C%A$,Be$o$k;~$NF14|$@$1G9$‘$N$G!$DL
?.$N%*!<%P%X%C%I$,>/J/F9$‘!%8e<T$G$O!$%W%m%;%C%5$rJ#?t$N%0%k!<%W$KJ,$1!$%0%k!<
%WFb$N%W%m%;%C%54V$NIi2YJ,;6$KCeL\$7!$8r:9H=DjCf$N8r:9$9$k%l%$$NK\?t$NB?$$=g$K%]
%j%4%s$r3F%W%m%;%C%53d$jEvFk!%8r:9$9$k%l%$$NB?$$$bNO!$%(%M%k%.!<$NJ|<M$,$[$\
9Tol$J$$$3Hr<(7F$*$j!$3,AX$,?<$/$JiJ$$!%8r:9$9$k%l%$$NK\?t$,>/$J$$;~O3
$N5U$G$"$k!%8r:9$9$k%l%$$,B?$/$bJ/>/J/bJ$$$bNO%]%j%4%sCf$KL@0E$,B8:_7F
$$$k3H$r<($7F*$j!$$3$N>l9g$K3,AX$,?<$/Jj7W;;$,7+$jJV5l$k!%$3lr3F%W%m%;%C
%5$K?6$jJ,$1Ii2Y6Q9U$r?^$k!%$7$+$7!$J|<M%Q%C%A$,Beok$?$S$K3F%W%m%;%C%5$KBP7F
%]%j%4%s$N:F3d$jEvF,9Tol!$DL?.NL$,A}$($k!%7?$,$C$F!$3F%W%m%;%C%5$r%0%k!<%W
2=7F%0%k!<%WFbGN:F3djEvF$r9T$$!$DL?.NL$r8:i9h&K9$k!%$=N?$a!$:G=i$K
%0%k!<%W$K%]%j%4%s$r3djEvF$k:]$K3F%0%k!<%W$NIi2Y$,6QEyKJkh$&$K9k!%

K\8&5fGO!$IY;NDL8&5f=j$G3+H/5l$?J,;6%a%b%j7?JBNs7W;;5!AP1000+$rMQ$$$F!$JB
Ns2=$N<B83$r9T$&!%$3lO64 Bf$N%;%k$G9=@.5lF*$j!$3F%;%k$OF0:n%/%m%C%/?t50MHz!$
64M %P%$%H$N%m!<%+%k%a%b%j!$%a%C%;!<%8%3%s%H%m!<%i!$5Z$S%M%C%H%o!<%/%G%P%$%9JI$G
9=@.5l$F$$$k!%$^$?!$3F%;%k$O%;%k-%;%kDL?.MQT-Net!$%V%m!<%I%-%c%9%HDL?.MQB-Net!$
$*$h$S%P%j%"F14|$H%9%F!<%?%9DL?.MQS-Net $N3<oN‘$N%M%C%H%o!<%/$G7k9g$5lk!%

K\O@J8GO!$$^$:Bh#2>O$G0lHLE*$J%i%8%*%7%F%#K!!$3,AX7?%i%8%*%7%F%#K!$NFCD’!$7W;;
J}K!$r=R$Y!$Bh#3>O$G3,AX7?%i%8%*%7%F%#K!Kh$k2hA|@8@.%7%9%F%‘$N9=@.$r=R$Y$k!%Bh
#4>O$G@EE*Ii2YJ,;6$HF0E*Ii2YJ,;6KD$$$F=RYk!%$^$?Bh#5>O$G:#2s9T$&<B83FbMF!$<B
837k2L!$9M;!$K$D$$$F=R$Y!$Bh#6>O$GK\O@J8$N7k8@$H:#8e$N2]Bj$r<($9!%

2 3,AX7?%i%8%*%7%F%#K!

2.1 %i%8%*%7%F%#K!$NFCD'$H7W;;J}K!

%i%8%*%7%F%#K!$O!$3H;6H?<MLL$NAj8_H?<M$Khk8z2L$r9MN8$7$F51EY$r5aakJ}K!G"$k[3]!%$3$N7k2L!$%i%8%*%7%F%#K!$O!$;kE@0\F0$K0MB8$7$J$$%7!<%s$NI=8=$d!$2:$d$+$J51EYJ,I[$NI=8=$KE,7F$$$k!%Nc$($P!$MM!9$J8w8;ND$/$kIT6Q0l$J1F$d4V@\>HL@$NB?$$<<Fb$NI=8=$KE,7F$$$k!%

3N<jK!GO!$3F3H;6H?<MLL$,J|<M9k8w$N%(%M%k%.!<$KCeL\$7!JD8$?7O$NCfK*1kJ?9U;~$N8w$N%(%M%k%.!<%P%i%s%9$r5a$ak3HKhj!$3F3H;6H?<MLL$N51EY$r7hD}$9$k!%$^$:!$F~<M8w$,A4$F$NJ}8~$KF1$86/EY$GH?<M9k$H2>Dj$9$k!%$3$N;~!$$"$k#1$DNLL+$iH/$9$k8w(%i%8%*%7%F%#)$O!$<+8JJ|<M8w!$5Z$SB>$NLL$+$iF~<M7F3H;6H?<M9k8w$G9=@.$5lk!%3N#1DNLL$+$i$N%i%8%*%7%F%#$r7hD}9kNO!$A4$F$NLLIAj8_4V$N4v2?3XE*$J4X78!$5Z$S3FLL$+$iH/$9$k8w$NNL$r5-=R$9k3H,I,MWHJ$k!%

$3$3G^$:!$3FJ*BN$NI=LL(%]%j%4%s)$r:Y$+$$%Q%C%A$H8F$PlkbN$KJ,3d$9$k!%%Q%C%Ai $H%Q%C%Aj $N%i%8%*%7%F%#$K4X9k4X78$r<0(1)$KI=$9!%

$$B_i A_i = E_i A_i + \rho_i \sum_{j=1}^{n} B_j F_{ji} A_j \tag{1}$$

$3$3$G!$

B_i : %Q%C%Ai $N%i%8%*%7%F%#!&(%M%k%.!<

E_i : %Q%C%Ai $N<+8JJ|<M%(%M%k%.!<

ρ_i : %Q%C%Ai $NH?<MN(

A_i : %Q%C%Ai $NLL@Q

A_j : %Q%C%Aj $NLL@Q

F_{ji} : %Q%C%Aj $+$i%Q%C%Ai XN%U%)!<%`%U%!%/%?(%(%M%k%.!<$,E~C#$9$k3d9g)

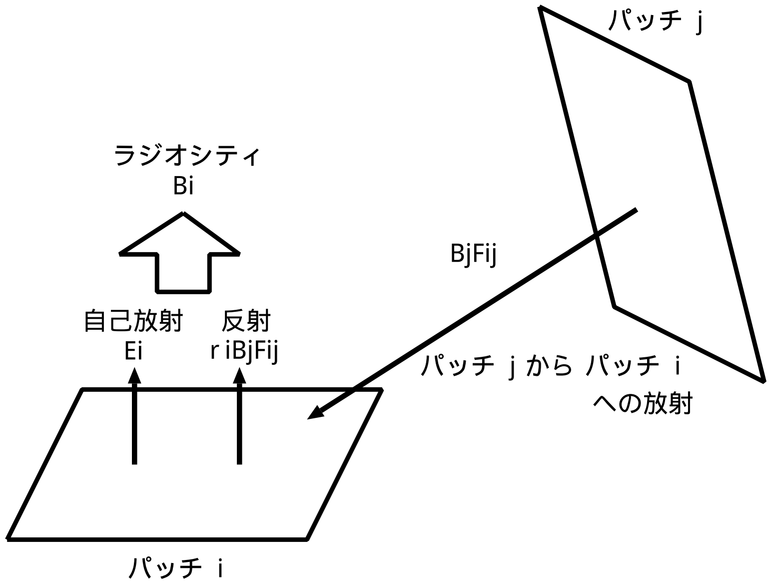
G"$k!%

<!$K!$%U%)!<%`%U%!%/%?$NBP>N@-$h$j

$$A_i F_{ij} = A_j F_{ji} \tag{2}$$

HJkN$G!$<0(1)$O<!$Nh&$KI=$;$k!%

$$B_i = E_i + \rho_i \sum_{j=1}^{N} B_j F_{ij} \tag{3}$$



?^1: %Q%C%Ai $N%i%8%*%7%F%#

=>CF!$7OA4BN$H7F$O!$

$$\left\{\begin{array}{l} B_1 = E_1 + \rho_1 \sum_{j=1}^{N} B_j F_{1j} \\ B_2 = E_2 + \rho_2 \sum_{j=1}^{N} B_j F_{2j} \\ \qquad\qquad \vdots \\ B_N = E_N + \rho_N \sum_{j=1}^{N} B_j F_{Nj} \end{array}\right. \tag{4}$$

$NO"N)J}Dx<0$,N)Filk!%3N<0(4) $r9TNs$N7AK9kH<!<0KJ$k!%

$$\begin{pmatrix} 1-\rho_1 F_{11} & -\rho_1 F_{12} & \dots & -\rho_1 F_{1N} \\ -\rho_2 F_{21} & 1-\rho_2 F_{22} & \dots & -\rho_2 F_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ -\rho_N F_{N1} & -\rho_N F_{N2} & \dots & 1-\rho_1 F_{NN} \end{pmatrix} \begin{pmatrix} B_1 \\ B_2 \\ \vdots \\ B_N \end{pmatrix} = \begin{pmatrix} E_1 \\ E_2 \\ \vdots \\ E_N \end{pmatrix} \tag{5}$$

3l$r2r$1$P!$A4FN%Q%C%A$N%i%8%*%7%F%#$,5aailk!%

3&7F5aail?%i%8%*%7%F%#Kh$j!$3F%Q%C%A$N51EY$,7hDj5l$k!%$=lrbH$K!$%l%s%@%j%s%0$r9T$$!$2hA|$r@8@.9k!%

2.2 %U%)!<%`%U%!%/%?7W;;

<0(1) \$G<(\$7\$?%U%)!<%`%U%!%/%? $F_{ij}$ \$O!\$%Q%C%A $i$ \$NJ|<M\$9\$k%(%M%k%.!<\$,%Q%C%A $j$ \$KE~C#\$9\$k3d9g\$r<(\$7\$F\$*\$j!\$\$3\$N%U%)!<%`%U%!%/%?\$r5a\$a!\$<0(5) \$r2r\$/\$3\$H\$K\$h\$j!\$3F%Q%C%A\$N%i%8%*%7%F%#\$,5a\$a\$i\$l\$k[3]!%

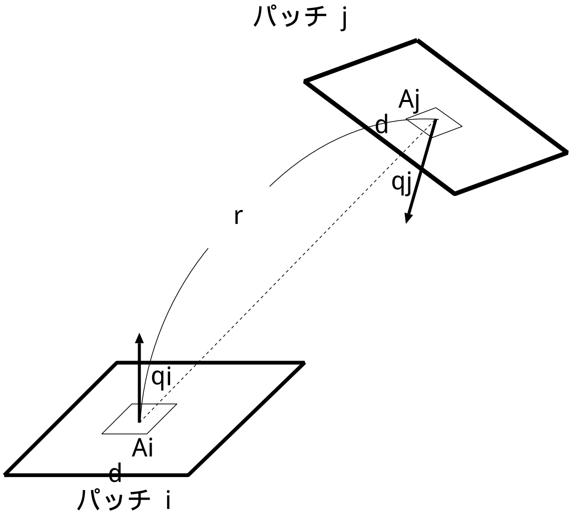
\$\$\$^!\$%Q%C%A i,j \$NLL@Q\$,\$=\$l\$>\$l A_i, A_j \$G\$"\$k\$H\$9\$k!%\$3\$N;~!\$%Q%C%A i \$K4^\$^\$l\$kHy>.NN0h\$+\$i%Q%C%A j \$K4^\$^\$l\$kHy>.NN0h\$X\$N%U%)!<%`%U%!%/%?\$N4X78\$r?^2\$K<(\$7!\$<0(6) \$,M?\$(\$i\$l\$k!%

$$F_{dA_i \to dA_j} = \frac{\cos\theta_i \cos\theta_j}{\pi r^2} V_{ij} \tag{6}$$

C"\$7 V_{ij} \$O

$$V_{ij} = \begin{cases} 1 & dA_i \text{\$H} A_j \text{\$N4V\$K<WJCJ*BN\$,B8:\_\$7\$J\$\$>l9g} \\ 0 & dA_i \text{\$H} A_j \text{\$N4V\$K<WJCJ*BN\$,B8:\_\$9\$k>l9g} \end{cases}$$

\$G\$"\$k!%



?^2: %U%)!<%`%U%!%/%?

<0(6) \$rNN0h A_j \$K\$D\$\$\$F@QJ,\$9\$k\$3\$H\$K\$h\$j!\$%Q%C%A i \$+\$iHy>.NN0h\$X\$N%U%)!<%`%U%!%/%?\$O<!<0\$K\$J\$k!%

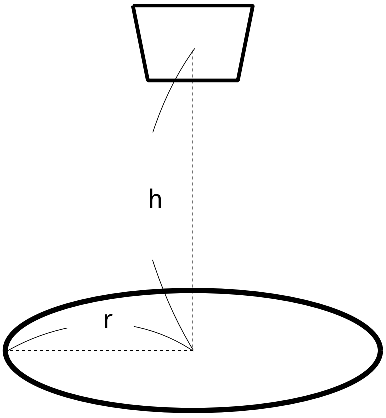
$$F_{dA_i \to A_j} = \int_{A_j} \frac{\cos\theta_i \cos\theta_j}{\pi r^2} V_{ij} dA_j \tag{7}$$

<!\$K!\$ A_j \$r m 8D\$N>.\$5\$JNN0h ΔA_j^k \$K:YJ,\$7!\$\$=\$l\$>\$l\$N:YJ,LL\$NCf1{\$r%5%s%W%k%]%\$%s%H\$H\$7\$FA*\$V\$H%U%)!<%`%U%!%/%?\$O<!<0\$K\$J\$k!%

$$F_{dA_i \to A_j} = \sum_{k=1}^{m} \frac{\cos\theta_i^k \cos\theta_j^k}{\pi (r^k)^2} V(dA_i, \Delta A_j^k) \Delta A_j^k \tag{8}$$

3NΔA_j^k $HF1$8NN0hFb$rJ?1_HW$G6a;w9k!%$3$3$G!$E@$+$iNN0hXN%U%)!<%`%U%!%/%?$O 0J2<$KJk3H$,CN$i1F$$$k!%

$$F_{dA_i \to \Delta A_j} = \frac{r^2}{h^2 + r^2} \tag{9}$$



?^3: E@$+$iNN0hXN%U%)!<%`%U%!%/%?

C"$7!$?^3 $NFsJ?LL$N4X78$OJ?9T$G5wN%$, h !$J?1_HW$NH>7B$, r G"$k!%$3$N<0$r0lHIE* JbNK=q$-D>$7$?$bN,<!<0KJ$k!%

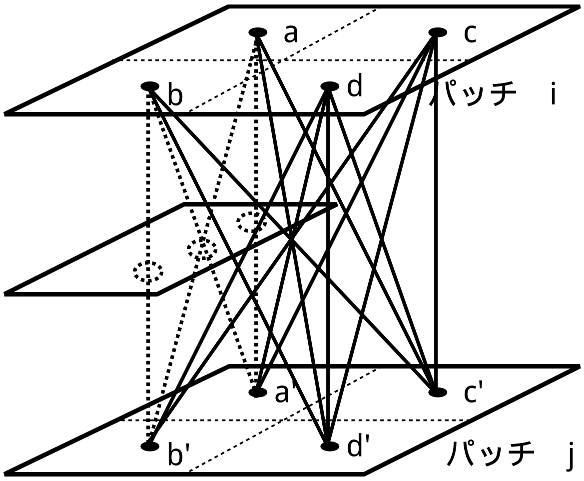
$$F_{dA_i \to \Delta A_j} = \frac{\Delta A_j \cos\theta_i \cos\theta_j}{\pi r^2 + \Delta A_j} \tag{10}$$

<0(10) $r<0$(8)$ $KBeF~$9kH

$$F_{dA_i \to A_j} = A_j \sum_{k=1}^{m} \frac{\cos\theta_i^k \cos\theta_j^k}{\pi (r^k)^2 + \frac{A_j}{m}} V(dA_i, \Delta A_j^k) \Delta A_j^k \tag{11}$$

%Q%C%A i >e$NHyJ,NN0h$+$i%Q%C%A j XN%U%)!<%`%U%!%/%?$O!$%Q%C%A $i$ $+$i%Q%C%A $j$ $X$N %U%)!<%`%U%!%/%?$N6a;w$K;H9k!%$=$N7k2L!$:G=*<0$O<0(12) HJ$j!$$=$N4X78$r?^4 $K <($9!%

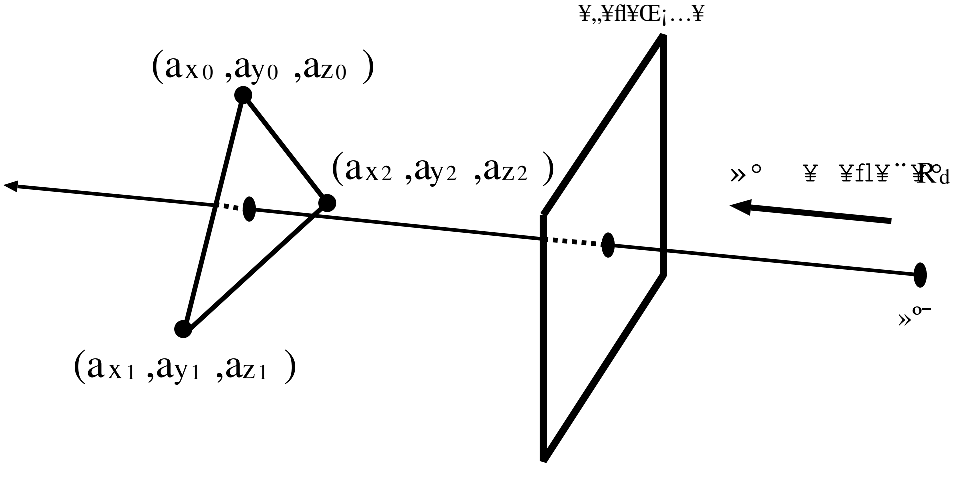
$$F_{ij} = \frac{A_j}{m} \sum_{k=1}^{m} \frac{\cos\theta_i \cos\theta_j}{\pi r^2 + \frac{A_j}{m}} V(A_i, A_j) \tag{12}$$



?^4: NN0h$+$iNN0hXN%U%)!<%`%U%!%/%?

<!$K!$$V_{ij}$$K4X9k8r:9H=Dj$N%"%k%4%j%:%`$r<($9[2]!%$3$3$G$O!$;kE@$R_0$$r86E@H7$F 9M$($k!%;03Q7A$N3FD:E@$O9TNs$P$$GI=9H<!Nh$&$KI=$;$k!%

$$P = \begin{bmatrix} a_{x0} & a_{x1} & a_{x2} \\ a_{y0} & a_{y1} & a_{y2} \\ a_{z0} & a_{z1} & a_{z2} \end{bmatrix} \tag{13}$$



$k! %$^$?! $; kE@ R_0 r+iG$?; k@~%Y% /%H%k R_d $O< !<0$GI=$9$3H,G-$k! %

$$R_d = P * A \tag{14}$$

%Q%i%a! <%?$O $(A = [a_0 \ a_1 \ a_2])$ H9$k! %; k@~%Y% /%H%k R_d $O%1%$$rHtP9; ~E@$G7hDj$7$F$$ $k! %$=N?aK%Q%i%a! <%?$O9TNs P $N5U9TNs$rMQ$$$F< !<0HJ$k! %

$$A = P^{-1} * R_d \tag{15}$$

R_d $,; 03QJ?LL$H8r: 9$9$k$?$aKO! $

$$a_0 \geq 0, a_1 \geq 0, a_2 \geq 0 \qquad \text{\$+\$D} \qquad |a_0| + |a_1| + |a_2| \neq 0$$

01$DL\$N>r7o$O! $; 03Q7A$N%]%j%4%sFb$K8rE@$,$"$k3H$r< ($7F*$j! $%Q%i%a! <%?Fb$N$= 1>1NMWAG$,01$DGbI iG"kH$-$O! $%]%j%4%s$r4^$`J?LL>e(%]%j%4%s30) $K8rE@$,$" k3HKJk! %Fs$DL\$N>r7o$O! $%Q%i%a! <%?$NA4FNMWAG$,0 GOL5$$$3Hr< (7F$*$j! $ A4$F0 $N; ~$O; kE@$H01CW$7$F$$$k; vKJ$k(; kE@$H8r: 9H=Dj$NBP>]$G$"$k%]%j%4%s$,01CW 7F$$$k)! %$3$1iFsD$N>r7o$rK~$?$9$3$H$G! $<B:]$K8r: 9$9$k3H$,J,$+$k! %$3$1$r%Q%C %A ij 4V$KMQ$$$k3H$G8r: 9H=Dj$r9T$&! %

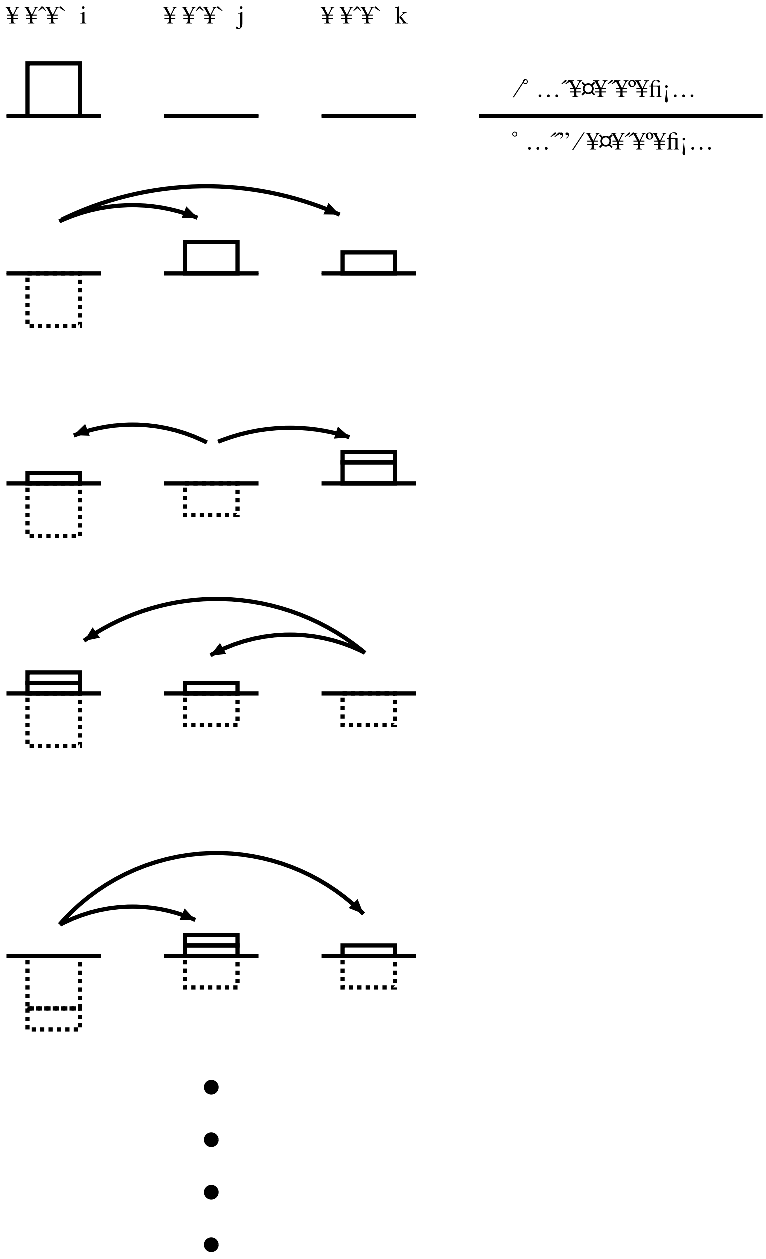
2.3 A2?JK!

0lHIE*$J%i%8%*%7%F%#K!$G$O%Q%C%A$N?t#2>h$KHfNc$9$k%a%b%jNL$H%U%)!<%`%U%!%/%?$N 7W; ;; ~4V$,I,MWHJ$k! %$3N3HO! $%Q%C%A?t$,Hs>o$KB?$/JC$?; ~$N3H$r9M$ (kH! $Bg JQ?<9o$JLdBjHJ$k! %$3$NLdBj$r2r7h9k$?$a$K Cohen iOA2?JE*$K2hA|$r5aakJ}K!$r Ds0F7?[3]! %

J|<M$K4X$7$FCmL\$9kH0J2<$N<0$,G-$k! %

$$B_j = B_j + B_i(\rho_j F_{ji}) \tag{16}$$

3N<0$r! $%i%8%*%7%F%#$NBg$-$$%Q%C%A i $+$i=gKE,MQ9k3HG=y! 9$K2r$K6aE1$F $$$/3H$,$G$-! $$3$1$r<}B+9k$^$G7+jJV9! %$^$?! $$"$kDxEY$NH?I|7?CJ3,$G7W; ;$r CfCG7F$b! $J|<M% (%M%k%.!<$NBg$-$$%Q%C%A$+$i$O! $4{$K% (%M%k%.!<$r<}=8$7$F$$$kNG! $ <L<BE*$J2hA|$r@8@.9k3H$,2DG=$G$"$k! %=>Mh$NO"N)J}Dx<0$r2r$/J}K!$G$O! $7W; ;$N:G Cf$O<0(5) K"$kA4%U%)!<%`%U%!%/%?$r; HMQ$9$kI,MW$,$"$k! %01J}! $$3$NJ}K!$G$O0lEY$K ; HMQ$9$k%U%)!<%`%U%!%/%?$O! $<0(16) Nh$&$K9TNs$N=D1NsJ,N_Gh$$! %3Nh&$K7W ; ;$5$;$k3HKhCF! $%a%b%j$rBgI}$K@aLs$9k3H,G-$k! %?^6$K%Q%C%A i,j,k $N% (%M %k%.!<$NO\F0$r< ($9[2]! %


¥¥ˆ¥` i
¥¥ˆ¥` j
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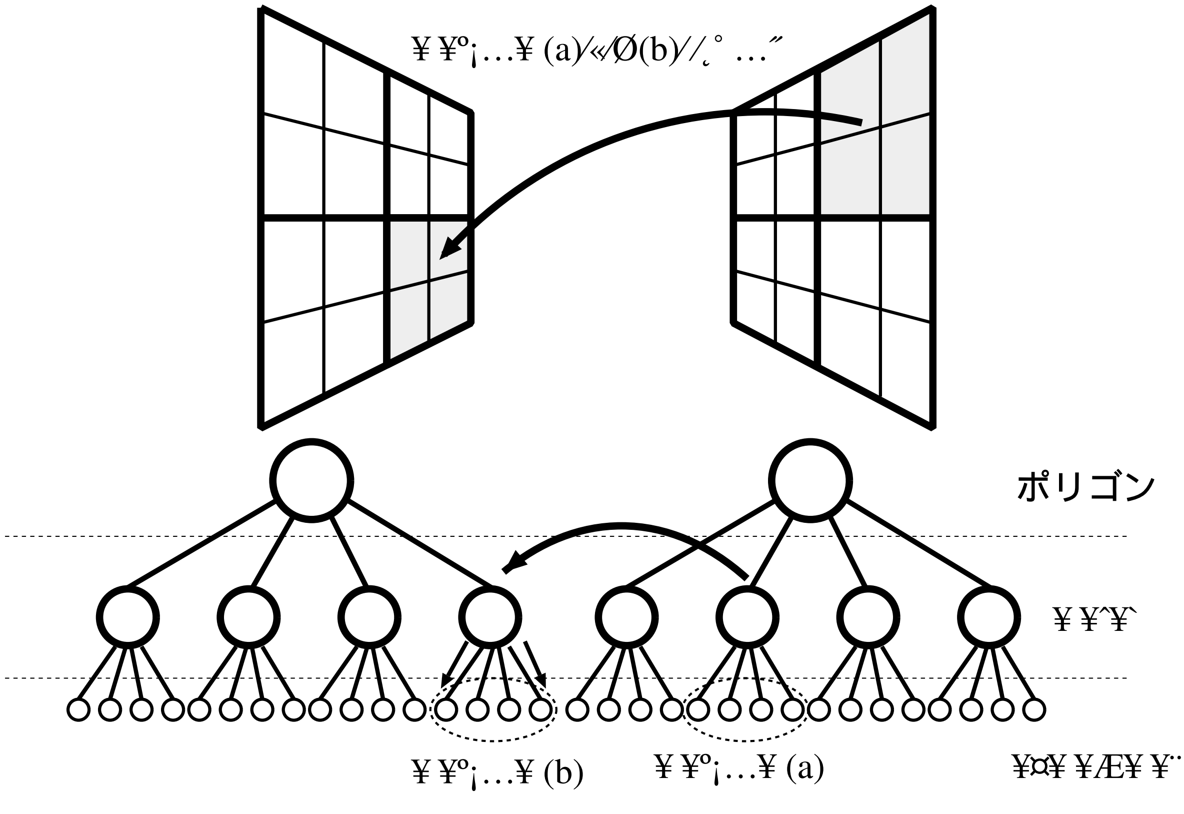
∕˚ …˝¥¤¥˝¥º¥fi¡…
˚ …˝˝’ /¥¤¥˝¥º¥fi¡…

2.4 3,AX7?%i%8%*%7%F%#K!$NFCD'$H7W;;J}K!

3l$^$G$N%i%8%*%7%F%#K!$G$O!$A4FN%Q%C%A4V$N%U%)!<%`%U%!%/%?$r5aak$?$a!$%i%8%*%7%F%#$r5aak$?$a$N7W;;%3%9%H$OG|BgJbNKJk!%$=$3$G!$7W;;%3%9%H$r:o8:$5$;$k$?$a$KDs0F$5l?N,!$3,AX7?%i%8%*%7%F%#K!$G$"$k[3]!%3,AX7?%i%8%*%7%F%#K!$OJ|<M$NC10L$r%Q%C%A$H$7!$F~<M$NC10L$r%(%l%a%s%H$HDj5A$7!$%Q%C%A$O%(%l%a%s%H$N=89g$H9k!%$^$?!$J|<M$r9T$&;~$O!$J|<M%Q%C%A$+$i%]%j%4%s$X$N%U%)!<%`%U%!%/%?$r7W;;$7!$<!$K!$%]%j%4%s$N;R(%Q%C%A)$KBP$9$k%U%)!<%`%U%!%/%?$r7W;;$7!$%]%j%4%sHN%U%)!<%`%U%!%/%?$N:9$rD4$Y!$5vMFHO0O$G$"$l$P!$$3$N%U%)!<%`%U%!%/%?$rMQ$$$F!$%(%l%a%s%H$KBP$7J|<M$r<B9T9k!%

3N9=B$$O!$LZ9=B$$rMQ$$$FI=8=9k3HKJ$k!%LZ9=B$$N:,$ND:E@$,%]%j%4%s$rI=$7!$%]%j%4%s$N$9$02<NAXN3FD:E@$r%Q%C%A$H9k!%$^$?!MUND:E@$,%(%l%a%s%H$r!$%Q%C%A$H%(%l%a%s%H$N4V$ND:E@$,%(%l%a%s%H$N%0%k!<%W$rI=$9!%3l$r?^7$K<($9!%%(%M%k%.!<



?^7: 4 J,LZ9=B$

$O3,AX:YJ,Cf$N$"$k%l%Y%kG"$kD:E@$+$iB>$ND:E@$XJ|<M$9$k!%$=Nh$&$JAj8_:nMQNRHD$r?^7Cf$NLp0u$G<($9!%3l$O4$D$N%(%l%a%s%H$N%0%k!<%W(a)$rI=$9%Q%C%A$+$i$N%(

%M%k% .! <$, ! $4 DN% (%1%a%s%H$N%0%k! <%W(b) $rI=$9%Q%C%A$KJ |<M$5$1$k3H$r< ($7$F$$ $k! %$b$7! $% (%1%a%s%H$hjb>e$N%1%Y%k$G$ND :E@$GJ |<M9kJi! $$=$N%1%Y%k$hjb2<$N D :E@$O>e$N%1%Y%k$G$N4X78$r<u$17Q$0! %

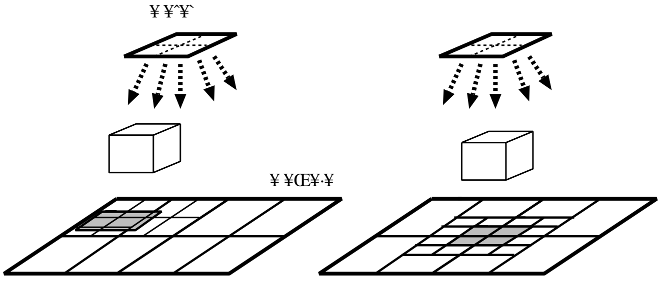
7W; ;J}K!$O! $$^$:4 J,LZ9=B$$r< ($93,AX%G! <%?$H0ICV%G! <%?$N2 DN%G! <%?9=B$$rMQ0U 9k! %< !$K! $$"$kD :E@$p$ $+$iB>$ND :E@$q$ XN%i%8%*%7%F%#$NJ |<M$K$D$$$F! $$^$:! $$=1>$1 $ND :E@$p,q$ GNJ |<M$,! $$h$j2<$N%1%Y%kGNB?$/$ND :E@GNJ |<M$K6a; w$G$-$k$+$rD4Yk! % D^$j! $$3$N2 E@$G$NJ |<M$9$k:]$N%U%)! <% `%U% !%/%?$N: 9$,! $5vMFHC0CFb$+$rD4$Y! $J |<M $r<B9T$9k+$r7h$a$k! %%f! <%6$N; XD j9k5vMFHC0O$O! $LZ9=B$$N: YJ,$r=g1~E*$K<B9T9k $?$a$HE,@Z$J% (%M%k% .! <$rJ |<M$9k?aKI,MWHJ$k! %$^$?! $$=1>1ND :E@p,q $,:YJ, 2DG=$+H]$+$rD4Yk! %: YJ,2DG=$+H]$+$O! $%f! <%6$,$"$i$+$8$a: G> .$NNN0h$r; XD j$7! $$3$1 $rMQ$$$FD4Yk! %

5aa?%U%)% `! <%U% !%/%?$N: 9$ ,> .$5$$$+! $: YJ,IT2DG=$J$H$-$OD :E@$p,q$ 4V$GJ |<M$r<B9T $9$k! %%U%)! <% `%U% !%/%?: 9$,Bg$-$$$H$-$O! $D :E@$q$ $N; R$rMQ$$$F$3$1$N: 9$r8 :i9! %7? $,CF! $D :E@$q$ r5iK: YJ,7F>e5-$N: 9$NHf3S! $: YJ,$N2DG=@-$rD4$Y! $>r7o$,K~$?$5$1 k^$GH?I |9k! %$3$3$GF@$?%U%)! <% `%U% !%/%?$rD :E@$p$ $+$iD :E@$q$ $NMU$ND :E@(% (%1%a%s %H) $X$N4X78$KE,MQ$9$k! %A4%]%j%4%s4V$G$N$9$Y$F$ND :E@4V$N%U%)! <% `%U% !%/%?$rD4$Y! $$3 $N4X78$rJ]B8$7$F$*$/! %

$3$1$^$G$GF@$?%U%)! <% `%U% !%/%?$rMQ$$$F! $D :E@$p$ $+$iA4FN%]%j%4%s$ND :E@$q$ 0J2<$N 3,AX$=1>1ND :E@r XNJ |<M$r<B9T$9$k! %$3$N<B9T$,=*N;7?8e! $?7$7$$%i%8%*%7%F%#$r J |<M$9$kD :E@$r7hak$?$a$K! $D :E@$r$ $,MU$NItJ,Ji3ND :E@$N%i%8%*%7%F%#$O<+8JJ |<M $HF~<M$7$?% (%M%k% .! <$NBg$-$5$r7W; ;$7! $J |<MC10L$G$"$k>e$N3,AX%Q%C%A$KEA$ ($k! %% (%1 %a%s%H$N%0%k! <%W$rI=$9D :E@GO! $2<AX$+$i<u$1<hC?%i%8%*%7%F%#$NJ?6Q$r5a$a! $>e$N AXK3NAXN%i%8%*%7%F%#H7FEA ($k! %$3$&$7FEA (i1$?%i%8%*%7%F%#$NC f$+$i! $< ! $KJ |<M$9$kD :E@$r7hD j9k! %3NJ |<M$HF~<M$r%i%8%*%7%F%#$,<}B+$9k^$G7+$jJV$9! %< } B+$7$?; ~E@$G: G=*E *$J%i%8%*%7%F%#$H7F7k2L$r=PNO$9$k! %

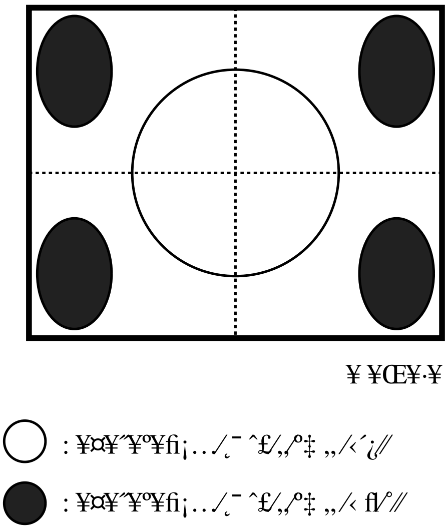
$^$?! $3,AX7?%i%8%*%7%F%#K!$GN10U9kE@$O! $$^$:! $1F$Khk3,AX$NJQ2=$,5s2i1k! % ?^8 (a) $K< ($9h&$J; ~! $$D$^$j! $1F$,Cf1{0J30K"$k; ~! $1F$NItJ,N_3,AX$r?<$/9k$3 H,G-$k! %?^8 (b) $K< ($9h&$K1F$,Cf1{K"kH$-! $3,AX$,?<$/$JiJ$$2DG=@-$,$" $k! %$3N3HO! $% (%M%k% .! <$NE~C#9k3d9gG"$k%U%)! <% `%U% !%/%?$NCM$,J?6Q2=$5$1$k $?$a$*$3$k$b$N$G$"$k! %$D$^$j! $J |<M%Q%C%A$+$i%]%j%4%s$KBP$9$k%U%)! <% `%U% !%/%?$NCM $H%]%j%4%s$N; RG"$k%Q%C%A$KBP9k%U%)! <% `%U% !%/%?$N: 9$,L5$/$J$C$F$7$^$&$?$a$K3, AX$,?<$/$J$i$J$/$J$k! %$3$1$rHr$1$k$?$a! $%U%)! <% `%U% !%/%?7W; ;Cf$N8r: 9H=DjIt$N%1%$ $rMQ$$$k! %J |<MB&$N3F%]%$%s%H4H$N%1%$$GB>$N%]%j%4%s$H8r: 9$9$kbN$rD4$Y! $%]%$%s %H4H$NHf3S$r9T$$! $>r7o$rK~$?$7$?; ~! $L5>r7o$K3,AX$r?<$/9kh&K9$k! %>r7o$O3F

%]%$%s%H$G$N8r:9$9$k%l%$$NK\?t$,?tK\$G!$$+D=$NK\?t$,$[$\F1$8$G$"$kH-G"$k!%



(a)–˘⁄‹ˆ..⁄¸⁄¢⁄º⁄˙⁄› (b)–˘⁄‹ˆ–ß⁄¸⁄¢⁄º⁄˙⁄›

?^8: 1F$N0LCV$Khk3,AX$NJQ2=



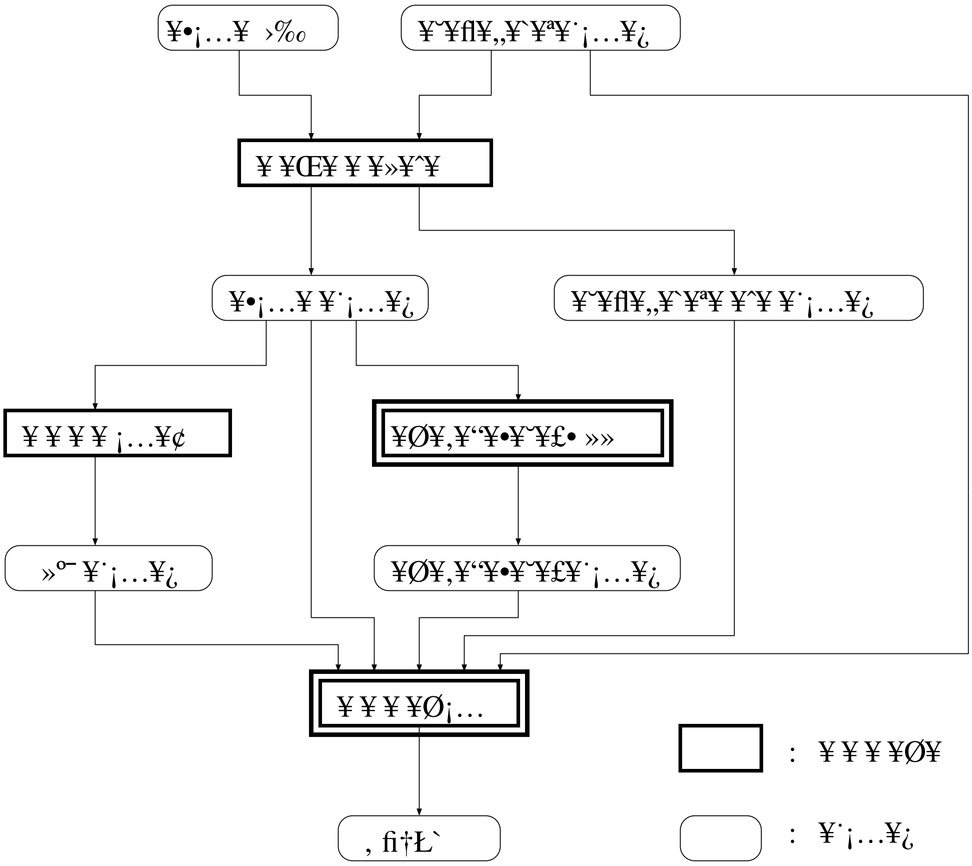
?^9: %]%j%4%sFb$N%(%M%k%.!<$NE~C#9k3d9g

<!$K!$%]%j%4%s$NLL@Q$NBg$-$$$bNK4X7F$O!$$"$kDxEY$NBg$-$5$KJ,3d$9$k!%$3$1$O?^9$K<($9h&$K!$%]%j%4%sCf1{ItKD$$$F$O3FJ|<M%Q%C%A$+iN%(%M%k%.!<$NE~C#$9$k3d9g$,B?$/$J$k!%$7$+$7!$%]%j%4%s$NC<KJ1PJk$[$I%(%M%k%.!<$NE~C#$9$k3d9g$,>/J/Jk!%$3$1$O%]%j%4%s$NLL@Q$,Bg$-$$$bN[$II=$1$k!%$D$^$j!$?^9$K<(9h$&$K%]%j%4%sKBP9$k%U%)!<%`%U%!%/%?$NJ?6Q$H!$4J,3d$7$?$b$N$NBP$9$k$=$1$>$1$N%U%)!<%`%U%!%/%?$NCM$,F1$8KJ$j!$3,AX$r9=@.$9k?aN:9$,L5$/Jj3,AX$,?<$/Ji$J$$2DG=@-$,$"$k!%<B:]$K$O!$>e5-Nh$&$KCf1{It$HC<It$H$N:9$,$"$ko1$G!$@53N$JJ|<M$,<B9T$5$1J/Jk!%hC$F!$$3Nh$&$K%]%j%4%s$NLL@Q$NBg$-$$$bNK4X9kJ,3d$,I,MW$HJk!%

3 2hA|@8@.%7%9%F%`$N9=C[

3.1 %7%9%F%`9=@.

3N>OGO!$K\%7%9%F%`$NA4BN9=A[$r<($9!%?^10$OK\%7%9%F%`$N=hM}$NN.$l$r<($7!$$=l>lN%W%m%0%i%`$NLr3d$r<($9!%K\%7%9%F%`$O8&5f<<Fb$G9Tol$F$$$k!$%i%8%*%7%F%#K!$NJBNs2=$N8&5f[11]!A[16] $G;HMQ$5lF$$$kbN$G!$>eEh;aKhCF3+H/5l$?!%K\8&5f$G$O?7$?$K3,AX7?%i%8%*%7%F%#7W;;It$H%l%s%@%i!<It$r:n@.$7!$%W%j%W%m%;%C%5It$H%W%l%S%e%"!<It$O4{B8NbNrN.MQ9k!%



?^10: %7%9%F%`9=@.

- %W%j%W%m%;%C%5It

  %7!<%s5-=R$r%7!<%s%G!<%?$KJQ49$9$kbN$G!$JQ49$7$?%7!<%s%G!<%?$O%W%l%S%e!<%"It$d3,AX7?%i%8%*%7%F%#7W;;It$G;HMQ$5lk!%%7!<%s5-=RCf$K%F%/%9%A%c%^%C%T%s%0$N;XDj$,$"kH$-$O%F%/%9%A%c%^%C%W%G!<%?$r%l%s%@%i!<$K=PNO9k!%

- %W%l%S%e!<%"It

  %7!<%s%G!<%?$rMQ$$$F%o%$%d%U%l!<%`%b%G%k$GI=<(9k!%3l$rMQ$$$F;kE@$r<+M3$K0\F0$5$;!G0U$N;~E@$G$N;kE@%G!<%?$r=PNO9k!%$^$?!$4{B8$N;kE@%G!<%?rFI_9~$_!$$=$N;~E@$G$N%7!<%s$NI=<(bG$-$kh&K9$k!%

- 3,AX7?%i%8%*%7%F%#7W;;It

  3,AX7?%i%8%*%7%F%#K!Kh$k2hA|@8@.$N3KHJ$k%W%m%0%i%`$G!$%W%j%W%m%;%C%5$G=PNO7?%7!<%s%G!<%?$rMQ$$$F!$3,AX7?%i%8%*%7%F%#7W;;$r<B9T$7!$%i%8%*%7%F%#%G!<%?$r=PNO$9$k!%

- %l%s%@%i!<It

  3l$^$G$N9TDx$G=PNO7?;kE@%G!<%?!$%7!<%s%G!<%?!$%i%8%*%7%F%#%G!<%?!$%F%/%9%A%c%^%C%W%G!<%?!$%F%/%9%A%c%G!<%?rFI_9~$_!$%l%s%@%j%s%0$r9T$$!$2hA|%G!<%?$r=PNO9k!%

<!@a$+$i3FIt$N=hM}Ey$K$D$$$F<($9!%

3.2 %W%j%W%m%;%C%5It

%W%j%W%m%;%C%5ItGO!$%f!<%6$,5-=R9k%7!<%s(example.rpd) $r%7!<%s%G!<%?(example.rad) $KJQ49$9$k[16]!%%f!<%6$,5-=R9k%7!<%s$O0J2<$NDL$j!%

```
p4 (x0, y0, z0),(x1, y1, z1),(x3, y3, z3),(pu, pv),(Rr, Rg, Rb)[,(Er, Eg, Eb)]
```

%]%j%4%s$N3D:E@$H%Q%C%A$NJ,3d?t!$%]%j%4%s$NH?<M78?t!$<+8JJ|<M%(%M%k%.!<$N=g$G5-=R9k!%$^$?!$<+8JJ|<M%(%M%k%.!<$K4X7FOI,MWJ;~N_5-=R9k!%%]%j%4%s$N3D:E@$O0 HV$ND:E@$r64$`1,3 HV$ND:E@$G9=@.$5lk!%$3$3GN%Q%C%A$NJ,3d?t$d%(%l%a%s%H$NJ,3d?t$O!$3,AX7?%i%8%*%7%F%#K!$N:G>.9=@.$G8GDj$5$l!$$3$l0J>e$N3,AX$O9=@.$5lJ$$!%$^$?!$%W%j%W%m%;%C%5It$G$O5-=R$7$?3D:E@$h$j;D$j$ND:E@2$HK!@~%Y%/%H%k$r=PNO$9k?aN=hM}$r9T$&!%

```
polygon4(180, -100, 0),(180, 100, 0),(-180, -100, 0),(5, 8),(0.95, 0.95, 0.95)
element 2
```

3N>l9g!$D:E@$N:BI8$,(180, -100, 0),(180, 100, 0),(-180, -100, 0) G"$j!$%Q%C%A$NJ,3d?t$,5 !_8 $N40 HJ$k!%$^$?!$%]%j%4%s$NRGB %P%s%IN=l>lNH?<M78?t$,0.95, 0.95, 0.95 G"$j!$<+8JJ|<M%(%M%k%.!<$oRGB %P%s%IN=l>l,0 G"$k!%:G8e$K%Q%C%A$NJ,3d?t$,2^2 $G4 HJ$k!%

$^$?!$=PNO$5lk%7!<%s%G!<%?$O!$0J2<Nh$&$KJk!%

```
4
180 -100 0
180 100 0
-180 -100 0
-180 -100 0
5 8
2
0 0 1
0 0.95
0 0.95
0 0.95
0
```

$3$3GO!$0lHV>e$N9T$+$iD:E@?t!$D:E@0!$D:E@1!$D:E@2!$D:E@3 $r<($7F*$j!$<!$K!$ %Q%C%A$NJ,3d?t(D:E@0 $+$iD:E@1 $NJ,3d?t$HD:E@0 $+$iD:E@2 $NJ,3d?t)!$%Q%C%A$+$i%(%l %a%s%HXNJ,3d?t(2 >h$N%(%l%a%s%H?t$KJ,3d) $r<($7$F$$$k!%<!$K!$%]%j%4%s$NK!@~%Y%/ %H%k$r<($7!$R %P%s%I$N<+8JJ|<M%(%M%k%.!<$HH?<M78?t!$G %P%s%I$N<+8JJ|<M%(%M%k%.!< $HH?<M78?t!$B %P%s%I$N<+8JJ|<M%(%M%k%.!<$HH?<M78?t$r<($7!$:G8e$K6@LIH?<M78?t$r<($9!%$3l,%]%j%4%s0lDrI=$7!$$3lr7+jJV7!$A4%]%j%4%s$rI=$9!%

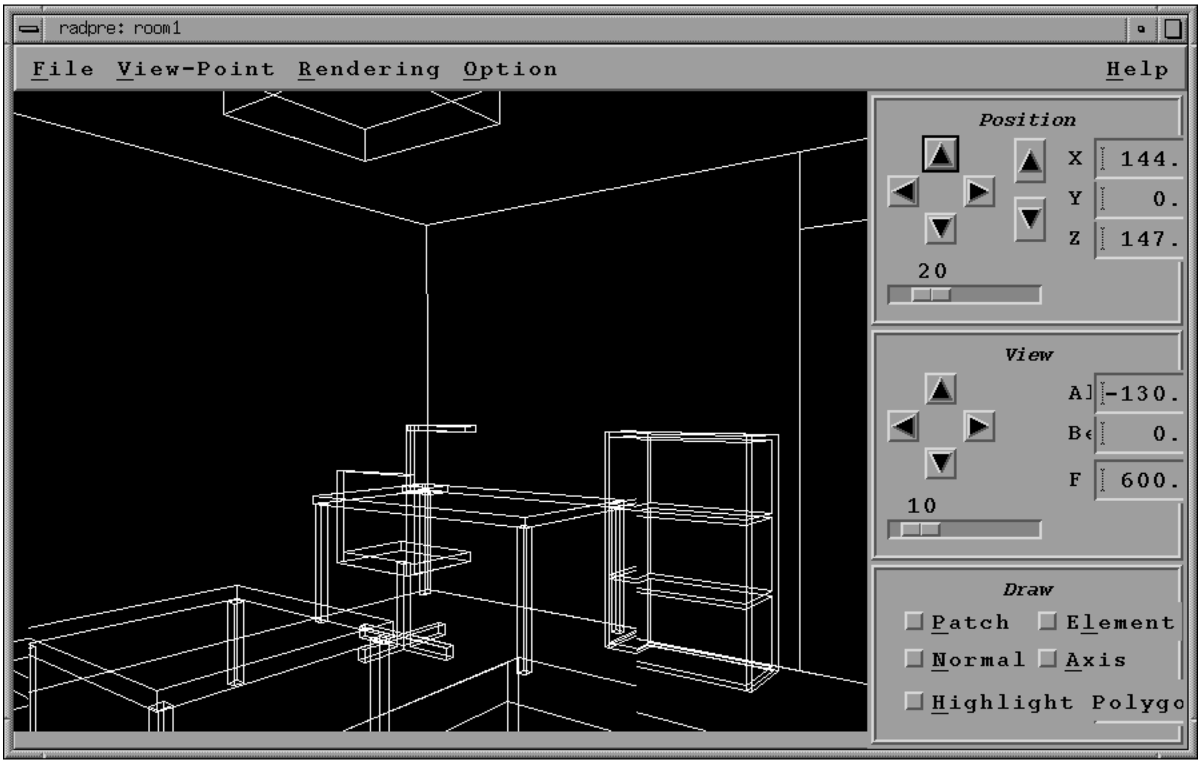
7+$7!$%7!<%s%G!<%?$K=q$+lF$$$k4D6-JQ?tJI$O3,AX7?%i%8%*%7%F%#K!$NbNHO 4X78J/!$3,AX7?%i%8%*%7%F%#7W;;It$G:o=|9k!%$^$?!$%Q%C%A$NJ,3d?t$d%(%l%a%s%H$N J,3d?t$N>pJs$bF1MMKI,MWH$;$:!$3,AX7?%i%8%*%7%F%#7W;;It$G:o=|7F!$%G!<%?$r%;%C %H$7!$7W;;$r9T$&!%

3.3 %W%l%S%e!<%"It

%W%l%S%e%"!<It$O!$%W%j%W%m%;%C%5It$G=PNO$7$?%7!<%s%G!<%?(example.rad) rFI_9~ $_!$;kE@$r7hDj$7!$;kE@%G!<%?(example.vpt) $r=PNO$9$k[16]!%?^11$K%W%j%W%m%;%C%5It $N%$%s%?!<%U%'!<%9It$r<($9!%

%W%j%W%m%;%C%5ItGO!$;kE@$+$i%9%/%j!<%s1[$7$K8+$?2hA|$r%o%$%d!<%U%l!<%`%b%G%k $GI=<($7!$;kE@%G!<%?$r7hDj9k!%=PNO5l$k;kE@%G!<%?$O<!NDLjKJ$k!%

```
144.679108 0.000000 147.144241
-130.000000 0.000000
600.000000
```



X 144.
Y 0.
Z 147.
20
Al -130.
Be 0.
F 600.
10
☐ Patch ☐ Element
☐ Normal ☐ Axis
☐ Highlight Polygo

?^11: %W%j%W%m%;%C%5It$N%$%s%?!<%U%'!<%9

$^$:!$l 9TL\$O;kE@:BI8(x!$y!$z) $r<($7F*$j!$<!$K;k@~J}8~(α!$β) $r<($7$F$$$k!%:G8e$K;kE@$H%9%/%j!<%s$^$G$N5wN%$rI=$9!%$3$N;kE@%G!<%?$K4pE-%l%s%@%j%s%0$r9T$&!%

3.4 3,AX7?%i%8%*%7%F%#7W;;It

3,AX7?%i%8%*%7%F%#It$O!$%W%l%S%e%"!<It$G=PNO$7$?%7!<%s%G!<%?(example.rad) $rF~NO$7!$3,AX7?%i%8%*%7%F%#7W;;$r9T$$!$%i%8%*%7%F%#%G!<%?(example.hrd,example.num) $r=PNO$9$k!%$3$N:]!$%7!<%s%G!<%?Cf$N4D6-JQ?t$r:o=|$7!$Beoj$K!$3,AX7?%i%8%*%7%F%#7W;;KI,MWJ%G!<%?$r%;%C%H$9kI,MW,$"$k!%

3,AX7?%i%8%*%7%F%#7W;;KI,MWJbNH=$NLr3d$rI=1$K<($9!%$^$?!$3,AX$r9=@.9k$?$aKI,MWJ%i%8%*%7%F%#%G!<%?$rI=2!$0ILCV%G!<%?$rI=3$K<($9!%FC$K!$I=1Cf!$MaxA $OJ|<M$r9T$&%N!<%I$N:GBgLI@Q$r;XDj$9kbNG$"$j!$$"$k%N!<%I$NLI@Q$,MaxA 0J>e$NH-$O!$$=$N%N!<%I$KBP7F!$%U%)!<%`%U%!%/%?7W;;$r9T$o$:!$3,AX$r?<$/$7!$7W;;$rB3$1$k!%MimA $O%(%l%a%s%H$N:G>.CM$r<($9$b$N$G$k!%MimA 0J>e$N$H$-$O!$3,AX$r9=@.$9$k!%$D$^$j!$MimA $NCM$K$h$j!$3,AX$N9=@.$r8BDj$7!$L5BL$J3,AX$rA}$d$5$J$$$h$&$K$9$k!%loop $O3FRGB $NJ|<M2s?t$r<($9!%ERROR $OJ|<M$r<B9T$9$k:]$N?F;R$N%U%)!<%`%U%!%/%?$N:9$r<($7$F$$$k!%ERROR 0JFbG"lPJ|<M$,<B9T$5lk!%

I=1: 3,AX7?%i%8%*%7%F%#MQ4D6-JQ?t

MaxA	%f!<%6$,;XDj$9$kJ|<M$r9T$&%N!<%I$NLI@Q$N:GBgCM
MimA	%f!<%6$,;XDj$9$k3,AX$r9=@.9k%(%l%a%s%H$NLI@Q$N:G>.CM
loop	J|<M$r<B9T$9$k2s?t
ERROR	J|<M$r<B9T$9$k:]$N?F;R$N%U%)!<%`%U%!%/%?$N:9

I=2: 3,AX7?%i%8%*%7%F%#MQ3,AX%G!<%?

*parent	<+%N!<%I$N?F
*children[4]	<+%N!<%IN=l>lN;R
L	0ILCV%G!<%?
RBg!$GBg!$BBg	RGB NLJ|<M%i%8%*%7%F%#
RBs!$GBs!$BBs	RGB $NJ\|<M:Q$_%i%8%*%7%F%#
RE!$GE!$BE	RGB $N<+8JJ|<M%(%M%k%.!<
Rrou!$Grou!$Brou	RGB $NH?<M78?t
F	%U%)!<%`%U%!%/%?

I=3: 3,AX7?%i%8%*%7%F%#MQ0LCV%G!<%?

x0!$y0!$z0	D:E@0
x1!$y1!$z1	D:E@1
x2!$y2!$z2	D:E@2
x3!$y3!$z3	D:E@3
Nx!$Ny!$Nz	K!@~%Y%/%H%k
A	LI@Q

$^$?!$3,AX7?%i%8%*%7%F%#7W;;8e$N%i%8%*%7%F%#%G!<%?$OF s<cN'((example.hrd)!$(example.num)) HJ$j!$example.hrd $O3F% (%l%a%s%H$N:BI8 (x0!$y0!$z0) $HRGB %P%s%I$N 7W;;7k2L$r=PNO$9$k!%example.num $O3F%]%j%4%s$N% (%l%a%s%H?t$r=PNO$9$k!%

3.5 %l%s%@%i!<It

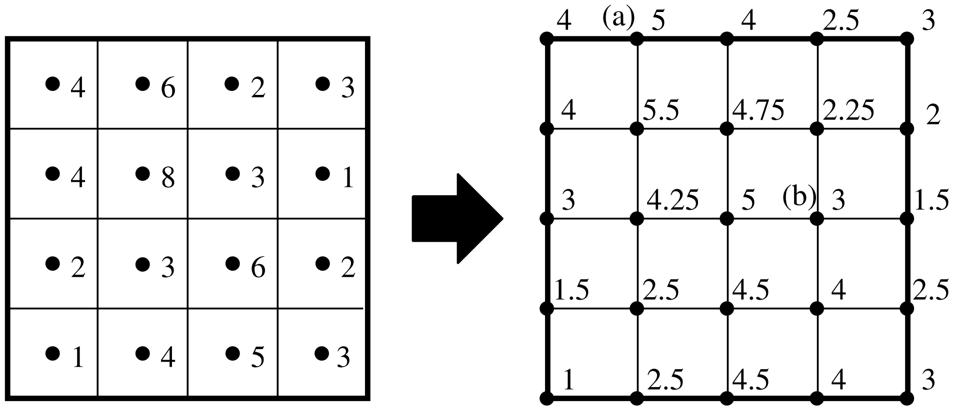
%i%8%*%7%F%#K!GOD>@\2hA|$rF@$k3H$,$G$-$J$$$N$G!$2?i+$N<jK!$rMQ$$$F%l%s%@%j%s%0$r9T$oJ1lPJi$J$$!%K\%7%9%F%'GO%l%$%H%l!<%7%s%0K!$rMQ$$$F<B8=9k!%

%l%$%H%l!<%7%s%0K!$O;kE@$+$i=P$?;k@~$,%9%/%j!<%s>e$NE@$rDL$j!$$$$m$$m$JJ*BN$K Ev$?$jH?<M!$6~@^$r7+jJV9!%$=$7$FJ*BN$N?'>pJsr=$N;k@~$K2C$($k3HKhCF!$%9%/%j!<%s>e$N?'$r7hD j$9$k!%$3$NMWNN$r%9%/%j!<%s>e$NA4$F$N%T%/%;%k$KE,MQ5;!$2hA|$r@8@.9k!%8=:_$O3H;6H?<MLL$N$_$r07CF$$$k$?$a!$H?<M$d6~@^!$F)2a$N=hM}$O9T$o$J$$!%

$3$3$G!$0lHIE*$J%l%$%H%l!<%7%s%0K!$H0[$J$kE@$O!$4{$K7W;;:Q$N?'CM%G!<%?$r07$&$?$a!$%l%s%@%j%s%0$r9T$&A0$KJd4V=hM}$rI,MWH9k3HG$"$k!%%i%8%*%7%F%#7W;;8e$N%G!<%?$r?^12$N:8$K<($9!%$3lr?^12$N1&$K<(9h$&$KJd4V=hM}$r9T$&!%3N=hM}$O3F%]%j%4%s$NC<$N%G!<%?$,B8:_$;$:!$%l%s%@%j%s%0$N:]$N%]%j%4%s$NC<$N?'$,Ci<B$KI|85$5lJ$$$?aI,MWHJk!%Nc$($P!$?^121&Cf(a) GO$(4+6)/2 = 5$ HJ$j!$(b) GO$(3+1+6+2)/4 = 3$ HJ$k!%

<!$K%l%$$r=P$7!$0lHV<jA0$N%]%j%4%s$,7hDj9k$H!$%]%j%4%s>e$N%i%8%*%7%F%#%G!<%?$r4p$K?'CM$r7hDj9k!%3N?'CM$O%l%$$H%]%j%4%s$N8rE@$r0O$`6aK5$N4 E@$rMQ$$$F7W;;$9$k!%$=$N%"%k%4%j%:%`$r0J2<$K<($9!%

?^14 $K<($9h&$K!$%]%j%4%s$H%l%$$N8rE@$,$(u,v)$ $N;~!$8rE@6aK5$N4 E@$O$(0,0)$!$$(0,1)$!$$(1,0)$!$$(1,1)$ $H7h$^$k!%$3lr<0(17) Kh$j!$?'CM%G!<%?$B_{(u,v)}$$O6aK5 4 E@$N?'CM%G!<%?$B_{(0,0)}$!$$B_{(0,1)}$!$$B_{(1,0)}$!$$B_{(1,1)}$$rMQ$$$F5aak!%$^$?!$?'CM%G!<%?$B_{(u,v)}$$O<0(17) Kh



(a) ¥Ø¥,¥“¥•¥˜¥£• »»,/˛ˆ˝

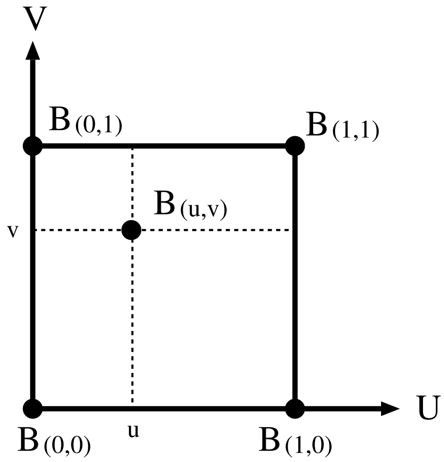
(b) ˚ · ‰Ł˝ ,/˛ˆ˝

?^12: Jd4V=hM}

$ j$ K$ h$ j7W; ;$ r9T$ &! %

$$B_{uv} = (1-u)(1-v)B_{00} + (1-u)vB_{01} + u(1-v)B_{10} + uvB_{11} \tag{17}$$

$ 3$ 3$ G(u,v) $ O$u : 0 \leq u \leq 1$!$ $: 0 \leq v \leq 1$ $ H$ J$ k$ h$ &$ K$ 9$ k! %



?^14: =PNO2hA|

4 JBNs2=Kh$k9bB.2=

4.1 LI@QNBg-$$=gKh$k@EE*Ii2YJ,;6

3,AX7?%i%8%*%7%F%#K!$rJBNs2=$9kK$"$?$j!$%]%j%4%s$r3F%W%m%;%C%5$K3djEvF$k@EE*Ii2YJ,;6$K$D$$$F=RYk!%

JBNs8z2L$r9b$ak?aK$O

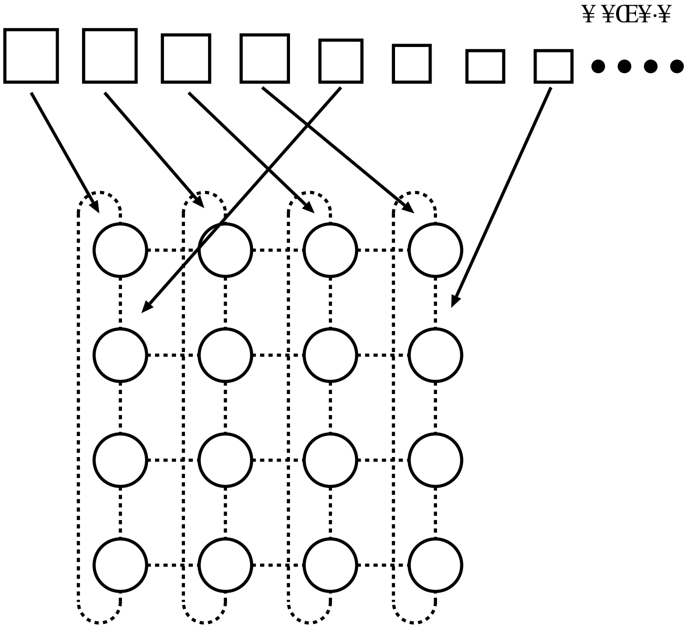
- 3F%W%m%;%C%5$NIi2Y$r6QEyK9$k
- DL?.%3%9%HrG$-$k$+$.$j:o8:$9$k

3H$,I,MW$G$"$k!%$^$?!$JBNs2=$OIY;NDI8&5f=j3+H/5l$?J,;6%a%b%j7?JBNs7W;;5!AP1000+>e$G<B8=$9$k!%

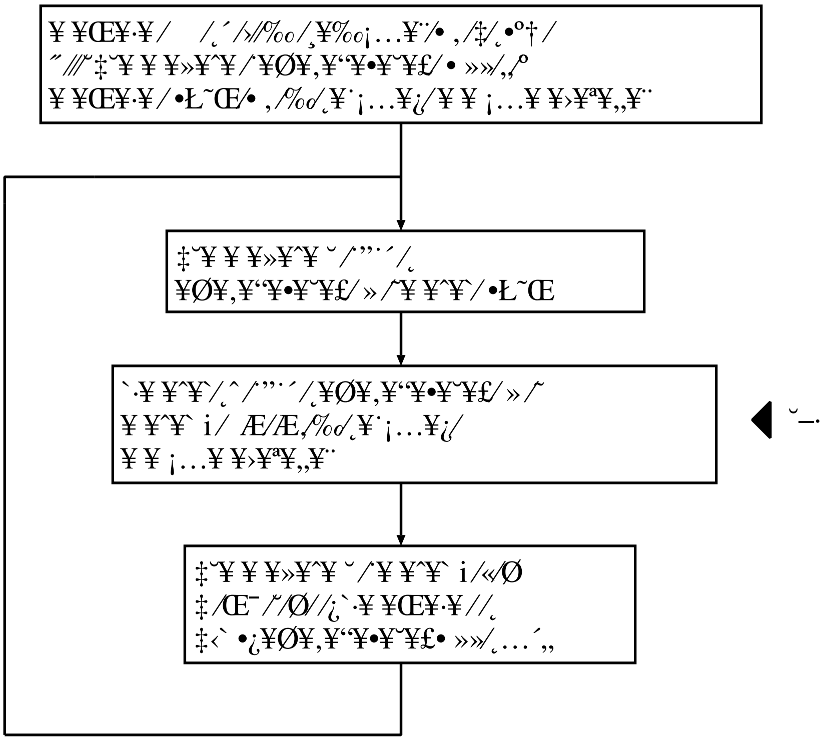
K\O@J8$GDs0F$9$k@EE*Ii2YJ,;6$O!$%]%j%4%s$rLI@QNBg-$$=g$K%=!<%H$7!$$3lr3F%W%m%;%C%5$K3d$jEvFk$H$$$&J}K!G"$k!%$3$NJ}K!$r?^15$K<($9!%2.4@a$G=R$Y$?$h$&$K!$%]%j%4%s$NLI@QNBg-$$$bNO!$1F$NBOLCV$d%]%j%4%s$NCf1{It$HC<It$N%U%)!<%`%U%!%/%?$N:9$,Bg$-$/Jk$?$a!$3,AX$,?<$/$J$k2DG=@-$,9b$$!%3l$r0l$D$N%W%m%;%C%5$K=8Cf5;kH%W%m%;%C%54V$NIi2Y6Q9U$,?^lJ$/$J$k!%$3N3Hr2r7h9k3H$,I,MW$HJj!$%]%j%4%s$rLI@QNBg-$$=g$K%=!<%H$7$?$bNr3F%W%m%;%C%5$K=g$K3djEvF$k!%$3$NJ}K!$rMQ$$$k$H!$Bg$-$J%]%j%4%sGN:YJ,$,:G0-:G8e$^$G9T$ol?H7Fb3F%W%m%;%C%5$NIi2Y$OJ]$?$l$F$$$k$H?dB,$5lk!%

3F%W%m%;%C%5$G3,AX7?%i%8%*%7%F%#7W;;$r9T$&:]!$J|<M%Q%C%A$r7hDj$9$k;~$KDL?.$,I,MW$HJk!%3l$OJ|<M%Q%C%A$N0LCV%G!<%?$HJ|<M%i%8%*%7%F%#$rDL?.9kbN$G!$%G!<%?H7$F>.$5$$!%$^$?!$LI@Q$NBg$-$J%]%j%4%s!Nc($P!$JI$rI=$9bNJI$O!$:GBgLI@Q$r;XDj$7!$J,3d$9kI,MW,$"$k!%3l$O!$%]%j%4%s$NLI@Q$,Bg$-$$$[$I!$3,AX$,?<$/Jj!$7W;;;~4V$,G|BgKJ$k2DG=@-$,$"$k!%D^$j!$%]%j%4%s$NLI@Q$NBg$-$JbN0lDG!$>.$5Jb$N0l$D$N?tG\$+$i?t==G\$N7W;;;~4V$N:9$KJk!%$=$N$?$a!$%]%j%4%s$NLI@QNBg-JbNOJ,3d7F!$3F%W%m%;%C%5$K3djEvF$k!%

$^$?!$%W%m%;%C%54V$NF14|$bJ|<M%Q%C%A$r7hDj9k;~KI,MWHJk!%D^$j!$A2?JK!$N0l2s$NJ|<MKBP7$F0l2s$NDL?.$H0l2s$NF14|HJ$j!$%W%m%;%C%54V$NF14|$HDL?.$N:o8:$HJj!$JBNs8z2L$,K>akh&KJ$k!%0lO"$N=hM}$NN.$l$r?^16$K<($9!%



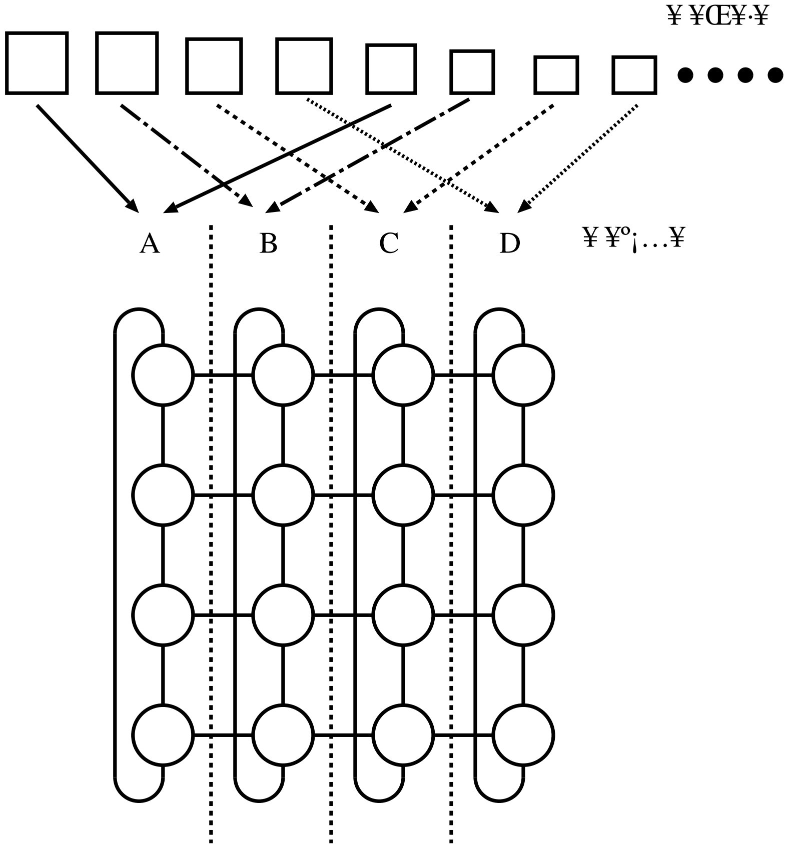
?^15: LL@QNBg-5Khk%]%j%4%s$N3d$jEv$FJ}K!



?^16: @EE*Ii2YJ,;6$N%"%k%4%j%:%`

4.2 8r:9H=DjKh$kFOE*Ii2YJ,;6

A2?JK!GNJ|<M%Q%C%A$,JQ2=$9$k;~!$3F%]%j%4%sKBP9$kJ|<M$N3d$j9g$$$G$"$k%U%)!<%`%U%!%/%?NCMNJQ2=$KJR4s$j$,@8$8$k!%$3N3HKhC$F!$%]%j%4%s$N3F%W%m%;%C%5$X$N3d$jEvF,@EE*G"kH!$J|<M%Q%C%A$,Beok;~!$3F%W%m%;%C%5$NIi2Y6Q9U$,?^$1J/Jk!%hC$F!$%W%m%;%C%54V$NIi2Y6Q9U$rL\E*H7$?<jK!$H7F!$FOE*Ii2YJ,;6$rDs0F9k!%$^$?!$K\8&5f$G$O%W%m%;%C%54V$NIi2YJ,;6$r?^$k0lJ}$G!$DL?.$N%*!<%P!<%X%C%I$N:o8:$r9MN8$K$$$l$F$$$k!%D^$j!$FOE*Ii2YJ,;6$O!$$^$:3F%W%m%;%C%5$N%0%k!<%W2=$r9T$$!$%0%k!<%WFb$G3F%W%m%;%C%5$N7W;;$9$k%]%j%4%s$N:F3djEvF$r9T$&J}K!G"$k!%

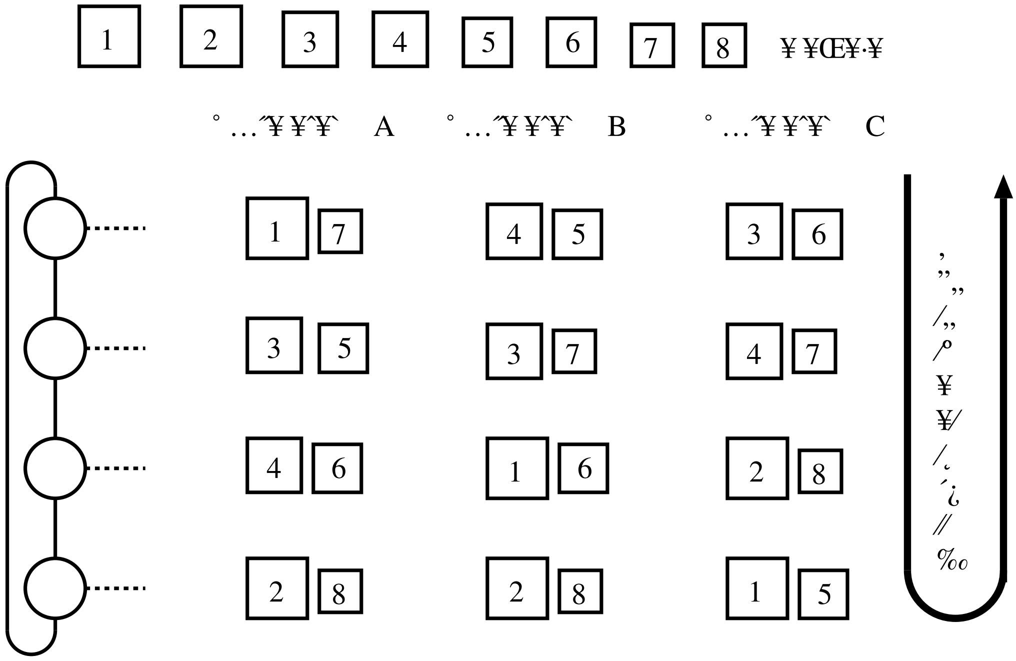


?^17: %0%k!<%WXN%]%j%4%s$N3d$jEv$FJ}K!

$^$:!$?^17$Nh&$K%W%m%;%C%5$r;MDN%0%k!<%W$KJ,$1$?8e!$%]%j%4%s$r3F%0%k!<%W$KLI@QNBg-$$=g$K3d$jEvFk!%%]%j%4%s$r%0%k!<%W$K3djEvF$?8e!$%0%k!<%W4VGOJ|<M%Q%C%A$N>pJs$N$_DL?.$r9T$$!$%]%j%4%s%G!<%?$NDL?.$O9T$o$J$$!%3lKh$j!$%0%k!<%W4VGNIi2Y6Q9U$r?^$j!$DL?.%3%9%H$r:o8:9k!%$^$?!$J|<M%Q%C%A$KhC$FO[$Jk,!$0lHIE*$K%]%j%4%s$NLI@Q$,Bg$-$$$[$I3,AX9=B$$,?<$/$J$j!$7W;;NL$,A}Bg$9$k2DG=@-$,$"$k!%

7?$,$C$F!$3F%0%k!<%WXN3djEvF$O%]%j%4%s$NLL@Q$r%Q%i%a!<%?$H9k!%

<!$K!$3F%0%k!<%W$K3d$jEvFil?%]%j%4%s$O!$J|<M%Q%C%A$,Be$o$k;~!$%0%k!<%WFb$N3F%W%m%;%C%5$G:F3djEvF$,9T$olk!%3l$OJ|<M%Q%C%A$N0LCVKhCF!$$=l>lN%]%j%4%sKBP9$k%U%)!<%`%U%!%/%?$NCM$,!$A0$NJ|<M%Q%C%A$NbN$HA4$/JQoCF7$^$&$?$aG"$k!%$3N3HKhj!$3,AX9=B$$N?<5,A0$NJ|<M$NH-NbNH$O0[$J$j!$7W;;NL$,$+JjJQ2=7F7^$&!%$3lr2sHr9k$?$a$K:F3d$jEvFN=hM}$r9T$&!%0lO"$N=hM}$r?^18$K<($9!%



?^18: 8r:9H=DjCf$N%1%$$NK\?tKh$k%]%j%4%s$N3djEvFJ}K!

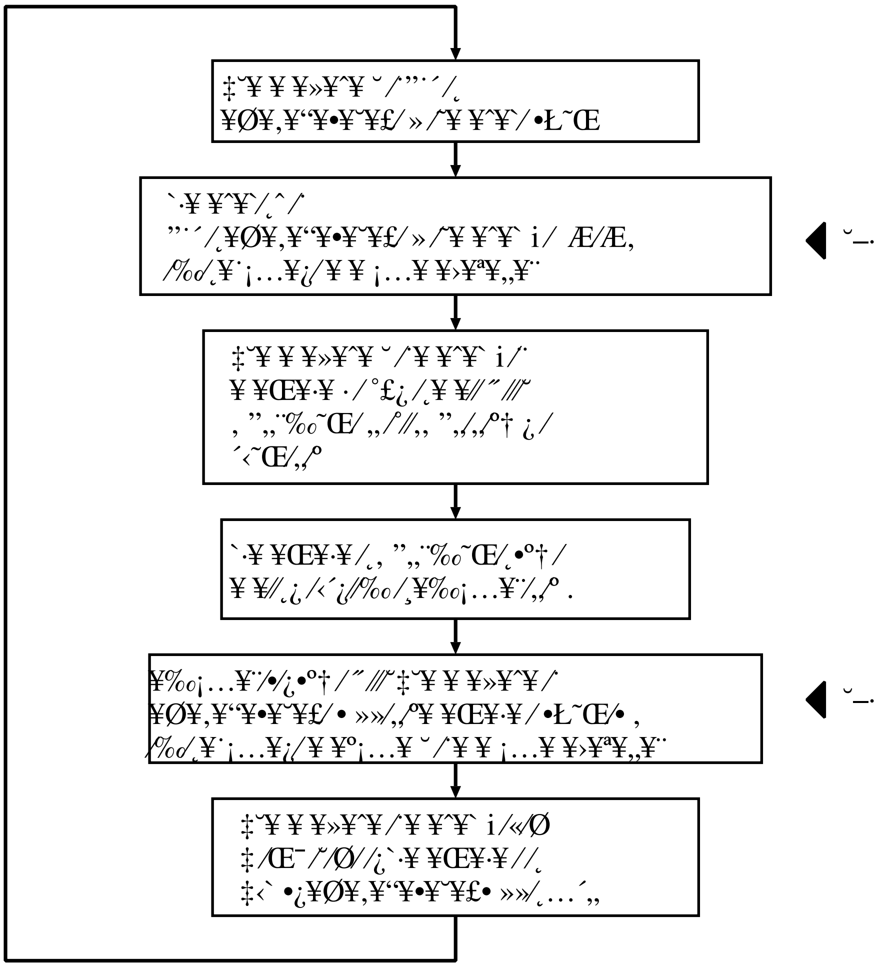
?^18$OJ|<M%Q%C%A$,JQ2=9k;~!$%0%k!<%WFb$N3F%W%m%;%C%5$G7W;;$9$k%]%j%4%s$N3djEvF$r<($7$F$$$k!%Nc$($P!$J|<M%Q%C%AA$N;~!$$3lH%0%k!<%WFb$K3d$jEvFilF$$$k%]%j%4%sHN%U%)!<%`%U%!%/%?$r5a$a!$8r:9$9$k%l%$$NB?$$=g$K%=!<%H$7!$3F%W%m%;%C%5$K3djEvF$k!%$3$N=hM}$rJ|<M%Q%C%AB!CK$bF1MM$K9T$&!%

8r:9$9$k%l%$$,B?$$%]%j%4%s$K4X$7FO!$%Q%C%A$NJ|<M9k[HsIN%(%M%k%.!<$,<u$1EO5lk,!$8r:9$9$k%l%$$,>/$J$$%]%j%4%s$O!$%(%M%k%.!<$N<u$1EO7,>.$5$$!%9JoA!$8r:9$9$k%l%$$,B?$$%]%j%4%s$d>/$J$$$bNO!$3,AXCf$N>eAX$ND:E@$H2<AX$ND:E@$H$N:9$,>/$J$$3Hr<($9!%8r:9$9$k%l%$$,B?$/$bJ/>/J/bJ$$>19gK*$$$F$O!$%]%j%4%sCf$K%Q%C%A$+iN8w$,E~C#$9$kNN0h$H7J$$NN0h$,4^$^lF$*$j!$$3Nh$&$J%]%j%4%s$O3,AXCf$N>eAX$ND:E@$H2<AX$ND:E@$H$N:9$r@8$`860x$HJj!$:YJ,$,7+jJV5$l!$7W;;NL

$,A}2C$9$k!%$3N3Hr9MN8$7$F!$8r:9$9$k%l%$$,B?$$=g$K%=!<%H$7$?$bNrMQ$$$F!$3F%W%m%;%C%5$K:F3djEvF$r9T$&%]%j%4%s$r7hDj$9$k!%

$^$?!$A02s$NJ|<M%Q%C%A$H:#2s$NJ|<M%Q%C%A$,!$F1$8%]%j%4%s$KB0$9$kH-!$3F%W%m%;%C%5$G7W;;9k%]%j%4%s$OJQ2=$7$J$$$h$&$K9k$7!%$D$^$j!FsD$NJ|<M%Q%C%A$,F10l$N%]%j%4%s$KB0$9$k3H$O!$$=l>lNJ|<M%Q%C%A$HB>$N%]%j%4%s4V$N0LCV4X78$,$[$HsIJQ2=$;$:!$%U%)!<%`%U%!%/%?$NCMb[Hs$IJQ2=$7$J$$$?aG$"$k!%3N3HKh$j!$%]%j%4%s$N3d$jEvFr9ToJ$$$3HG!$DL?.%3%9%H$N:o8:$r9T$&!%

3NJ}K!GO!$F14|$,Fs2s$"$j!$%i%8%*%7%F%#$r7W;;9k%]%j%4%sN3l^GN7k2LrI,MWH9kNG!$DL?.%3%9%H$,$+$+k3HKJk!%7+$7!$:F3djEvF$r9T$&3H$G%W%m%;%C%54V$NIi2Y6Q9U$,?^$l!$$3N3HKhjJBNs8z2L$,K>$akh$&$KJk!%3N0lO"$N=hM}$NN.lr?^19$K<($9!%



?^19: FŒ*Ii2YJ,; 6$N%"%k%4%j%:%`

5 <B83$HI>2A

5.1 <B83J}K!

:#2s<B83$G;HMQ$9$k%7!<%s$O!$It20(%]%j%4%s?t:238) G"$k!%

5.2 @aGO!$3,AX7?%i%8%*%7%F%#K!$NI>2A$r9T$&!%3,AX7?%i%8%*%7%F%#K!GN%U%)!<%` %U%!%/%?$N:9$NJQ2=$KH<$&!$7W;;;~4V$N<B83$r9T$$!$<!$K!$%U%)!<%`%U%!%/%?7W;;Cf$K;H MQ$9$k%1%$$NK\?t$NJQ2=$KH<$&!$7W;;;~4V$N<B83$r9T$&!%$3NFsD$N<B83$O!$%U%)!<%`%U%! %/%?$NCM$,5Z$\$97W;;;~4V$K4X$9$k<B83$G$"$k!%:G=i$N<B83$O!$3,AX$r9=@.$9$k$?$a$NH= Dj4p=`$G$"$k!$%U%)!<%`%U%!%/%?$N:9$r87$7$/$9$k;v$G!$$h$j@53N$J%U%)!<%`%U%!%/%?$r MQ$$F%(%1%a%s%H$KJ|<M$7!$$3$1$Khk7W;;;~4VKD$$FNbNG$"$k!%

<!$N<B83$O!$%U%)!<%`%U%!%/%?$r7W;;$9$k:]!$=P$9%1%$$NK\?t$rJQ2=$5$;!$%U%)!<%`%U%! %/%?<+?H$N8m:9$NJQ2=$r8+$k!%$3$1$O!$7W;;BP>]$NJ|<M%Q%C%A!$F~<M%N!<%I!$$=1>1N %5%s%W%j%s%0%]%$%s%H$N?t$rJQ2=$5$;!$%U%)!<%`%U%!%/%?$N@:EY$H!$$=$1$KH<$&<B9T;~4V $NJQ2=$r8+$k!%$^$?!$%U%)!<%`%U%!%/%?7W;;GHtP$9%1%$$NK\?t$rJQ2=$5$;$?:]$N%U%)!< %`%U%!%/%?$NCM$NJQ2=$rD4Yk!%

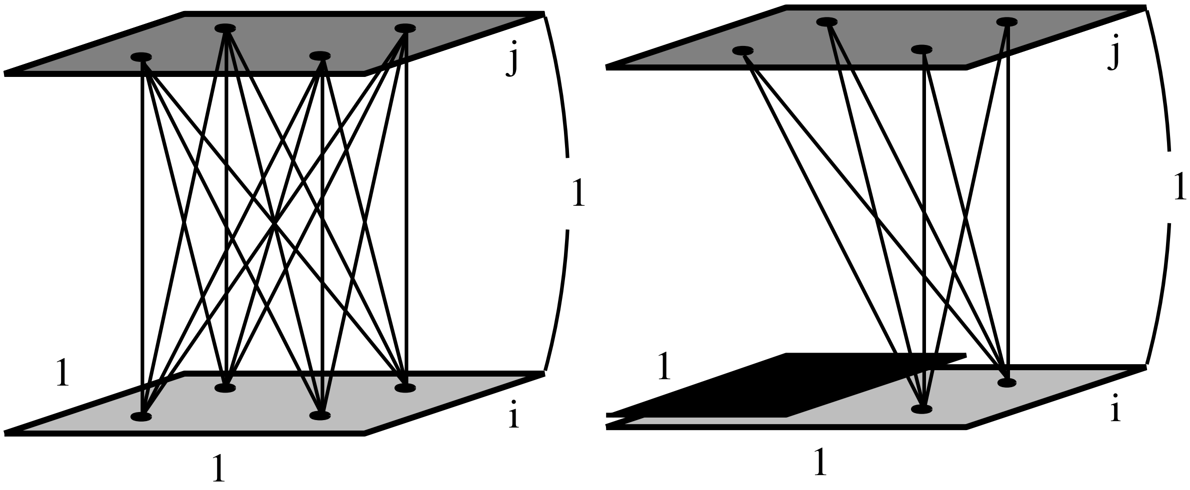
5.3 @aGO!$@EE*Ii2YJ,;6$NJBNs<jK!$N<B83$r9T$&!%<B83$K4X7F$O!$AP-1000 $N%7%_%e %1!<%?$rMQ$$!$1!$4!$16 Bf$r;HMQ9k$H2>Dj$7!$3F%;%k$N7W;;;~4V$rD4$Y!$Ii2Y6Q0U$,?^ 1F$$k$+D4$Y$k!%$^$:!$3F%;%k$K3d$jEvFi1k%]%j%4%s$NLL@Q$NAmOB$,!$%]%j%4%s$N AmLL@Q$r%;%k?t$G3d$C$?CM0J>e$KJi$J$$h$&3d$jEvFk<B83$r9T$&!%<!$K!$%]%j%4%sLL @QNBg-JbNrJ,3d$7!$>e5-$HF1$8>r7o$G<B83$r9T$&!%

5.2 3,AX7?%i%8%*%7%F%#K!$NI>2A

:G=i$N<B83$O!$3,AX7?%i%8%*%7%F%#K!$G$N%U%)!<%`%U%!%/%?$N:9$NJQ2=$KH<$&7W;;;~4V $NHf3S$G$"$k!%$3$N<B83$O!$%U%)!<%`%U%!%/%?7W;;$N%1%$$NK\?t81 K\(J|<M%Q%C%A9 J,3d!$ F~<M%N!<%I9 J,3d) $N;~!$J|<M$r9T$&:]$N%N!<%I$N?F;R4V$N:9$r10%!$20%!$30% $KJQ2= 5;!$7W;;$r9TC?!%<B9T7k2L$O!$$$$:1b!$630 J,$G$"$j!$=PNO%G!<%?$b0lCW7?!%3N 3H$O!$%U%)!<%`%U%!%/%?$N:9$r;XDj$5$($9$1$P!$J|<M%Q%C%A$+$i!$J|<M$r<B9T$9$k3F%] %j%4%s$N%N!<%I$,!$0lDj$G$"$k$3$H$r<($7$F$$k!%$5$i$K!$%U%)!<%`%U%!%/%?7W;;$N>r7o $,F1$8G"k?$a!$=PNO%G!<%?$,F1$8KJkH9M$($i1k!%

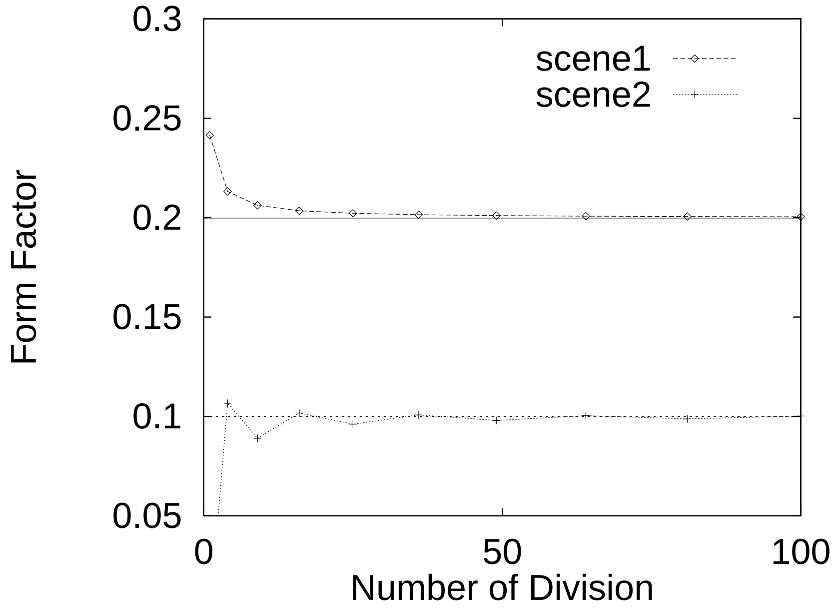
<!$K!$%U%)!<%`%U%!%/%?7W;;Cf$K;HMQ$9$k%1%$$NK\?t$NJQ2=$KH<$&!$7W;;;~4V$NHf3S$G $"$k!%$^$:!$%U%)!<%`%U%!%/%?7W;;GHtP$9%1%$$NK\?t$rJQ2=$5$;$?:]$N%U%)!<%`%U%!%/ %?$NCM$NJQ2=$rD4$Y$k!%%MQ$$$k%G!<%?$O!$?^20$K<($9$h$&$J!$D9$51 $NN)J}BN$N>eLL$HD1 LL$G$"$j!$$3$N4V$N%U%)!<%`%U%!%/%?CM$rD4Yk!%3N%G!<%?$N%U%)!<%`%U%!%/%?$NCM$O

0.200043 HCNi1F$$$k[3]!%



¥•¡…¥ 1 ¥•¡…¥ 2

?^20: %U%)!<% `%U%!%/%?$N%F%9%H%G!<%?



?^21: %U%)!<% `%U%!%/%?$NJQ2=

3N7k2Lhj!$%U%)!<%`%U%!%/%?$NCM$O!$7W;;$r9T$&%l%$$rA}$d$9$3$H$G!$M}A[CM$K6a$E$$$F$$$k$3$H$,J,$+$k!%<!$K!$%U%)!<%`%U%!%/%?$r7W;;9k%l%$$NK\?t$rJQ2=$5$;$k3HKh$k!$7W;;~4V$NJQ2=$rI=4$K<($9!%

I=4: %U%)!<%`%U%!%/%?$N:9$NJQ2=KBP9$k7W;;~4V

<table>
<tr><td>%U%)!<%`%U%!%/%?$N:9</td><td>16 K\</td><td>81 K\</td><td>256 K\</td></tr>
<tr><td>2hA|(It20$N2hA|)</td><td>120(min)</td><td>630(min)</td><td>1950(min)</td></tr>
</table>

3N7k2Lhj!$%U%)!<%`%U%!%/%?7W;;Cf$N%l%$$NK\?t$rJQ2=$5$;$k$3$H$G!$%U%)!<%`%U%!%/%?$NCM$rCi<B$K:F8=G-!$J|<M$r9T$($k$,!$%l%$$NK\?t81 K\$G$b!$10 ;~4V0J>e$+$+kN$G!$C`<!=hM}$@$1GO8=<BE*GJ$$!%hC$F!$%l%$$NK\?t$O16 K\$r;HMQ$7!$3,AX7?%i%8%*%7%F%#7W;;$r9T$&h&K9$k!%

5.3 @EE*Ii2YJ,;6$NI>2A

K\@aGO!$JBNs2=$KH<$&@EE*Ii2YJ,;6$N<B83$r9T$&!%:G=i$N<B83$O!$4.1 @a$G=RY?h&$K!$%]%j%4%s$NLL@Q$NBg$-$$=g$K%=!<%H$7$?$bNr3F%;%k$K3d$jEvFkbN$G!$3F%;%k$K3d$jEvFilk%]%j%4%s$NLL@Q$NAmOB$,!$%]%j%4%s$NAmLL@Q$r%;%k?t$G3d$C$?CM0J>e$KJi$J$$$h$&!$%]%j%4%s$r3d$jEvFk!%$^$?!$I=5$G$O!$%U%)!<%`%U%!%/%?$N:9!$20%!$%U%)!<%`%U%!%/%?7W;;$N%l%$$r81 K\$G<B83$r9T$C$?7k2L$r<(7F$$$k!%$^$?!$$3$N<B83$O!$%o!<%/%9%F!<%7%g%s>e$GAP-1000 $N%7%_%e%l!<%?$rMQ$$$F9TC?!%

3N7k2LKhkH!$4 Bf;HMQ$9$k;~!$1 Bf$N;HMQ;~$KHf$Y!$Ls3 G\$NB.EY8~>e$,4|BT$G$-$k$,!$16 Bf;HMQ9k$HLs5 G\$NB.EY8~>e7+4|BTG-$J$$!%3l$O4!$16 Bf;HMQ;~!$%;%kID $,2 $K3d$jEvFilk%]%j%4%s$N7W;;$,!$B>$N%]%j%4%s$N7W;;~4V$KHf$Y!$$HFbBg$-$JbNKJ$j!$FC$K!$16 Bf;HMQ;~$K3d$jEvFilF$$$k%]%j%4%s$N7W;;~4V$,!$$HFbBg$-$JbNKJ$k!%$3N?$a!$3F%;%kGNIi2Y6Q9U$,?^$lJ/Jj!FCK!$16 Bf;HMQ$7$?$H$-!$Ls5 G\$NB.EY8~>e7+F@k3H,G-J/JC$?!%$^$?!$$3$10J>e$N%;%k$r;HMQ$7Fb!$%;%kID3 $G=hM}$7$?%]%j%4%s$,$"$k8B$j!$B.EY8~>e$,F@$ilJ$$!%

I=5: 3F%;%k$G=hM}$9$k%]%j%4%s?t$H=hM};~4V(1)

%;%kID	%]%j%4%s?t	7W;;;~4V(min)
1 Bf		
0	238	1059:31
4 Bf		
0	22	208:21
1	72	247:03
2	72	322:39
3	72	291:32
16 Bf		
0	1	145:28
1	1	145:49
2	1	231:11
3	1	194:46
4	1	30:44
5	9	28:49
6	23	36:34
7	23	42:27
8	23	30:04
9	23	31:48
10	22	25:16
11	22	24:09
12	22	27:45
13	22	23:05
14	22	23:11
15	22	22:50

<!$K!$A0$N<B83$HF1$8>r7o$G!%%]%j%4%s$N:GBgLL@Q$r;XDj$7!$$=$10J>e$N%]%j%4%s$rJ,3d$7!$3F%W%m%;%C%5$K3djEvF$k<B83$N7k2L$rI=6$K<($9!%$3$N7k2L$h$j!$3F%;%k$K3d$jEvFilk%]%j%4%s?t$,$[$\F1$8KJC?!%7+$7!$%]%j%4%s$rJ,3d$7!$3d$jEvFk$?$a!$%]%j%4%s?t$,A}$(!$7W;;;~4V$,A}2C$7$?!%$3lO!$;XDj$7$?:GBgLL@Q$,>.$5$9$.$?$?$a!$J,3d$7$?%]%j%4%s$K4X7F!$J,3d$9$kA0$O!$$3$3$G;XDj7?:GBgLL@Qhj!Bg-$JLL@Q$X$NJ|<M$,9Tol$?$+i@$H9M$(il$k!%$=N?$a!$16 Bf;HMQ;~$GLs8 G\$NB.EY8~>e7+4|BTG-$J$$!%

I=6: 3F%;%k$G=hM}$9$k%]%j%4%s?t$H=hM};~4V(2)

%;%kID	%]%j%4%s?t	7W;;;~4V(min)
16 Bf		
0	23	139:52
1	23	123:11
2	23	120:08
3	23	115:54
4	23	105:38
5	23	118:36
6	23	133:21
7	23	128:28
8	23	123:20
9	23	134:06
10	23	129:50
11	23	119:07
12	23	129:35
13	23	111:31
14	23	120:30
15	22	129:43

6 $*$ojK

K\O@J8GO!$3,AX7?%i%8%*%7%F%#K!$Khk2hA|@8@.%7%9%F%`$H$=$NJBNs2=$K$D$$$F=R$Y$?!%3,AX7?%i%8%*%7%F%#K!$O!$%i%8%*%7%F%#7W;;$r9T$$!$$=$N7k2L$rMQ$$$F%l%s%@%j%s%0$r9T$&$?$a!$0lO"$N2hA|@8@.%7%9%F%`$N9=C[$r9TC?!%$^$?!$3,AX7?%i%8%*%7%F%#K!$NJBNs2=KD$$$F8!F$$7!$AP-1000 $N%7%_%e%l!<%?>e$G$N<B83$r9TC?!%

K\8&5fGO!$$3l^$G8&5f<<$GJ5lF$-$?%i%8%*%7%F%#K!$NJBNs2=$N%7%9%F%`$N%W%j%W%m%;%C%5It$H%W%l%S%e"!<It$rN.MQ$7!$3,AX7?%i%8%*%7%F%#7W;;It$H%l%s%@%i!<It$r9=C[$7$?!%3,AX7?%i%8%*%7%F%#7W;;ItGO!$%7!<%s%G!<%?$rMQ$$!$3,AX7?%i%8%*%7%F%#7W;;$r9T$$!$%i%8%*%7%F%#%G!<%?$r=PNO9k!%%l%s%@%i!<ItGO!$$3l^$G=PNO$7$?%G!<%?$rMQ$$!$%l%s%@%j%s%0$r9T$$!$2hA|$r=PNO9k!%$^$?!$=PNO$7$?2hA|$O!$$HFb%j%"%kG"k,!$5U$K!$%l%s%@%j%s%0$KG|Bg$J;~4V$,$+$+kh$&$KJC$?!%

JBNs2=K"$?$C$F!$3,AX7?%i%8%*%7%F%#K!$O!$%]%j%4%sC10L$G7W;;$r9T$&$?$a!$B.EY8~>e$O3F%;%k$K3djEvF$k%]%j%4%s$K0MB8$9$k!%$=$N$?$a!$K\8&5f$GDs0F7?!$@EE*Ii2YJ,;6!$F0E*Ii2YJ,;6$O!$%W%m%;%C%5$K3d$jEvFk%]%j%4%sKD$$$FCeL\$7$?!%

@EE*Ii2YJ,;6GO!$%]%j%4%s$rLL@QNBg-$$=g$K%=!<%H$7!$$3lr3F%W%m%;%C%5$K3d$jEvFk!%3l$O!$F14|$,#12s$H!$%(%M%k%.!<$rJ|<M9k%Q%C%AN_$NDL?.$G:Q$`!%$^$?!$3F%;%k4V$NIi2Y6Q9U$r?^k?aK!$LL@Q$NBg$-$J%]%j%4%s$rJ,3d$7!$%;%k$K3djEvF$kJ}K!$rHC$?!%$3lKhj!$It20(%]%j%4%s?t:238) $rMQ$$!$%7%_%e%l!<%7%g%s$7$?7k2L!$4 %;%k;HMQ;~GO!$Ls3 G\!$16 %;%k;HMQ;~!$Ls8 G\$NB.EY8~>e$,4|BT$G$-$k!%

F0E*Ii2YJ,;6KD$$$F$O!$J|<M9k%Q%C%A4H$KIi2Y$rM=B,$7!$3F%W%m%;%C%5$K%]%j%4%s$r3djEvF$kJ}K!$G$"$k!%Ii2YM=B,$O%U%)!<%`%U%!%/%?7W;;$N%l%$$rMQ$$$F9TC?!%$^$?!$A02s$NJ|<M%Q%C%A$H:#2s$NJ|<M%Q%C%A$,F1$8>l9g!$J|<M%Q%C%A$HB>$N%]%j%4%s$N0LCV4X78$,$[$\F1$8$"$k$?$a!$3F%;%k4V$G$O%]%j%4%s$N3djEvF$r9T$o$J$$!%3N3H$G!$DL?.NL$r:o8:$7!$B.EY8~>e$r9bak=hM}$r9T$&!%

:#8e$N2]Bj$H7F!$(1) K\%7%9%F%`$G<BAuG-$k%]%j%4%s$N3H=<!%8=:_!$0l7$($k%]%j%4%s$O;M3Q7AN_G"kN$G!$J#;($J2hA|$N:n@.$,9T$($J$$!%;03Q7A$N%]%j%4%s$r2C$($k3H$G!$$h$jJ#;($J2hA|$r@8@.$G$-$kh&K9$k!%(2) %]%j%4%s$N7A>uKh$j!$:GE,$J3,AX9=B$$KJQ2=5;$k!%Nc$($P!$:YD9$$%]%j%4%sKBP7FO!$D9JU$r4 J,3d9k!%(3) %l%s%@%i!<ItGN!$%l%s%@%j%s%0$K$+$+$k;~4V$N:o8:!%(4) @EE*Ii2YJ,;6$O!$LL@QNBg-$J%]%j%4%s$rJ,3d9k;~$N!$E,@Z$J:GBgLL@Q$N7hDj!%$^$?!$<B5!$G$N7W;;$r9T$$!$%7%_%e%l!<%7%g%sDL$j$N7k2L$,F@ilk+!%(5) F0E*Ii2YJ,;6$O!$Ds0F7?%"%k%4%j%:%`$N<B8=$,5s2ilk

<U<-

K\8&5f$N5!2q$rM?$($F2<5j!$?t!9$N=u8@$rD:$-$^$7$?;3:j>!9065<x!$>eEhL@;a$K?4$h$j?<$/46<U$N0U$rI=7^$9!%

$^$?!$K\8&5f$K$"$?$j!$$$$m$$$mJLLG5.=E$J8f0U8+$dNe$^$7$rD:$-$^$7$?K\8&5f<<$N3'MM$K?4$h$j46<UCW$7$^$9!%

;29MJ88%

[1] Bg@P ?J0 l!$KRLn 8wB'!$“%0%i%U%#%C%/%9”!$F |K\I>O@<R!$1994!%

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[11] >eEh L@!$;3:j>!90!$EOJU F)!$F@4] 1Q>!“%H%i%s%9%T%e!<%?Kh$k%i%8%*%7%F%#K!$N JBNs2=”!$>pJs=hM}3X2qBh48 2sA49qBg2qO@J8=8!$No. 2, pp. 373-374!$1994.

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