mac.for を利用して、convection.for を作成する。
ソースファイル名：convection.for, 実行ファイル名：convection.out

```
$ cp   mac.for   convection.for
$ vi   convection.for
$ gfortran   -o    convection.out    convection.for
$ ./ convection.out
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```
      program conv

      parameter(imax = 60, jmax = 30)
      real*8   p(imax,jmax), pn(imax,jmax), g(imax,jmax)
      real*8   dx, dy, pmax, pmin, norm
      integer i, j, nx, ny
      character a(imax,jmax)

      u(imax,jmax), v(imax,jmax), un(imax,jmax), vn(imax,jmax)
      d(imax,jmax)
      dt, re, tmp1, tmp2, tmp3, error
      integer nb
      character b(imax,jmax), c(imax,jmax)

      real*8   e(imax,jmax), en(imax,jmax)
      real*8   emax, emin, pr, gr
      emax = 1.0; emin = 0.0; pr = 1.; gr = 10.;

      dt = 0.2; re = 10.;
      dx = 1.; dy = 1.; nx = 20; ny = 20
      dx = 1.; dy = 1.; nx = 30; ny = 20

c..   initial condition
      do i = 1, nx; do j = 1, ny
       e(i,j) = (emax + emin)*0.5
       u(i,j) = 0.
       v(i,j) = 0.
       p(i,j) = 0.
       pn(i,j) = 0.
      enddo; enddo

      do m = 1, 10000

c..   boundary condition
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```
      do i = 1,nx
       e(i,1 ) = emax
       e(i,ny) = emin
       u(i,1 ) = 0.
       u(i,ny) = 0.
       v(i,1 ) = 0.
       v(i,ny) = 0.
       pn(i,1 ) = pn(i,2)
       pn(i,ny) = pn(i,ny-1)
      end do

      do j = 1,ny
       e(1 ,j) = e(2 ,j)
       e(nx,j) = e(nx-1,j)
c        u(1 ,j) = u(2 ,j)        (←コメント・アウト，c を先頭に入力)
c        u(nx,j) = u(nx-1,j)      (←コメント・アウト，c を先頭に入力)
       u(1 ,j) = 0.
       u(nx,j) = 0.
       v(1 ,j) = 0.
       v(nx,j) = 0.
       pn(1 ,j) = pn(2 ,j)
       pn(nx,j) = pn(nx-1,j)
c        pn(1 ,j) = 1.0           (←コメント・アウト，c を先頭に入力)
c        pn(nx,j) = 0.9           (←コメント・アウト，c を先頭に入力)
      end do

c..   pressure
      do n = 1, 1000

       do i = 1, nx; do j = 1, ny
        p(i,j) = pn(i,j)
       end do; end do

       do i = 2, nx-1
        do j = 2, ny-1
         d(i,j) =
     1
```

$$D=\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y} \rightarrow D_{i,j}=\frac{u_{i+1,j}-u_{i-1,j}}{2\Delta x}+\frac{v_{i,j+1}-v_{i,j-1}}{2\Delta y}$$

```
         g(i,j) =
     1
```

$$g=-\left\{\left(\frac{\partial u}{\partial x}\right)^2+2\frac{\partial u}{\partial y}\cdot\frac{\partial v}{\partial x}+\left(\frac{\partial v}{\partial y}\right)^2\right\}+\frac{D^n}{\Delta t}$$

```
      2
      3
      4
        end do
       end do

       do i = 2,nx-1; do j = 2,ny-1
        pn(i,j) =
     1
     2
       end do; end do

       pmax = 0.; pmin = 100.; norm = 0.
       do i = 1, nx; do j = 1, ny
        if(abs(p(i,j)-pn(i,j)) .gt. norm) norm = abs(p(i,j)-pn(i,j))
        if(pn(i,j) .gt. pmax) pmax = pn(i,j)
        if(pn(i,j) .lt. pmin) pmin = pn(i,j)
       end do; end do

       if(norm    .le. 0.001) go to 100

      enddo

100    do i = 1, nx; do j = 1, ny
        p(i,j) = pn(i,j)
       end do; end do

c..    velocity
       do i = 1, nx; do j = 1, ny
        un(i,j) = u(i,j)
        vn(i,j) = v(i,j)
       end do; end do

       do i = 2, nx-1
        do j = 2, ny-1
         tmp1 =
         tmp2 = vn(i,j)*(un(i,j+1) - un(i,j-1))/dy*0.5
         tmp3 = (un(i+1,j    ) - 2.*un(i,j) + un(i-1,j    ))/dx**2
     1         + (un(i    ,j+1) - 2.*un(i,j) + un(i    ,j-1))/dy**2
         u(i,j) = un(i,j)
```

$$\frac{\partial^2 p}{\partial x^2}+\frac{\partial^2 p}{\partial y^2}=g$$

$$\rightarrow \quad \frac{p_{i+1,j}-2p_{i,j}+p_{i-1,j}}{\Delta x^2}+\frac{p_{i,j+1}-2p_{i,j}+p_{i,j-1}}{\Delta y^2}=g_{i,j}$$

$$\rightarrow p_{i,j}=\frac{p_{i+1,j}\Delta y^2+p_{i-1,j}\Delta y^2+p_{i,j+1}\Delta x^2+p_{i,j-1}\Delta x^2-g_{i,j}\Delta x^2\Delta y^2}{2\left(\Delta x^2+\Delta y^2\right)}$$

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=-\frac{\partial p}{\partial x}+\frac{1}{\mathrm{Re}}\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}\right)$$

$$\rightarrow$$

$$\frac{u_{i,j}^{n+1}-u_{i,j}^{n}}{\Delta t}+u_{i,j}^{n}\frac{u_{i+1,j}^{n}-u_{i-1,j}^{n}}{2\Delta x}+v_{i,j}^{n}\frac{u_{i,j+1}^{n}-u_{i,j-1}^{n}}{2\Delta y}$$

$$=-\frac{p_{i+1,j}^{n}-p_{i-1,j}^{n}}{2\Delta x}+\frac{1}{\mathrm{Re}}\left(\frac{u_{i+1,j}^{n}-2u_{i,j}^{n}+u_{i-1,j}^{n}}{\Delta x^2}+\frac{u_{i,j+1}^{n}-2u_{i,j}^{n}+u_{i,j-1}^{n}}{\Delta y^2}\right)$$

$$\rightarrow u(i,j)=u_{i,j}^{n+1},\ \ un(i,j)=u_{i,j}^{n},\ v(i,j)=v_{i,j}^{n+1},\ \ vn(i,j)=v_{i,j}^{n}$$

$$tmp1=u_{i,j}^{n}\frac{u_{i+1,j}^{n}-u_{i-1,j}^{n}}{2\Delta x}\quad tmp2=v_{i,j}^{n}\frac{u_{i,j+1}^{n}-u_{i,j-1}^{n}}{2\Delta y}$$

$$tmp3=\frac{u_{i+1,j}^{n}-2u_{i,j}^{n}+u_{i-1,j}^{n}}{\Delta x^2}+\frac{u_{i,j+1}^{n}-2u_{i,j}^{n}+u_{i,j-1}^{n}}{\Delta y^2}$$

$$u_{i,j}^{n+1}=u_{i,j}^{n}-\Delta t\left(tmp1+tmp2+\frac{p_{i+1,j}^{n}-p_{i-1,j}^{n}}{2\Delta x}-\frac{tmp3}{\mathrm{Re}}\right)$$

```
1       - dt*(tmp1 + tmp2 + 0.5*(p(i+1,j)-p(i-1,j))/dx - tmp3/re)

      tmp1 = un(i,j)*(vn(i+1,j) - vn(i-1,j))/dx*0.5
      tmp2 = vn(i,j)*(vn(i,j+1) - vn(i,j-1))/dy*0.5
      tmp3 =
1           +
      v(i,j) = vn(i,j)
1       - dt*(tmp1 + tmp2 + 0.5*(p(i,j+1)-p(i,j-1))/dy - tmp3/re)
    end do
    end do


      do i = 2, nx-1; do j = 2, ny-1
       v(i,j) = v(i,j)
1   + dt*gr/re**2*(e(i,j) - (emax + emin)*0.5)
      enddo; enddo


      do i = 1, nx; do j = 1, ny
       en(i,j) = e(i,j)
      enddo;enddo


      do i = 2, nx-1; do j = 2, ny - 1
       tmp1 = u(i,j)*(en(i+1,j   ) - en(i-1,j     ))/dx*0.5
     .          + v(i,j)*(en(i   ,     ) - en(i   ,     ))/dy*0.5

       tmp2 = 1./re/pr*( ( en(     ,j     ) - 2.*en(     ,j) + en(     ,j     ) ) /dx**2
     .                  + ( en(i   ,     ) - 2.*en(i,     ) + en(i   ,     ) ) /dy**2 )
       e(i,j) = en(i,j) + dt*(-tmp1 + tmp2)
      end do; end do

c.. graphics
      if(mod(m,10) .eq. 0) then
       write(*,*) m

      do i = 1, nx; do j = 1, ny
       if(e(i,j) .le. emax*1.0                ) a(i,j)= '9'
       if(e(i,j) .le. emax*0.9 + emin*0.1) a(i,j)= '8'
       if(e(i,j) .le. emax*0.8 + emin*0.2) a(i,j)= '7'
       if(e(i,j) .le. emax*0.7 + emin*0.3) a(i,j)= '6'
       if(e(i,j) .le. emax*0.6 + emin*0.4) a(i,j)= '5'
       if(e(i,j) .le. emax*0.5 + emin*0.5) a(i,j)= '4'
```

$$\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}=-\frac{\partial p}{\partial y}+\frac{1}{\mathrm{Re}}\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}\right)+\frac{Gr}{\mathrm{Re}^2}(T-T_m)$$

$$\rightarrow \quad tmp1=u\frac{\partial v}{\partial x},\ tmp2=v\frac{\partial v}{\partial y},\ tmp3=\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}$$

$$\rightarrow \quad v_{i,j}^{n+1}=v_{i,j}^{n}-\Delta t\left(tmp1+tmp2+\frac{p_{i,j+1}^{n}-p_{i,j-1}^{n}}{2\Delta y}-\frac{tmp3}{\mathrm{Re}}\right)$$

$$v_{i,j}^{n+1}=v_{i,j}^{n}+\Delta t\frac{Gr}{\mathrm{Re}^2}\left(T-\frac{T_{\max}+T_{\min}}{2}\right)$$

$$\frac{\partial T}{\partial t}+u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}=\frac{1}{\mathrm{Re}\,\mathrm{Pr}}\left(\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}\right)$$

$$\rightarrow \quad \frac{T_{i,j}^{n+1}-T_{i,j}^{n}}{\Delta t}+u_{i,j}^{n}\frac{T_{i+1,j}^{n}-T_{i-1,j}^{n}}{2\Delta x}+v_{i,j}^{n}\frac{T_{i,j+1}^{n}-T_{i,j-1}^{n}}{2\Delta y}$$
$$=\frac{1}{\mathrm{Re}\,\mathrm{Pr}}\left(\frac{T_{i+1,j}^{n}-2T_{i,j}^{n}+T_{i-1,j}^{n}}{\Delta x^2}+\frac{T_{i,j+1}^{n}-2T_{i,j}^{n}+T_{i,j-1}^{n}}{\Delta y^2}\right)$$

$$\rightarrow e(i,j)=T_{i,j}^{n+1},\ \ en(i,j)=T_{i,j}^{n},$$

$$tmp1=u_{i,j}^{n}\frac{T_{i+1,j}^{n}-T_{i-1,j}^{n}}{2\Delta x}+v_{i,j}^{n}\frac{T_{i,j+1}^{n}-T_{i,j-1}^{n}}{2\Delta y}$$

$$tmp2=\frac{1}{\mathrm{Re}\,\mathrm{Pr}}\left(\frac{T_{i+1,j}^{n}-2T_{i,j}^{n}+T_{i-1,j}^{n}}{\Delta x^2}+\frac{T_{i,j+1}^{n}-2T_{i,j}^{n}+T_{i,j-1}^{n}}{\Delta y^2}\right)$$

$$T_{i,j}^{n+1}=T_{i,j}^{n}-\Delta t(-tmp1+tmp2)$$

```
          if(e(i,j) .le. emax*0.4 + emin*0.6) a(i,j)= '3'
          if(e(i,j) .le. emax*0.3 + emin*0.7) a(i,j)= '2'
          if(e(i,j) .le. emax*0.2 + emin*0.8) a(i,j)= '1'
          if(e(i,j) .le. emax*0.1 + emin*0.9) a(i,j)= '0'
        end do; end do

          do j = ny,1,-1
            write(*,*) (a(i,j),i = 1,nx)
          end do
          write(*,*) '*---------------------------*'
        endif

      end do

      call exceldata(                    )                    (←入力しない)

      stop
      end

      subroutine exceldata(                    )              (←入力しない)

      real*8  p(imax,jmax), e(imax,jmax)                       (←入力しない)
      integer nx, ny          (←入力しない)

      open(unit = 10, file = 'pressure', status= 'unknown')    (←入力しない)
        do j = 1, ny                                           (←入力しない)
          write(10,200)(p(i, j), i = 1, nx)                    (←入力しない)
        end do                                                 (←入力しない)
      close(10)                                                (←入力しない)

      open(unit = 30, file = 'energy', status= 'unknown')      (←入力しない)
        do j = 1, ny                                           (←入力しない)
          write(30,200)(e(i, j), i = 1, nx)                    (←入力しない)
      end do                                                   (←入力しない)
      close(30)                                                (←入力しない)

200   format(1x, 30e15.6)                                      (←入力しない)

      return                                                   (←入力しない)
      end                                                      (←入力しない)
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      5000
00000000000000000000000000000000
11111111111000000001111111111111
22333443333211001123333333322
44455555544332112234455555544
66666666554421123455666666666
66666666655432234556666666666
77766666666532235666666666777
77766666666542245666666666777
77766655566554324556655566777
77766555555554334555555556777
77765555555554334555555556777
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77765555555554334555555556777
87765555555544334555555556783
87766555555444334455555567783
88876654444443344444556678888
99887765544444444444566778899
99999887655433233345677889999
99999999999999999999999999999
*---------------------------*
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