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RESCALING OF EQUIPOTENTIAL SMOOTHING

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MASTER

August 17, 1982

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August 30, 1982

TO: Distribution

FROM: A. Winslow

SUBJECT: UCID-19486

Please insert attached corrected page 4 to above document.
Correction made on equation (5).

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It is a simple matter to rescale the weights so that distant points have the same weights as close points. We merely calculate α , β , and γ as usual at each point and then create new coefficients as follows:

$$\begin{aligned}\alpha' &= \left(\frac{\gamma}{\alpha}\right) \alpha = \gamma \\ \beta' &= \sqrt{\frac{\gamma}{\alpha}} \beta \\ \gamma' &= \gamma\end{aligned}\tag{5}$$

In effect we make $|\vec{r}_{\psi}| = |\vec{r}_{\phi}|$; that is why we must rescale β by the square root of the factor used to rescale α .

The effect of this rescaling is shown in Fig. 2, showing the same problem as Fig. 1 at approximately the same problem time but with rescaling. The radial zoning is now uniform.

We are grateful to W. Zagotta for stimulating the writing of this memo.

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Abstract

A method is described for locally rescaling the curvilinear coordinates used in continuous rezoning of Lagrangian meshes by the "equipotential" method. In this way the zone aspect ratio may be brought closer to unity.

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Rescaling of Equipotential Smoothing

A. M. Winslow and R. T. Barton

Continuous rezoning of 2D hydrodynamic codes is sometimes based on "equipotential" smoothing. When the zone aspect ratio is large, this smoothing has the property that distant mesh points have a weaker effect than close mesh points, so that the aspect ratio does not tend to reduce itself. This effect is shown in Fig. 1, showing a test problem due to W. Zagotta, where the angular zoning is approximately uniform but the radial zoning is not.

A rescaling of the equipotential equations to correct this effect may be carried out as follows.

The equipotential zoning equations for $\phi(x,y)$ and $\psi(x,y)$:

$$\begin{aligned}\nabla^2 \phi &= 0 \\ \nabla^2 \psi &= 0\end{aligned}$$

are solved by inverting them to obtain the two equations for x and y :

$$\alpha \vec{r}_{\phi\phi} - 2\beta \vec{r}_{\phi\psi} + \gamma \vec{r}_{\psi\psi} = 0 \tag{1}$$

where $\vec{r} = x\hat{i} + y\hat{j}$, $\alpha = \vec{r}_\psi^2$, $\beta = \vec{r}_\psi \cdot \vec{r}_\phi$, $\gamma = \vec{r}_\phi^2$.

When differenced, they take the form

$$\sum_i w_i (\vec{r}_i - \vec{r}) = 0 \quad (2)$$

where the sum is over the neighbors $\vec{r}_i$ of the point $\vec{r}$.

The weights w_i are shown below:

Solving (2) for $\vec{r}$ we get

$$\vec{r} = \frac{\sum_i w_i \vec{r}_i}{\sum_i w_i} \quad (3)$$

When equations (3) are used for rezoning, problems may arise when the mesh spacing in the two directions is quite different. Consider the case where the mesh lines are orthogonal and parallel to the coordinate axes:

Then $w_2 = w_6 = x_{\psi}^2 = (\Delta x)^2$

$w_4 = w_8 = y_{\phi}^2 = (\Delta y)^2$

$w_1 = w_3 = w_5 = w_7 = 0$

and equations (3) become

$$\vec{r} = \frac{\vec{r}_2 + \vec{r}_6 + \xi^2 (\vec{r}_4 + \vec{r}_8)}{2 (1 + \xi^2)} \quad (4)$$

where $\xi^2 \equiv (\Delta y / \Delta x)^2$. We see that, when $\xi^2 \gg 1$, equation (4) become:

$$\vec{r} = 1/2 (\vec{r}_4 + \vec{r}_8);$$

i.e., the position of point $\vec{r}$ is only affected by its nearest neighbors $\vec{r}_4$ and $\vec{r}_8$. Conversely, for $\xi^2 \ll 1$, $\vec{r}$ is only affected by $\vec{r}_2$ and $\vec{r}_6$.

It is a simple matter to rescale the weights so that distant points have the same weights as close points. We merely calculate α , β , and γ as usual at each point and then create new coefficients as follows:

$$\begin{aligned}\alpha &= \left(\frac{\gamma}{\alpha}\right) \alpha = \gamma \\ \beta &= \sqrt{\frac{\gamma}{\alpha}} \beta \\ \gamma &= \gamma\end{aligned}\tag{5}$$

In effect we make $|\vec{r}_{\psi}| = |\vec{r}_{\phi}|$; that is why we must rescale β by the square root of the factor used to rescale α .

The effect of this rescaling is shown in Fig. 2, showing the same problem as Fig. 1 at approximately the same problem time but with rescaling. The radial zoning is now uniform.

We are grateful to W. Zagotta for stimulating the writing of this memo.

Figure 1. No rescaling ($t = .0088$)

Figure 2. With rescaling ($t = .0090$)

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