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Articles

Solving Nonlinear Equations, Part 1: Solving a Single Nonlinear Equation

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Except for the solution of dynamic problems with explicit integration in time, nonlinear finite element analyses require the solution of nonlinear algebraic equations. This chapter introduces some of the basic solution methods for solving a single nonlinear equation,

$$f(u) = 0 \tag{1}$$

where u is the unknown, and $f(\cdot)$ is an algebraic function. All algebraic equations can be put in this form, and therefore there is no loss in generality by limiting the discussion to this form. The function is assumed to be continuous enough that its first derivative is finite. These methods are all iterative, that is, given a value of u at iteration i, u_i, a new value is calculated for iteration $i+1$, u_{i+1}. The method is applied until the magnitude of the function is close enough to zero that the solution is acceptable. The general flow of the solution method is

```
do i = 1, n
   if (|f(u)| > ε) then
     update u
   else
     exit loop
   endif
enddo
```

This general algorithm requires

- The definition of $f(\cdot)$.
- An initial guess for the solution, u.
- A maximum number of iterations, n.
- A convergence criterion, ϵ.

The definition of $f(\cdot)$ for the finite element method in solid mechanics is the difference between the external forces and the internal forces. A common strategy for generating an initial guess for u is to use the solution for u from the previous time step. Notice that the iteration scheme is constructed as a do-loop which limits the number iterations to a maximum of n to prevent an infinite loop. Although some solution methods are guaranteed to converge, nothing requires them to converge in a reasonable amount of time. The convergence criterion is a simple one, but choosing the appropriate value of ϵ is often difficult; typically it is a small fraction of the value of $f(u)$ on the first iteration,

$$\epsilon = s \cdot f(u_1) \tag{2}$$

This, of course, begs the question of how to choose s. Like most difficult problems, the best solution is to make it someone else's problem, in other words, make it part of the required input specified by the user. Most commercial finite element codes have a heuristic strategy that picks a value somewhere between 10^{-2} and 10^{-4}.

1 Newton Iteration

Newton iteration, when it works, converges to the solution faster than any other numerical solution method in common use. It also generalizes easily to systems of algebraic equations, which isn't true for the majority of the methods. Like

The Taylor expansion of the function $f(u)$ around the value of u_i is

$$f(u) = 0 = f(u_i) + \frac{\mathrm{d}f(u_i)}{\mathrm{d}u}\triangle u + \frac{1}{2}\frac{\mathrm{d}^2 f(u_i)}{\mathrm{d}u^2}(\triangle u)^2 + \mathcal{O}\left((\triangle u)^3\right) \tag{3}$$

where

$$\triangle u = u - u_i. \tag{4}$$

Keeping only the linear terms gives

$$0 \approx f(u_i) + \frac{\mathrm{d}f(u_i)}{\mathrm{d}u}(u_{i+1} - u_i) \tag{5}$$

which may be solved for the updated value u_{i+1},

$$u_{i+1} = u_i - f(u_i)/\frac{\mathrm{d}f(u_i)}{\mathrm{d}u}. \tag{6}$$

1.1 Will Newton Iteration Converge?

Newton Iteration will converge provided that the initial guess, u_0, is "close enough" to the solution. Mathematics gives some insight into when the guess is close enough for convergence, but in practice, it's simpler and more reliable to simply try it.

First, we'll look at a generic iteration scheme, which can be written in the form

$$u_{i+1} = g(u_i). \tag{7}$$

We want to know under what circumstances u_i approaches a limiting value of u, call the *fixed point* in mathematics, as i approaches infinity. For this analysis, we'll define converging as

$$|u_{i+1} - u_i| < |u_i - u_{i-1}|, \tag{8}$$

for all $i > I$, where I is some unknown, problem dependent constant. In other words, the difference between successive values of u is required to always decrease after some number of iterations. This requirement is overly strict, but it greatly simplifies the analysis. Equation 7 is substituted into Equation 8 to give

$$|g(u_i) - g(u_{i-1})| < |u_i - u_{i-1}|, \tag{9}$$

or

$$\frac{|g(u_i) - g(u_{i-1})|}{|u_i - u_{i-1}|} < 1. \tag{10}$$

As $i \to \infty$, the left-hand term approaches the derivative of g,

$$\left|\frac{\mathrm{d}g(u)}{\mathrm{d}u}\right| < 1. \tag{11}$$

For Newton Iteration,

$$
\begin{aligned}
g(u) &= u - f(u) / \frac{\mathrm{d}f(u)}{\mathrm{d}u} && (12) \\
\frac{\mathrm{d}g(u)}{\mathrm{d}u} &= 1 - \frac{\mathrm{d}f(u)}{\mathrm{d}u} / \frac{\mathrm{d}f(u)}{\mathrm{d}u} + f(u)\frac{\mathrm{d}^2 f(u)}{\mathrm{d}u^2} / (\frac{\mathrm{d}f(u)}{\mathrm{d}u})^2 && (13) \\
&= f(u)\frac{\mathrm{d}^2 f(u)}{\mathrm{d}u^2} / \left(\frac{\mathrm{d}f(u)}{\mathrm{d}u}\right)^2. && (14)
\end{aligned}
$$

Convergence is therefore indicated for u if

$$
\left| f(u)\frac{\mathrm{d}^2 f(u)}{\mathrm{d}u^2} / \left(\frac{\mathrm{d}f(u)}{\mathrm{d}u}\right)^2 \right| < 1. \tag{15}
$$

This condition says that if Equation 15 is satisfied, the next value of u calculated with Newton Iteration should be closer to the solution than the current value. There were a lot of assumptions made to arrive at Equation 15 in terms of the smoothness of the function, etc, and therefore, in practice with real-world problems, the next value of u may not be better. So while Equation 15 is interesting, it has no practical value.

On a qualitative level, Equation 15 tells us that a large gradient in the function, $|\mathrm{d}f(u)/\mathrm{d}u|$, helps convergence, while a large curvature, $\sim |\mathrm{d}^2 f(u)/\mathrm{d}u^2|$, is bad. It also reinforces the obvious, namely, being far away from the solution, indicated by a large value of $|f(u)|$, isn't good.

1.2 How Fast Will Newton Iteration Converge?

The convergence rate is how quickly the difference decreases between the current estimate of the solution and the exact solution. Assuming that the current value is sufficiently close to the solution, an estimate of the convergence rate in terms of the current error can be derived via a Taylor series.

The error at iteration $i+1$ is

$$
e_{i+1} = u_{i+1} - u \tag{16}
$$

which can also be expressed as

$$
e_{i+1} = u_i - f(u_i) / \frac{\mathrm{d}f(u_i)}{\mathrm{d}u} - u \tag{17}
$$

$$= u_i - u - f(u_i)/\frac{\mathrm{d}f(u_i)}{\mathrm{d}u} \tag{18}$$

$$= e_i - f(u_i)/\frac{\mathrm{d}f(u_i)}{\mathrm{d}u}. \tag{19}$$

The next two steps are unmotivated, but are necessary steps on the path to the convergence rate estimate. First, the fraction in the error expression is cleared,

$$e_{i+1} = \frac{e_i \frac{\mathrm{d}f(u_i)}{\mathrm{d}u} - f(u_i)}{\frac{\mathrm{d}f(u_i)}{\mathrm{d}u}}. \tag{20}$$

Next, $f(u)$ is expanded in a Taylor series in terms of the error,

$$f(u) = f(u_i - (u_i - u)) \tag{21}$$

$$= f(u_i - e_i) \tag{22}$$

$$0 = f(u_i) - \frac{\mathrm{d}f(u_i)}{\mathrm{d}u} e_i + \frac{1}{2}\frac{\mathrm{d}^2 f(u_i)}{\mathrm{d}u^2} e_i^2 + \mathcal{O}\left(e_i^3\right). \tag{23}$$

The last equation gives the approximate relation

$$\frac{\mathrm{d}f(u_i)}{\mathrm{d}u} e_i - f(u_i) \approx \frac{1}{2}\frac{\mathrm{d}^2 f(u_i)}{\mathrm{d}u^2} e_i^2 \tag{24}$$

and, on substitution into Equation 20,

$$e_{i+1} \approx \frac{1}{2}\left(\frac{\mathrm{d}^2 f(u_i)}{\mathrm{d}u^2} / \frac{\mathrm{d}f(u_i)}{\mathrm{d}u}\right) e_i^2 \tag{25}$$

Newton Iteration is said to converge quadratically because $e_{i+1} \sim e_i^2$. If this convergence rate estimate holds, close to the solution, the number of significant figures in the solution doubles with every iteration : $e_i = 0.1$, $e_{i+1} = 0.01$, $e_{i+2} = 0.0001$, $e_{i+3} = 0.00000001 \ldots$.

1.3 Example

Before considering problems with slow convergence, we'll look at one that behaves according to the mathematical estimates that have been developed:

$$f(u) = (u - 10)(u + 10) = u^2 - 100 \tag{26}$$

$$\frac{\mathrm{d}f(u)}{\mathrm{d}u} = 2u \tag{27}$$

$$
\begin{aligned}
u_{i+1} &= u_i - \frac{u_i^2 - 100}{2u_i} & (28)\\
u_{\text{initial}} &= 100 & (29)\\
u_{\text{exact}} &= \pm 10 & (30)
\end{aligned}
$$

The results of the Newton iteration are:

Iteration i	u_i	e_i	$\frac{1}{2}\left(\frac{\frac{\mathrm{d}^2 f(u_{i-1})}{\mathrm{d}u^2}}{\frac{\mathrm{d}f(u_{i-1})}{\mathrm{d}u}}\right) e_{i-1}^2$
1	100.000000000	90.000000000	
2	50.500000000	40.500000000	40.500000000
3	26.240099010	16.240099010	16.240099010
4	15.025530120	5.025530120	5.025530120
5	10.840434673	0.840434673	0.840434673
6	10.032578511	0.032578511	0.032578511
7	10.000052896	0.000052896	0.000052896
8	10.000000000	0.000000000	0.000000000

Starting at iteration 5, the number of digits of accuracy in u_i doubles with every iteration. For all the iterations, the estimated error based on the convergence rate, Equation 25, agrees exactly with the exact error e_i. The agreement is exact because $f(u)$ is quadratic, and all the higher order terms that were ignored in the derivation of the estimate are *exactly* zero.

1.4 Examples of Difficulties

Aside from a bad initial guess for u, the two primary sources of difficulties are small first derivatives and large second derivatives. Even simple functions, with derivatives of all orders, can produce convergence difficulties. Figure 1 shows Newton iteration cycling repetitively through two points forever.

The quadratic function $f(u) = u^2 - 100$ converged very quickly in an earlier example, however, consider the simplest quadratic function,

$$
\begin{aligned}
f(u) &= u^2 & (31)\\
\frac{\mathrm{d}f(u)}{\mathrm{d}u} &= 2u & (32)\\
u_{i+1} &= u_i - \frac{u_i^2}{2u_i} = \frac{1}{2}u_i & (33)
\end{aligned}
$$

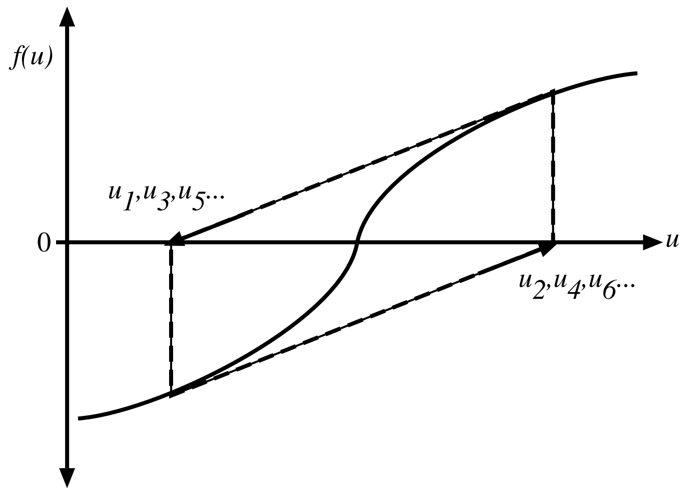


Figure 1: A smooth function that doesn't converge with Newton iteration.

$$u_{\text{initial}} = 100 \tag{34}$$
$$u_{\text{exact}} = 0 \tag{35}$$

In this case,

$$e_i = u_i - 0 = \frac{1}{2}u_{i-1} = \frac{1}{2}e_{i-1} \tag{36}$$

which shows linear, not quadratic, convergence. This occurs because the first derivative approaches zero at the same rate as the error, and is exactly zero at the solution.

Another function which exhibits poor convergence properties is the exponential,

$$f(u) = e^{\lambda u} - 1 \tag{37}$$
$$\frac{\mathrm{d}f(u)}{\mathrm{d}u} = \lambda e^{\lambda u} \tag{38}$$
$$u_{i+1} = u_i - \frac{e^{\lambda u_i} - 1}{\lambda e^{\lambda u_i}} = u_i - \frac{1 - e^{-\lambda u_i}}{\lambda} \tag{39}$$
$$u_{\text{initial}} = 10^{-2} \tag{40}$$
$$u_{\text{exact}} = 0 \tag{41}$$

For $\lambda = 10^3$ and $u_{\text{initial}} = 10^{-3}$, the results are:

Iteration i	u_i	e_i	$\frac{1}{2}\left(\frac{\frac{\mathrm{d}^2 f(u_{i-1})}{\mathrm{d}u^2}}{\frac{\mathrm{d}f(u_{i-1})}{\mathrm{d}u}}\right) e_{i-1}^2$
1	9.9999998E-03	9.9999998E-03	0.0000000E+00
2	9.0000452E-03	9.0000452E-03	4.9999998E-02
3	8.0001686E-03	8.0001686E-03	4.0500407E-02
4	7.0005040E-03	7.0005040E-03	3.2001349E-02
5	6.0014154E-03	6.0014154E-03	2.4503528E-02
6	5.0038907E-03	5.0038907E-03	1.8008493E-02
7	4.0106024E-03	4.0106024E-03	1.2519461E-02
8	3.0287249E-03	3.0287249E-03	8.0424660E-03
9	2.0771022E-03	2.0771022E-03	4.5865873E-03
10	1.2023950E-03	1.2023950E-03	2.1571768E-03
11	5.0286868E-04	5.0286868E-04	7.2287682E-04
12	1.0766189E-04	1.0766189E-04	1.2643846E-04
13	5.5930349E-06	5.5930349E-06	5.7955416E-06
14	1.5611900E-08	1.5611900E-08	1.5641020E-08
15	1.2186502E-13	1.2186502E-13	1.2186571E-13

Note that for the first 10 iterations,

$$u_i \approx u_{i-1} - \frac{1}{\lambda}, \tag{42}$$

and exhibits a convergence rate that is independent of the error, i.e., $e_i \sim (e_{i-1})^0$. Only in the last five iterations does the asymptotic error estimate agree with the actual one, and only in the last two iterations is the quadratic convergence rate observed.

This exponential problem may seem artificial, but similar functions do occur in practice. For example, in single crystal plasticity models, a power law relates the plastic slip rate on a crystal plane to the ratio of the shear stress projected on the slip plane to a yield stress,

$$\dot{\gamma} = \dot{\gamma}_0 \left(\frac{\tau}{\tau_y}\right)^n. \tag{43}$$

The exponent n is often set to large values ($\sim$ 100) to create a sharply defined yield point in the stress-strain relationship. Naturally, using large values frequently creates numerical difficulties in calculations.

2 Secant Iteration

Secant iteration simply takes the value of $f(u)$ at two points, connects them with a straight line, and calculates where the lines crosses zero.

$$f(u) \approx \frac{f(u_i) - f(u_{i-1})}{u_i - u_{i-1}}(u - u_{i-1}) + f(u_{i-1}) \tag{44}$$

$$u_{i+1} = u_{i-1} - \frac{u_i - u_{i-1}}{f(u_i) - f(u_{i-1})} f(u_{i-1}) \tag{45}$$

This method is cheaper per iteration than Newton iteration because it doesn't require the evaluation of the derivative of the function. With the reduction in cost comes a reduction in the theoretical convergence rate, although in practice, the observed difference is highly dependent on the problem being solved.

The secant method requires two initial values for u to start the iteration. In the absence of any insight into the problem, a typical choice for the pair of starting values is u_0 and $u_0 + \epsilon$, where ϵ is a small number. As the method converges, the distance between the last two successive values grows smaller, and the approximation of the derivative by the finite difference,

$$\frac{\mathrm{d}f(u)}{\mathrm{d}u} = \frac{f(u_i) - f(u_{i-1})}{u_i - u_{i-1}}(u - u_{i-1}) + f(u_{i-1}) \tag{46}$$

approaches the exact derivative, and the convergence rate approaches the rate for Newton iteration.

3 Methods That Are Guaranteed to Converge

The theory of continuous functions guarantees that least one solution to $f(u) = 0$ exists between the two points u_L and u_R if

$$f(u_L) \cdot f(u_R) \leq 0. \tag{47}$$

Any algorithm that successively reduces the separation of u_L and u_R while continuing to satisfy Equation 47 will converge to a solution.

For many applications, the primary difficulty is finding an appropriate interval $[u_L, u_R]$ for starting the iteration. However, the two common applications for this class of methods are line searches and solving for the increment in equivalent plastic strain in plasticity, and the intervals are easy to determine. Line searches are commonly used as part of a solution strategy for systems of nonlinear equations, and the interval for the line search is usually pre-defined as $[0, 1]$. From continuum mechanics, the magnitude of the plastic strain incrment must be somewhere between zero (an elastic solution) and the magnitude of the total strain increment.

3.1 The Bisection Method

The bisection method is very simple: The function is evaluated in the midpoint of the interval, and based on its sign, the midpoint becomes either the new left or right point of the interval. Written in terms of pseudo-code, the bisection method is

```
f_L = f(u_L)
f_R = f(u_R)
u = (u_L + u_R)/2
do i = 1, n
   if (|f(u)| > ϵ) then
     f_avg = f(u)
     if (f_avg · f_L ≥ 0) then
       u_L = u
       f_L = f_avg
     else
       u_R = u
       f_R = f_avg
     endif
     u = (u_L + u_R)/2
   else
     exit loop
   endif
enddo
```

Each iteration reduces the width of the interval by a factor of two, confining the solution to an interval of length $(u_R - u_L)/2^n$ after n iterations. While other algorithms may converge faster provided certain conditions are met regarding the derivatives, etc, the bisection method has a guaranteed convergence rate without regard to any conditions beyond the underlying continuity of the function.

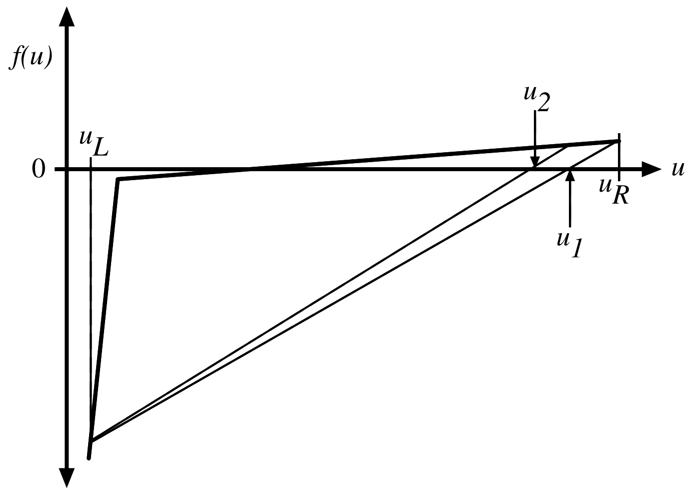


Figure 2: The first two iterations, u_1 and u_2 using regula falsi, demonstrating a case of slow convergence.

3.2 The Regula Falsi Method

Regula falsi is a similar in structure to the bisection method except that u is calculated with the secant method, replacing u_{i-1} and u_i with u_L and u_R in Equation 44. If the function is well behaved, then regula falsi will converge faster than the bisection method, however it can converge very slowly for simple functions, such as the bilinear stress-strain relation for plasticity (Figure 2).

3.3 Ridder's Method

Ridder's method is a very robust method that works well for a wide variety of problems, including solving for the increment in equivalent plastic strain in strongly nonlinear plasticity models. The original reference is

Ridders, C. J. F., 1979, *IEEE Transaction on Circuits and Systems,* vol. CAS-26, pp. 979-980.

however it was popularized in the very popular book *Numerical Recipes: The Art of Scientific Computing.* This book is available with its programs written in Fortran, C, and C++, and the original editions in Fortran and C are available on-line as PDF files at `http://www.library.cornell.edu/nr/`.

The function is evaluated two times for every iteration. The first evaluation is at the midpoint of the interval,

$$u_M = \frac{1}{2}(u_L + u_R) \tag{48}$$

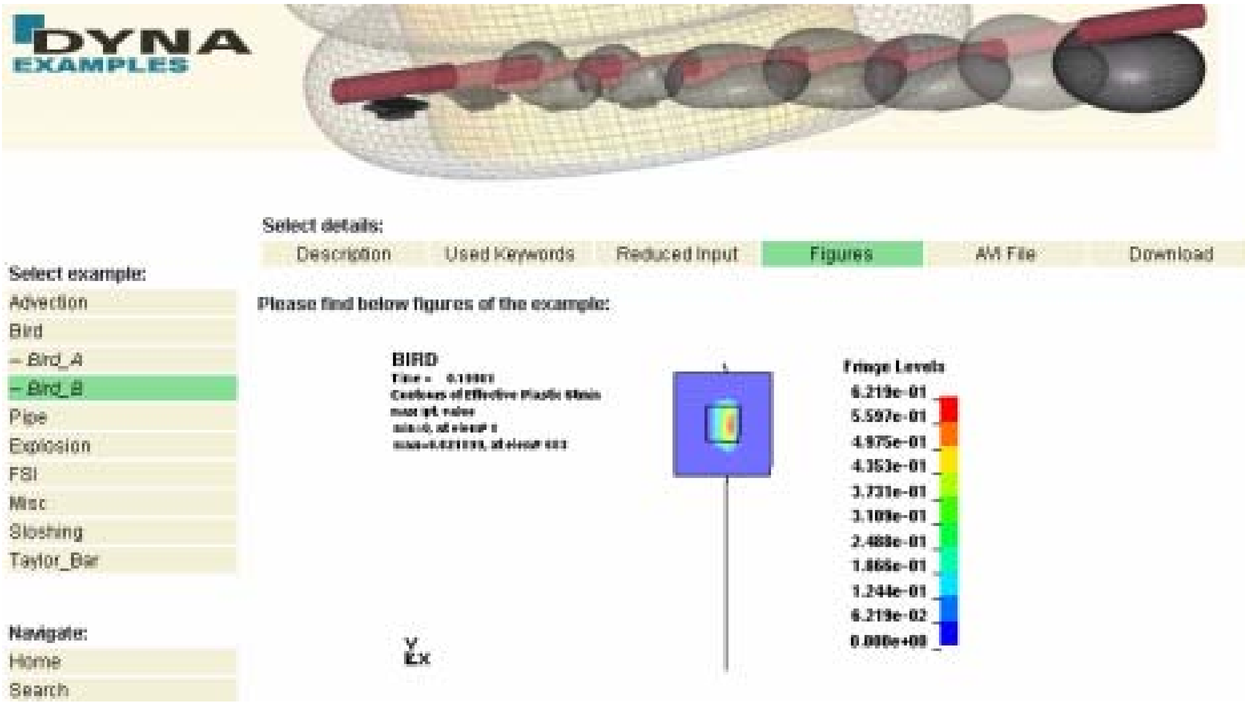
$$f_M = f(u_M) \tag{49}$$

The location of the solution is a function of the two endpoints and the midpoint,

$$u = u_M + (u_M - u_L)\frac{\text{sign}|f_L - f_R| f_M}{\sqrt{f_M^2 - f_L f_R}}. \tag{50}$$

The standard method updates the interval using u in the same manner as the bisection and regula falsi methods. A simple modification used by the author which seems to significantly increase the robustness of the method and slightly imporve the speed of convergence is to perform a second update on the interval using u_M if $f(u_M) \cdot f(u) < 0$.

DYNA*more* extends online-offering



Under the web address www.dynaexamples.com interested users of LS-DYNA can access an extensive collection of example problems from many application areas of LS-DYNA. This internet service includes introductory examples from highly nonlinear high-speed dynamic problems, examples based on implicit time-stepping methods, which include static or nonlinear low-speed dynamical problems or even special problems like fluid-structure-coupling or thermal applications. The example description includes all necessary input files and provides post-processing of the results in form of pictures and videos. This service has been initiated by DYNAmore, the German distributor of LS-DYNA. After passing the initial status the webpage shall be used as an open forum for the whole user community of LS-DYNA to exchange examples of different applications. The website can be used free of charge. The users are very welcome to download the examples and to explore the different capabilities of LS-DYNA.

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HP Helps US Clamp Down on Counterfeiting – Imaging Expertise used to deter digital fakes

http://www.hp.com/hpinfo/newsroom/feature_stories/2004/04counterfeit.html

Visit HP at Exhibit Booth 01

Jan. 2004 -- Take a look at that dollar, Euro, yen, pound or peso in your wallet. Is it real or counterfeit? How can you be sure?

Counterfeiting used to be the domain of skilled criminals with expensive engraving and printing equipment. Not so today, thanks to advances in computer and printing technologies that have dramatically reduced the cost and difficulty of reproducing realistic-looking fakes.

Not surprisingly, that's unsettling to a company like HP. That's why researchers at HP Labs and experts from the company's printing and imaging business got together at the request of U.S. and international officials to help clamp down on counterfeiting.

"As the world's largest printing and imaging company, it was important to us to lead the industry in this area," says George Lynch, Director of Strategic Technology for HP's Imaging and Printing Business.

A Growing Problem

In 1995, less than two percent of counterfeit money in the U.S. was produced electronically, according the U.S. Secret Service. Last year, counterfeiters turned out $44 million in U.S. currency -- nearly 40 percent of it using digital equipment like color copies, scanners and ink jet printers.

The U.S. greenback, the world's most popular currency, is also the most counterfeited because it is so universally accepted.

"There's a lot at stake," says Neerja Raman, director of the Imaging Systems Lab at HP Labs. "If we want the world to continue to have faith in U.S. currency, we at HP have to have a zero-tolerance policy for counterfeiting."

Preventing fakes while protecting image quality

Lynch, Raman and many others at HP put their considerable imaging expertise to work, collaborating with officials and technical teams from various public- and private-sector organizations. (The names of these organizations must remain confidential).

The challenge: find a way to prevent the reproduction of U.S. banknotes on home equipment without affecting the quality or the print speed of everything else.

"We had to have a solution that was inexpensive, and it had to be unobtrusive," says HP Labs researcher Henry Sang. "Nobody's going to pay an extra $50 for a printer because it prevents counterfeiting, and they're not going to buy one that won't print green or that prints three times slower because it's trying to detect a counterfeit."

Challenges and constraints

Until the 1990s, when the U.S. Bureau of Engraving and Printing added new security measures such as a watermark and a security thread, U.S. banknotes had changed little for decades. Federal officials told the HP team they wanted to keep it that way.

That precluded any major changes to the currency itself, including techniques used by some other currencies. The Euro, for example, contains fluorescent fibers and foil features, which cannot easily be reproduced by conventional copiers or printers.

To recommend how to best approach the problem, the R&D team first had to learn more about how currency was being counterfeited, then determine ways to prevent it. For example, it's possible to give a scanner the ability to detect when it's scanning a $20 bill. But it's also possible to find a high-quality, printable image of a $20 bill on the Internet, or to take a digital photograph of it, so just blocking the scanner won't totally eliminate counterfeiting.

Another challenge: Most people can't identify a counterfeit bill. Sang says federal officials showed him one-sided bills and even black and white bills that had been passed.

"Counterfeits don't have to be good enough to be undetectable by the government or by banks. They just have to be good enough to be passed from person to person," he says. "By the time you pass it to a store clerk and the store takes it to the bank and the bank is able to detect it, the criminal is long gone."

Detection and deterrence

So, what could be done? The team attacked four key issues: Can the bill be passed? Can we detect counterfeiting intrusions on low-cost machines? Can we prevent the printing of counterfeit bills? Can we we help authorities who have to prosecute the criminal who produced the bills?

Researchers came up with a host of recommendations, applying technical knowledge in image processing, color management and information embedding to devise several counterfeit deterrence methods.

Although they cannot disclose exactly what or whose technologies federal officials finally adopted -- at the risk of tipping off criminals -- team members made suggestions for a wide range of techniques for document and hardware design to thwart counterfeiters.

"We made recommendations for a range of tests and procedures," says Sang.

Recommendations

Measures HP suggested include:

- Multi-level detection and deterrence - a detection scheme that uses an algorithm to separate suspicious documents from those free of suspicion. Additional, more complex algorithms determine if the suspicious document is a "secure" one that's likely to be currency, and then either provide a "selectively deteriorated" print or disable printing of that document completely.

- Two-sided documents - This technique takes advantage of the front-to-back registration accuracy of HP printers by changing the position of objects an infinitesimal amount, too little to be seen by most people, but enough so that a machine can detect it.

- Color detection - This is a key technology because humans are very good at detecting differences in color. This technique would detect the characteristic color of frequently counterfeited documents ("banknote green"). Were a user to attempt to print a banknote using the exact green in the correct density for a bill, the printer could modulate the color somewhat to produce distinct, visible bands of color. The change in the color wouldn't be visible in other images that use lots of green (photos of trees, for example), but would be evident in bills.

- Printer identification - Researchers provided data on how officials could better measure properties of a counterfeit to identify what kind of printer and ink may have been used to produce it.

- Government lab - The R&D team developed a proposal for a laboratory the federal government could establish to continue research into anti-counterfeiting technologies.

In May 2003 U.S. officials announced a radical new design for the $20 bill that includes several new, confidential counterfeit-deterrence features. These measures include adding light shades of blue, peach and green to the $20 bill as an anti-counterfeiting measure. (Note: The peach bills premiered in October 2003).

Printing and Imaging expertise

HP was able to respond as quickly as it did to counterfeiting concerns in part because of HP Labs' deep expertise and continued research in imaging and printing. In addition, HP's imaging and printing business made the effort to integrate anti-counterfeiting measures into devices to demonstrate how these techniques worked.

"Hewlett-Packard and its employees have been clear leaders in our work with the printer industry," Paul O'Neill, then-Secretary of the U.S. Treasury Department, said in a letter to HP CEO Carly Fiorina. "HP employees involved in this work have been innovative and professional, and a credit to your company."

Other Applications

Of course, HP isn't going into the currency-printing business, but the company has used its experience to pursue new research in secure printing and imaging.

A team in the Imaging System Lab has been working on ways to embed information in printed documents for authentication, security and other purposes, called "Graphical Barcodes." In one application, users might be able to print authenticable, customized postage stamps with a company logo, personal initial or other image that contains the same information that an ordinary bar code would.

Another application of the Graphical Barcode injects a "digital life" into printed documents. When a document is printed with a graphical barcode, the barcode contains all the information about this document including its digital source. So when the document is to be copied, instead of producing its photographic image, the original document is retrieved from the digital source and printed.

“Fax back” and authentication

This technology can also enable "fax back." A document containing an information-embedded image (a logo, for instance) is faxed to a recipient. The recipient can write on it for reply. Because of the embedded information, the recipient can fax it back without even dialing the phone number because the fax machine recognizes that it is a "fax back" document by the Graphical Barcode.

This technology can also be used for authenticating hardcopy documents like a diploma, a birth certificate and a land deed, etc. The information-embedding logo on the document contains all the critical information that cannot be tampered with or counterfeited.

"Almost any anti-counterfeiting technology can be defeated," says Sang. "The challenge for us is to make it that much harder to do it."

Tgen Quickens pace of genomic research with IBM and Linux Cluster Solution
Excerpt from: http://www-306.ibm.com/software/success/cssdb.nsf/csp/bemy-5wzqen

Visit IBM at Exhibit Booth 20

TGen relies on IBM @server technology and Linux to conduct its ground-breaking genomic studies, which help uncover new, more effective targets and treatment approaches for diseases.

TGen responds to the needs of scientists for medical data to study genomes and the genetic changes contributing to disease progression and resistance to therapy.

Application	High-performance Linux cluster for compute-intensive genomics research
Business Benefits	Ability to model and analyze complex biological systems using realistic datasets; capacity to solve data-intensive research problems quickly; scalable IT environment to meet future needs; enhanced laboratory productivity to help establish TGen as a leader in genomics research
Servers	IBM @server® Cluster 1350 comprising IBM @serverxSeries® 335 with Intel® Xeon(tm) processors; IBM @serverpSeries® 650 and 690; IBM TotalStorage® FAStT700 Storage Server; IBM 3584 LTO Tape Library
Software	IBM AIX 5L(tm); IBM Cluster Systems Management for Linux; IBM DB2® Universal Database(tm) Enterprise Edition; IBM DB2 Intelligent Miner(tm) for Data; IBM WebSphere® Application Server; IBM Tivoli® Storage Manager; Red Hat Linux
Services	IBM Global Services--Integrated Technology Services

From cotton to citrus, Arizona has gained prominence in a number of industries. Arizona State University (ASU), a leader in genomics research, is pushing to add biotechnology to that list, as it is seen as a key economic force that can draw additional industries to the state.

To that end, ASU and the state of Arizona, the City of Phoenix and others, recruited a leading scientist affiliated with the National Institutes of Health (NIH) to establish a non-profit research institute for genomics research. The Translational Genomics Research Institute (TGen), the result of this effort, is expected to attract business and researchers that otherwise may not have considered settling in Arizona.

Established in 2002 with 23 scientists, Phoenix-based TGen responds to the needs of scientists for medical data to study genomes and the genetic changes contributing to disease progression and resistance to therapy. To carry out this mission, TGen required a high-performance computing facility that would support the organization's efforts in developing and validating diagnostic tests for genomics research--allowing TGen to solve data-intensive research problems quickly. TGen looked to ASU and IBM to accomplish its goal.

While TGen boasts rich scientific expertise, the organization knew that it needed to collaborate with a technology vendor to realize its research goals. The organization looked for a company that could provide the IT infrastructure--preferably based on an affordable, high-performance Linux cluster--as well as ongoing technical support. "TGen and ASU teamed to evaluate vendors, and our choice was IBM, because we felt that IBM's extensive life sciences experience and advanced computational biology technologies made it the ideal candidate to help us implement a robust computing platform," says Dr. William Lewis, vice provost for IT at ASU, which hosts the platform.

Currently under construction, the new TGen headquarters in Arizona will house the company state-of-the-art systems for conducting life sciences research.

Allying with IBM for success

TGen researchers were well versed in the high performance and scalability of the Linux operating environment based on their previous experience at the NIH. "We knew that Linux would provide the open, reliable computing platform that we were after--at an attractive price," says Dr. Edward Suh, CIO, TGen.

Linux cluster technology scales well to meet the need for processing exponentially growing biomedical data from varying sources. It enables biomedical researchers to perform compute- and data-intensive tasks, such as the analysis of gene-to-gene interactions using large volumes of gene expression data, within a reasonable amount of computer time (hours and days rather than weeks and months) by harnessing the power of inexpensive processors.

During its vendor evaluation, TGen found that IBM expressed the greatest interest in collaborating with TGen on genomics research. In helping TGen architect a state-of-the-art research facility, IBM is providing a comprehensive solution comprising hardware, software, storage and consulting services.

One research area at TGen that is sure to benefit from the high-performance Linux cluster is the study of melanomas among patients with different genetic compositions. These compositions affect how the cancers will react to various drug and treatment methods. Using genomics technology, TGen and ASU can help determine the most effective treatment methods for different patients. “We use millions of realistic datasets in our research, and to get the compute results we want at the speed in which we need them, there’s no better solution than a powerful, reliable Linux cluster,” explains Suh.

Robust, reliable research platform

Through its affiliation with ASU, TGen is also part of the IBM Scholar’s Program, receiving complimentary software and support to create the new research facility. Working with IBM Global Services--Integrated Technology Services, TGen is deploying a powerful IT infrastructure that includes an IBM @serverCluster 1350 with 512 IBM @serverxSeries 335 systems with Intel Xeon processors. The Cluster 1350 runs Red Hat Linux and serves as the production system that does the genome sequencing. Designed for handling high-performance workloads, the Cluster 1350 is a flexible, integrated system that includes all of the hardware necessary to create a comprehensive cluster, delivering maximum computing power in a minimal amount of floor space.

“The system arrived ready to be racked, stacked and cabled,” recalls Suh. “IBM provided hardware and Linux software installation support for the Cluster 1350. With IBM consultants coordinating the setup, we were able to focus on our core research activities.” With their domain expertise in life science, IBM successfully installed the Cluster 1350 in about 4 months.

TGen identifies the genes that play a role in our susceptibility to disease. It partners with academic, clinical and corporate entities to bring the fruits of these discoveries directly to patients.

The Cluster 1350, deployed with IBM Cluster Systems Management (CSM) for Linux software, provides an easy-to-configure platform that manages the cluster of xSeries servers from a single point of control. This capability simplifies cluster management and enhances the efficiency of system administrators, allowing administrators to easily monitor hardware and software events. The CSM for Linux software also includes automated recovery features for rapid problem detection and resolution

In addition, TGen and ASU are deploying several IBM @serverpSeries systems running IBM AIX 5L operating system to complete the IT infrastructure. Two pSeries 690 systems function as the main research servers--housing mathematical and scientific research applications that analyze the genomic data. The autonomic computing capabilities of the p690s, such as self-healing and self-protection, enable TGen to provide continuous server operation for its scientists, while minimizing system administration.

The genomic data will reside in IBM DB2 Universal Database running on a pSeries 650 system. TGen will also use the proven mining algorithms in DB2 Intelligent Miner for Data to uncover data patterns for predictive analyses. Together, DB2 and the data mining software will provide a robust information management platform for TGen's genomic research.

Two additional pSeries 650 systems will function as Web servers, utilizing IBM WebSphere Application Server to provide TGen and ASU scientists with transparent Web access to the database analysis tools. Using these resources, TGen has implemented a Web-based client/server computing environment from which researchers can access databases and run application tools available on the Cluster 1350 and pSeries systems.

For data storage, TGen plans to use three IBM TotalStorage FAStT 700 Storage Servers, SAN switches and an IBM 3584 LTO Tape Library. IBM Tivoli Storage Manager protects research data by storing backup and archive copies of data on offline storage.

Solving scientific puzzles

As part of the alliance, TGen and the IBM Computational Biology Center--which is closely affiliated with IBM's life sciences initiatives--will collaborate to create algorithms to further new areas of genomics research. By combining biology and computer science, the algorithms developed at the Computational Biology Center will be used to help analyze the content of patient records to help formulate therapeutic strategies to treat illnesses.

The new system, which will soon be fully operational, will facilitate high levels of laboratory productivity and help position TGen as a top genomics research institution. Suh concludes. "Our partnership with IBM is far reaching, providing the technology and support that will help us achieve our goal of bringing genomic knowledge to the patient's bedside--facilitating quicker and more effective healthcare."

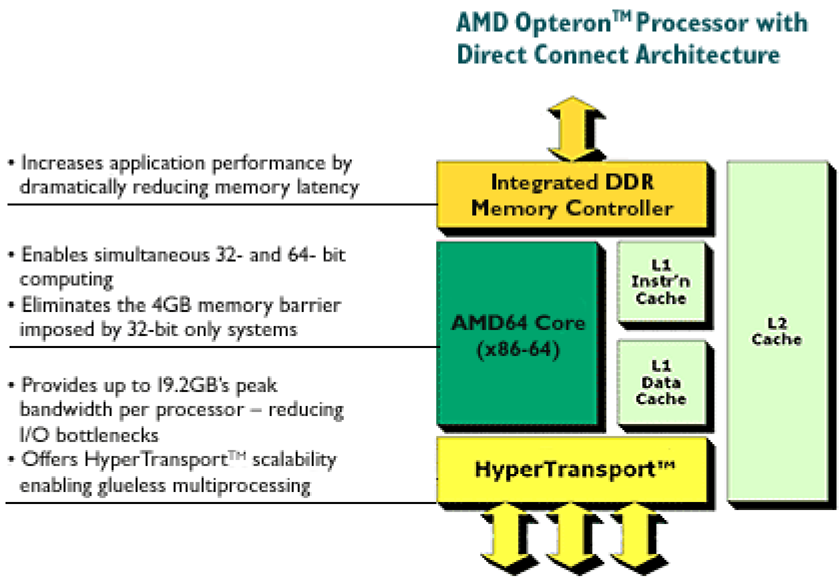
For more information - P*lease contact your IBM sales representative or IBM Business Partner*

Visit our Web site at: ***ibm.com/linux***

AMD Opteron™ Processor for Servers and Workstations
© Copyright AMD
Exhibit Booth 10

The AMD Opteron™ processor, enabling simultaneous 32- and 64-bit computing, represents the landmark introduction of the AMD64 architecture. The AMD Opteron processor is designed to run existing 32-bit applications with outstanding performance and offers customers a simplified migration path to 64-bit computing. This evolutionary processor provides a dramatic leap forward in compatibility, performance, investment protection, and reduced total cost of ownership (TCO). The AMD Opteron processor is offered in three series: the 100 series (1-way), the 200 series (1 to 2-way), and the 800 series (up to 8-way).

The AMD Opteron processor integrates key system elements:



AMD Opteron™ Processor Benefits

The AMD Opteron processor provides a highly scalable architecture that delivers next-generation performance as well as a flexible upgrade path from 32- to 64-bit computing. With a single architecture designed to meet current and future business needs, the AMD Opteron processor can help to minimize the integration complexities presented by business environments today and in the future.

Benefit	Feature
Simultaneous 32- and 64-bit computing capabilities	Allows users to run 32-bit and/or 64-bit applications and operating systems as they desire—without sacrificing performance
Direct Connect Architecture addresses and helps reduce the real challenges and bottlenecks of system architectures	Increases memory latency performance, provides more balanced throughput and I/O, and allows for more linear symmetrical multiprocessing
Support of up to three (3) coherent HyperTransport links, providing up to 19.2GB/s peak bandwidth per processor	Provides substantial I/O bandwidth for your current and future application needs
256 Terabytes of memory address space	Creates a significant performance benefit for applications in which large (or many) datasets are held in memory
Scales from 1-way to 8-way across entire data or compute centers utilizing the same hardware and software infrastructure	Allows for maximum flexibility in IT infrastructure, helping contribute to bottom line success
Integrated memory controller reduces latencies during memory access in a SMP server system	Yields fast computational processing for increased performance and productivity
Low-power processors in HE (55 Watt) and EE (30 Watt) - Providing uncompromised performance	Increased compute density; lower TCO for datacenters with limited power budgets

Putting the AMD Opteron™ processor to work

The AMD Opteron processor is available in 1 to 8-way servers and 1 to 4-way workstation solutions. Usage segments for the processor include:

- Worldwide Enterprises, Small-Medium Businesses, and Government/Education Institutions
- Companies who require faster database transactions, or support for more users on e-commerce type applications
- Customers needing quick graphics response such as CAD and DCC
- Industries with computational intensive tasks for financial modeling and scientific applications

FEA Information Inc. Participants

Commercial, Contributing, and Educational

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FEA Information Inc.

Preview of the
8th International LS-DYNA Users Conference

Please visit our participant's Exhibit Booths:

Booth Number	Exhibitor
01	HP
04	Fujitsu
06	Arup
09	ETA
10	AMD
14	Linux Networx
18	MSC.Software
19	NEC
20	IBM
21	SGI
22	ANSYS Inc.

Keynote Speakers:

Dr. Priya Prasad
Ford Technical Fellow
Safety Research & Advanced Engineering
Ford Motor Company USA
"Future Challenges in Vehicle Safety"

Dr. Ted Belytschko
Walter P. Murphy Professor
Northwestern University
"Developments and Challenges in Computational Mechanics"

Mr. Lawrence J. Achram
Vice President
Virtual Engineering & Crossfire
DaimlerChrysler
"Powering the Record Chrysler Group Product Onslaught"

Dr. John O. Hallquist
President
LSTC
"LS-DYNA Development"

Golf Outing

THE LINKS OF NOVI

50395 10 Mile Road - Novi, Mi 48374
Sunday May 2nd, 11:15 AM Tee Time

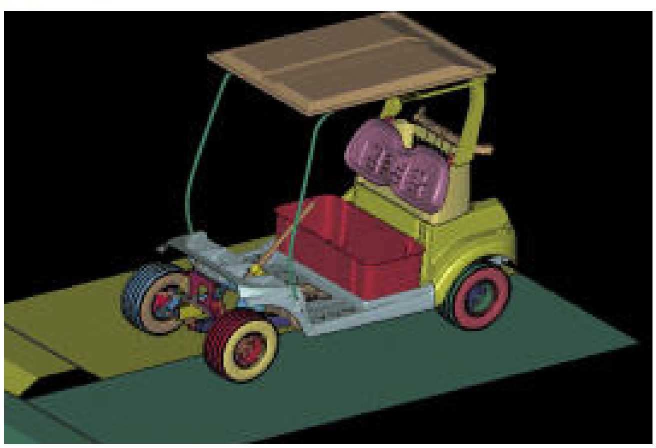
In coordination with the 8th International LS-DYNA Users Conference you are cordially invited to shoot an early round of golf this season at Links Of Novi.

The Links of Novi is a Par 72 - USGA Rule Course. This club has three nine hole courses that are played in three eighteen-hole combinations. The East Course has tight fairways, and locals say it's a shotmaker's course. Water hazards (seven ponds) come into play on five holes. The West Course has water coming into play on eight holes. The South Course is short and tight, but it has no water hazards. This is a good course for beginners just taking up the game. Overall, the greens on all 27 holes are either elevated, tiered, or surrounded by sand bunkers. The club personnel have chosen the East/West Combination as their favorite.

The first tee time will be 11:15 AM. Please arrive early. Lunch and drinks will be served before and during the game. Club rental is available at the Club House or contact Arthur Tang to see if other arrangements can be made.

RSVP for golfing at the Links of Novi is required. If you wish to attend the golf outing and did not indicate so on your 8th International LS-DYNA User's Conference Registration form, please contact Arthur Tang (248) 705-1203. Transportation for out of town players can be arranged.

Play golf with VPG



A Day at the Park
&
The 8th International LS-DYNA Users Conference

Detroit Tigers vs. Seattle Mariners
Comerica Park, Detroit MI
Sunday, May 2, 2004
Game time 1:05pm

Join us for a fun filled afternoon to see the Detroit Tigers play the Seattle Mariners at Comerica Park.

This game will feature several key international ball players:

- **Seattle Mariners Right Fielder Ichiro Suzuki**
- **Pitcher Shigetoshi Hasegawa**
- **Tigers First Basemen Carlos Pena.**

Meet us in the lobby of the Hyatt Regency Dearborn:

- **11:30am on Sunday, May 2nd,**
- **Round trip transportation will be provided from the hotel to the ballpark.**
- **Bus will leave the Hyatt at 12:00 sharp!**

If you are a local and would like to meet us at the ballpark, please contact **Melissa Carlson for ticket arrangements.** A beverage and light lunch of pizza or hot dog at the ballpark is also included.

There is more to Comerica Park than the field.

Filled with one-of-a-kind attractions, Comerica Park is a combination ballpark, theme park and baseball museum. The home of the Detroit Tigers is truly a ballpark for the 21st Century. Comerica Park is the place for the whole family to enjoy the game in a whole new way.

RSVP for the baseball outing is required. If you wish to attend the Detroit Tigers game and did not indicate so on your 8th International LS-DYNA User's Conference registration form; please contact **Melissa Carlson** (248) 729-3010 x 282.

8th International LS-DYNA Users Conference

May 2- 4, 2004
Hyatt Regency Dearborn
Dearborn, Michigan

Sunday May 2nd

11:00 a.m. - 5:00 p.m.	**Golf Outing, Links of Novi** ***"Sponsored by ETA"***	
11:30 p.m. - 5:00 p.m.	**Baseball Game** *Detroit Tigers vs. Seattle Mariners,* Comerica Park ***"Sponsored by ETA"***	
5:00 p.m. - 6:00 p.m.	**Registration** ***"Sponsored by IBM"***	Outside of the Hubbard Foyer
5:00 p.m. - 6:00 p.m.	**Pre-Conference Seminar:** *"VPG 3.0 A New Pre/Post Environment for LS-DYNApc"*	Springwells Ballroom
6:00 p.m. - 8:00 p.m.	**Welcome Reception** ***"Sponsored by Linux Networx"***	Dearborn Ballroom
5:00 p.m. - 8:00 p.m.	**Exhibition**	Hubbard Foyer

Monday May 3rd

7:30 a.m. – 4:00 p.m.	Registration ***"Sponsored by IBM"***	**Outside of the Hubbard Foyer**
7:30 a.m. – 8:20 p.m.	Continental Breakfast ***"Sponsored by NEC"***	**Dearborn Ballroom**
8:00 a.m. – 6:00 p.m.	Exhibition	**Hubbard Foyer**
8:20 a.m.	Welcome and Opening Remarks	**Springwells Ballroom**

8:35 a.m. Keynote Presentations — Springwells Ballroom

8:35 **Dr. Priya Prasad** "*Future Challenges in Vehicle Safety*"
Ford Technical Fellow
Safety Research & Advanced Engineering
Ford Motor Company

9:20 **Dr. Ted Belytschko** "*Developments and Challenges in Computational Mechanics*"
Walter P. Murphy Professor
Northwestern University

10:05 a.m. — Coffee Break – "Sponsored by Verari Systems" — Dearborn Ballroom

10:20 **Mr. Lawrence J. Achram** "*Powering the Record Chrysler Group Product Onslaught*"
Vice President
Virtual Engineering and Crossfire
DaimlerChrysler Corporation

11:00 a.m. Common Session — Springwells Ballroom

11:00 **Development of Shipping Package Drop Analysis Capability at Westinghouse**
J. F. Staples, Westinghouse Electric Company LLC, Columbia, SC

11:30 **A Summary of the Space Shuttle Columbia Tragedy and the Use of LS-DYNA in the Accident Investigation and Return to Flight Efforts**
Matthew Melis, NASA Glenn Research Center, Cleveland, OH

12:00 p.m. — Lunch – "*Sponsored by HP*" — Dearborn Ballroom

Monday May 3rd

1:00 p.m. Session 1 -- Crash / Safety (1) Springwells Ballroom

1:00 **Prediction of Seat Deformation in Rear Crash Using LS-DYNA**
Biswanath Nandi, Lear Corporation

1:25 **Strain Rates in Crashworthiness**
Moisey B. Shkolnikov

1:50 **An Evaluation of Active Knee Bolsters**
Zane Z. Yang, Delphi Corporation

2:15 **Development of a Hybrid Energy Absorbing Reusable Terminal (HEART) Using Finite Element Modeling in LS-DYNA for Roadside Safety Applications**
Nauman M. Sheikh, Texas Transportation Institute, The Texas A&M University System

2:40 **Curved Barrier Impact of a NASCAR Series Stock Car**
Eric A. Nelson, Altair Engineering, Troy, MI

1:00 p.m. Session 2 -- Methods Development Stanley Steamer Suite

1:00 **A Process of Decoupling and Developing Optimized Body Structure for Safety Performance**
John M. Madakacherry , Technical Specialist, General Motors

1:25 **Virtual Try Out and Process Optimization for an Innovative Conic Poles Production Concept**
A. Anglani, Department of Innovation Engineering, University of Lecce, Italy

1:50 **FEA - Calculation of the Hydroforming Process with LS-DYNA**
Michael Keigler, Aalen University, Germany

2:15 **Implicit and Explicit Finite Element Simulation of Soft-Pad Grinding of Silicon Wafers**
A.H. Zhao, Department of Industrial and Manufacturing Systems Engineering, Kansas State University

2:40 **FEA – Simulation of Bending Processes with LS-DYNA**
Peter Gantner, Aalen University, Germany

1:00 p.m. Session 3 -- Simulation Technolgy (1) Stearns Knight Suite

1:50 **The Use of LS-DYNA in the Columbia Accident Investigation and Return to Flight Activities**
Jonathan Gabrys, The Boeing Company, Philadelphia,PA

1:25 **Test and Analysis Correlation of Foam Impact onto Space Shuttle Wing Leading Edge RCC Panel 8**
Edwin L. Fasanella, US Army Research Laboratory, Vehicle Technology Directorate, Hampton, VA

1:00 **Application of Non-Deterministic Methods to Assess Modeling Uncertainties for Reinforced Carbon-Carbon Debris Impacts**
K. Lyle, NASA Langley Research Center, Hampton, VA

2:15 **Material Modeling of Space Shuttle Leading Edge and External Tank Materials for Use in the Columbia Accident Investigation**
Kelly Carney, NASA Glenn Research Center Cleveland, OH

2:40 **Modeling the Nonlinear, Strain Rate Dependent Deformation of Shuttle Leading Edge Materials with Hydrostatic Stress Effects Included**
Robert K. Goldberg, NASA Glenn Research Center, Cleveland, OH

Monday May 3rd

1:00 p.m. Session 4 -- Fluid/Structure — Pierce Arrow Suite

1:00 **The Use of LS-DYNA to Simulate the Water Landing Characteristics of Space Vehicles**
Benjamin A. Tutt, Irvin Aerospace Inc, Santa Ana, CA

1:25 **Modeling of Fuel Sloshing Phenomena Considering Soild-Fluid Interaction**
Jean Ma, Plastics Products and Processing CAE, Visteon Corporation

1:50 **Investigation of the Arbitrary Lagrangian Eulerian Formulation to Simulate Shock Tube Problems**
C.P. Salisbury, University of Waterloo, Ontario, Canada

2:15 **The Effects of Numerical Results and Computing Time Due to Mass Scaling in Rolling Analysis**
J.Y. Chin, Theme Engineering Inc, Korea

2:40 **ALE and Fluid Structure Interaction in LS-DYNA**
M. Souli, Laboratoire de Mécanique de Lille, France

3:05 p.m. Coffee Break – *"Sponsored by Verari Systems"* — Dearborn Ballroom

3:20 p.m. Session 5 -- Crash/Safety (2) — Springwells Ballroom

3:20 **Study of a Driver Airbag Out-Of-Position Using ALE Coupling**
Wenyu Lian, General Motors

3:40 **A Benchmark Study of CAE Sensor Modeling Using LS-DYNA**
C. C. Chou, Passive Safety R&A, Ford Motor Company

4:10 **A FE Modeling and Validation of Vehicle Rubber Mount Preloading and Impact Response**
Sae U. Park, DaimlerChrysler Corporation

4:35 **Influence of Pre-stressed Parts in Dummy Modeling - Simple Considerations -**
Ulrich Franz, DYNAmore, Germany

5:00 **IIHS Side Impact Analysis Using LS-DYNA/Madymo Coupling**
Jiri Kral, TNO Madymo North America, Livonia, MI

5:15 **FEM for Impact Energy Absorption with Safety Plastic**
Iulian Lupea, The Oakwood Group, Dearborn, MI

3:20 p.m. Session 6 -- Material Technology — Stanley Steamer Suite

3:20 **Modeling Crushable Foam for the SAFER Racetrack Barrier**
Robert W. Bielenberg, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, NE

3:45 **Implementation of a Constitutive Model for Aluminum Foam Including Fracture and Statistical Variation of Density**
A. Reyes, Structural Impact Laboratory (SIMLab), Department of Structural Engineering, Norwegian University of Science and Technology, Trondheim, Norway

4:10 **Theory and Evaluation of Concrete Material Model 159**
Yvonne D. Murray, APTEK, Inc., Colorado Springs, CO

4:35 **A Model for Process-Based Crash Simulation**
O.-G. Lademo, SINTEF Materials and Chemistry, Structural Impact Laboratory (SIMLab) Department of Structural Engineering, Norwegian University of Science and Technology, Trondheim, Norway

5:00 **Application of LS-DYNA in Identifying Critical Stresses Around Dowel Bars**
Samir N. Shoukry, West Virginia University, Morgantown, WV

5:25 **Formability Modeling with LS-DYNA**
Torodd Berstad, SINTEF Materials and Chemistry, Trondheim, Norway

3:20 p.m. Session 7 -- Simulation Technology (2) — Stearns Knight Suite

3:20 **Development of an LS-DYNA Model of an ATR42-300 Aircraft for Crash Simulation**
Karen E. Jackson, U.S. Army Research Laboratory, Vehicle Technology Directorate, Hampton, VA

5:25 **Validation of LS-DYNA Computer Code for Seismic Qualification of Reactivity Control Mechanisms**
A.S. Banwatt, Atomic Energy of Canada Ltd., Mississauga, Ontario, Canada

3:45 **A Study on Shock Wave Propagation Process in the Smooth Blasting Technique**
Masahiko Otsuka, Graduate School of Science and Technology, Kumamoto University, Japan

4:10 **Vulnerability of Bridge Piers to Impact by Heavy Vehicles**
Sherif El-Tawil, Dept. of Civil and Env. Eng., U. of Michigan, Ann Arbor, MI

4:35 **Modeling of Welded Structures Residual Strains**
Sergey Medvedev, United Institute of Informatics Problems, National Academy of Sciences of Belarus, Minsk, Republic of Belarus, Russia

5:00 **Nonlinear Finite Element Analysis of Airport Approach Lighting Structures Under Impact Loading**
M. Nejad Ensan, Institute for Aerospace Research, National Research Council, Canada

3:20 p.m. Session 8 -- Penetration/Explosive Modeling — Pierce Arrow Suite

3:20 **Preliminary Assessment of Non-Lagrangian Methods for Penetration Simulation**
Leonard E. Schwer, Schwer Engineering & Consulting Services, Windsor, CA

3:45 **Energy Absorbing Sandwich Structures Under Blast Loading**
Dong Kwan (David) Lee, Department of Mechanical Engineering, University of Nevada, Las Vegas, Las Vegas, NV

4:10 **Transient Response of a Projectile in Gun Launch Simulation Using Lagrangian and ALE Methods**
Ala Tabiei, Department of Aerospace Engineering & Engineering Mechanics, University of Cincinnati, Cincinnati, OH

4:35 **Effects of Pre-Pressurization on Plastic Deformation of Blast-Loaded Square Aluminum Plates**
R.L. Veldman, Hope College, Department of Physics and Engineering, MI

5:00 **Explosive Welding of Light Weight Metal Sheets**
Yamato Matsui, Graduate School of Science and Technology, Kumamoto University, Japan

5:25 **Simulation of Energy Absorbing Materials in Blast Loaded Structures**
Michael J. Mullin, Department of Mechanical Engineering, University Nevada Las Vegas, Las Vegas, NV

5:50 **Moving Beyond the Finite Elements, a Comparison Between the Finite Element Methods and Meshless Methods for a Ballistic Impact Simulation**
Murat Buyuk, FHWA/NHTSA-NCAC, National Crash Analysis Center, The George Washington University, Ashburn, VA

6:00 Exhibition closes for the day

7:00 p.m. – 9:00 p.m. Conference Banquet – "*Sponsored by Intel and SGI*" Dearborn Ballroom

Tuesday May 4th

7:00 a.m. – 8:00 p.m.	Continental Breakfast ***"Sponsored by Cray"***	Dearborn Ballroom
7:30 a.m.	Registration ***"Sponsored by IBM"***	Outside of the Hubbard Foyer
8:00 a.m. – 4:00 p.m.	Exhibition	Hubbard Foyer

8:00 a.m. Session 9 -- Metal Forming Technology (1) — Springwells Ballroom

8:00 **Review of Sheet Metal Forming Simulation – Progress to Date, Future Developments**
Trevor Dutton, Dutton Simulation Ltd, UK, England

8:25 **An Eulerian Finite Element Model of the Metal Cutting Process**
A. Raczy, Department of Mechanical, Automotive and Materials Engineering, University of Windsor, Ontario, Canada

8:50 **Determination of Optimal Cutting Conditions in Orthogonal Metal Cutting Using LS-DYNA with Design of Experiments Approach**
David P. Masillamani, Department of Mechanical and Industrial Engineering, University of Texas at El Paso, El Paso, TX

9:15 **Simulation and Analysis of the Beverage Can Necking Process Using LS-DYNA**
Jordan-Cordera, Mechanical Engineering Department, ITESM Campus Toluca, Mexico

9:40 **Learning Module for Using Dynaform® to Study the Effects of Die-Entry and Punch-Nose Radii on Drawing Cups**
W.K. Waldron, Mechanical Engineering Department, Kettering University, Flint, MI

8:00 a.m. Session 10 -- Optimization — Stanley Steamer Suite

8:00 **LS-OPT Capabilities for Robust Design**
Nielen Stander, Livermore Software Technology Corporation, Livermore, CA

8:25 **Crashworthiness Design of Vehicle Structures via Equivalent Mechanism Approximations**
Karim Hamza, Department of Mechanical Engineering, University of Michigan, Ann Arbor, MI

8:50 **Horizontal Tailplane Subjected to Impact Loading**
M. Hörmann, CAD-FEM GmbH, Grafing/Munich, Germany

9:15 **Robustness Study of an LS-DYNA Occupant Simulation Model at DaimlerChrysler Commercial Vehicles using LS-OPT**
Frank C. Günther, Commercial Vehicles Analysis, DaimlerChrysler

9:40 **An Investigation of Structural Optimization in Crashworthiness Design Using a Stochastic Approach**
Larsgunnar Nilsson, Engineering Research Nordic AB, Sweden

8:00 a.m. Session 11 -- Simulation Technology (3) — Stearns Knight Suite

8:00 **Finite Element Analysis of Unanchored Structures Subjected to Seismic Excitation**
Sreten Mastilovic, Bechtel SAIC Company, LLC

8:25 **Simulation of Cure Volume Shrinkage Stresses on Carbon/Vinyl Ester Composites in Microindentation Testing**
Tom Mase, Composite Materials and Structures Center, Michigan State University, East Lansing, MI

8:50 **Effect of Triggering Mechanism on the Load-Displacement Response and Folding Pattern of Square Aluminum Tubes**
H. El-Hage, University of Windsor, Ontario, Canada

9:15 **Numerical Modeling of Woven Carbon Composite Failure**
Paul F. Deslauriers, University of Waterloo, Ontario, Canada

9:40 **LS-DYNA Implicit for Dent Performance Evaluation**
Gagan Tandon, Altair Engineering Inc., Allen Park, MI

8:00 a.m. Session 12 -- Computing/Code Technology (1) Pierce Arrow Suite

8:00 **LS-DYNA Communication Performance Studies**
Ananthanarayanan Sugavanam, High Performance Computing, IBM

8:25 **Improving Crash Analysis by Increasing Throughput of Large-Scale Simulations**
Dale I. Dunlap, Platform Computing, Ontario, Canada

8:50 **Determining the MPP LS-DYNA Communication and Computation Costs with the 3-Vehicle Collision Model and the Infiniband Interconnect**
Yih-Yih Lin, Hewlett-Packard Company

9:15 **SPH Performance Enhancement in LS-DYNA**
Gregg Skinner, Advanced Technical Computing Center NEC Solutions (America), Inc.

9:40 **Experiences with LS-DYNA Implicit MPP**
Cleve Ashcraft, Livermore Software Technology Corporation, Livermore, CA

10:05 a.m. Coffee Break – "*Sponsored by Verari Systems*" Dearborn Ballroom

10:25 a.m. Session 13 -- Metal Forming Technology (2) Springwells Ballroom

10:25 **Numerical Simulation of Aluminum Alloy Forming Using Underwater Shock Wave**
Hirofumi Iyama, Dept. of Mechanical and Electrical Engineering, Yatsushiro National College of Technology, Japan

10:50 **Through Process Modelling of Self-Piercing Riveting**
R. Porcaro, Structural Impact Laboratory (SIMLab), Department of Structural Engineering, Norwegian University of Science and Technology, Trondheim, Norway

11:15 **Application of FEA in Stamping Auto Underbody Parts**
Yuyuan Wang, Canadian Engineering & Tool, Windsor, Ontario, Canada

11:40 **The Dynamic Problems in High Speed Transfer Stamping System**
Ming-Chang Yang, Metal Industries Research and Development Centre, Taiwan

12:05 **A New Concept on Stamping Die Surface Compensation**
Li Zhang, Theme Development Department, Advance Stamping Manufacturing Engineering, DaimlerChrysler Corporation

10:25 a.m. Session 14 -- Drop and Impact Simulation — Stanley Steamer Suite

10:25 **Drop Simulation for Portable Electronic Products**
Raymon Ju, Flotrend Corporation, Taipei, Taiwan

10:50 **Simulation and Verification of the Drop Test of 3C Products**
Hsing-Ling Wang, Aviation Management Department, Chinese Air Force Academy, Taiwan

11:15 **Predictive Numerical Modeling of Foreign Object Damage**
Pierangelo Duó, Department of Engineering Science, University of Oxford, UK, England

11:40 **Blast Impact on Aluminum Foam Composite Sandwich Panels**
Rajan Sriram, Department of Materials Science & Engineering, The University of Alabama at Birmingham, Birmingham, AL

12:05 **Numerical Modeling of Ballistic Penetration of Long Rods into Ceramic/Metal Armors**
Khodadad Vahedi, Department of Mechanical Engineering, Louisiana Tech University

10:25 a.m. Session 15 -- Visualization — Stearns Knight Suite

10:25 **Immersive Visualization and Collaboration with LS-PrePost-VR and LS-PrePost-Remote**
Todd J. Furlong, Inv3rsion, LLC, Goffstown, NH

10:50 **VPG Solutions Using MotionView®**
Michael White, Altair Engineering, Troy, MI

11:15 **Rapid Development of Multiple Fold Patterns for Airbag Simulation in LS-DYNA Using Oasys Primer**
Miles Thornton, Arup, UK, England

11:40 **Fast New Methodology for Regulatory Test Simulation**
Velayudham Ganesan, ESI Group

12:05 **Application and Correlation of a Virtual Proving Ground Simulation for a Minivan**
Ulrich Stuhec, NAC Design Verification Department, Ford Motor Company, Dearborn, MI

10:25 a.m. Session 16 -- Computing/Code Technology (2) — Pierce Arrow Suite

10:25 **Improved LS-DYNA Performance on Sun Servers**
Youn-Seo Roh, Sun Microsystems, Inc.

10:50 **Benefits of Scalable Server with Global Addressable Memory for Crash Simulation**
Christian Tanasescu, SGI Inc.

11:15 **A Mesh-free Analysis of Shell Structures**
C. T. Wu, Livermore Software Technology Corporation, Livermore, CA

12:30 p.m. Lunch – "*Sponsored by Microsoft*" — Dearborn Ballroom

Tuesday May 4th

1:30 p.m. Common Session -- Computing Infrastructure Springwells Ballroom

Cray
HP
Intel
IBM
Linux Networx
Microsoft
NEC
SGI
Verari Systems

3:45 p.m. Keynote Presentation Springwells Ballroom

John O. Hallquist, President, LSTC ***"LS-DYNA Development"***

Thank you for your participation in the 8th International LS-DYNA Users Conference!

May 5th & 6th Post-Conference Training Seminars

(Seminars are conducted at the University of Michigan, Dearborn)

Advanced Crashworthiness	*Paul A. Du Bois*
ALE/Eulerian Fluid/Structure Interaction	*M'hamed Souli, Ph.D.*
Heat Transfer Analysis	*Arthur Shapiro, Ph.D.*
Implicit Analysis	*Bradley Maker, Ph.D.*
LS-OPT	*Nielen Stander, Ph.D.*
LS-PREPOST	*Philip Ho*
Metal Forming	*Xinhai Zhu, Ph.D.*

NORTH AMERICAN CHAPTER
Your Invitation

Engineers rely on computer modelling and simulation methods and tools as vital components of the product development process. As these methods develop at an ever-increasing pace, the need for an independent, international authority on the use of this technology has never been more apparent.

NAFEMS is the only worldwide independent association dedicated to this technology.

Companies from numerous industries and every part of the globe have invested heavily in engineering technologies such as Finite Element Analysis and Computational Fluid Dynamics. But how do they ensure they get the best return from their investment? How do they develop and enhance their capabilities? How do they know they are using the technology in the most effective way?

NAFEMS is uniquely placed to help answer these questions.

An outstanding opportunity exists to get involved with the newly formed North American Chapter of NAFEMS at a truly exciting stage in its early development.

What does this mean for me and my company?

Volunteering to serve in the Chapter will give you and your company exceptional prospects for professional growth and success. **You can:**

- Gain invaluable networking contacts with leading individuals in the engineering analysis community
- Receive professional recognition for you and your organization
- Establish advocacy opportunities, representing your company's interests and influencing technology development strategies
- Take advantage of the expanded industry, vendor and user contacts within a professional community and network of peers
- Improve the profile of you and your organization by speaking at NAFEMS events - sharing your technical knowledge
- Influence the activities of NAFEMS in North America and be directly involved in their delivery
- Stay totally up to date with the very latest advances in the marketplace - the ultimate competitive advantage
- Achieve personal and professional satisfaction from knowing that you are assisting with the development of strategies for the effective use of simulation technologies

What's Involved?

Meetings of the Chapter will be held twice each year. These meetings will provide a forum for focused discussion. Experience and knowledge will be exchanged. NAFEMS staff will attend and actively participate in the meetings. Actions will be placed on NAFEMS which will ensure that the work of NAFEMS delivers clear and tangible benefits to its North American members.

Plans for a series of meetings throughout North America in summer 2004 are at an advanced stage.

Contact NAFEMS HQ for further details.

What Opportunities Are Available Now?

Many senior individuals from major corporations and vendors, as well as analysis specialists have already asked to be involved. If you feel that you can make a contribution, have views about the use of analysis or want to learn more about the North American Chapter, contact NAFEMS Headquarters at info@nafems.org

NAFEMS already has a strong international presence in many countries throughout the globe.
For information on your local NAFEMS chapter, please contact NAFEMS HQ.

Get Involved - Contact NAFEMS today

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