Strategies for Using the ADAMS Integrators

by

Michael Steigerwald
Mechanical Dynamics, Inc.

The optimum selection of methods and parameters for mechanical systems simulation (MSS) is quite complex. Ideally, MSS tools will automatically make these selections. Until such intelligence can be included, guidelines developed from the theory of numerical methods and the expertise of experienced users are employed.

A survey of the numerical methods for mechanical systems simulation is presented, followed by an algorithm of strategies for using the methods available in ADAMS (Automatic Dynamic Analysis of Mechanical Systems). Finally, a vision for the future of numerical methods for mechanical systems simulation is presented.

ADAMS Dynamic Solution Techniques

- *Survey of Solution Techniques*
- *Strategies for Using the ADAMS Integrators*
- *Future Vision of Solution Techniques*

ADAMS

Survey of Solution Techniques

- *Implicit vs. Explicit Methods*
- *Variable Step Methods*
- *Differential/Algebraic Equations*

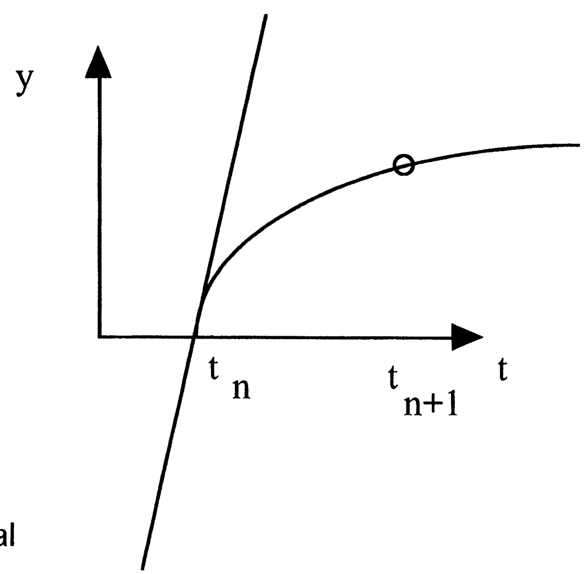
Mechanical
Dynamics

Implicit vs. Explicit Methods

- *Explicit: linear in y' & easier to derive*
- *Implicit: more stable & nonlinear in y'*

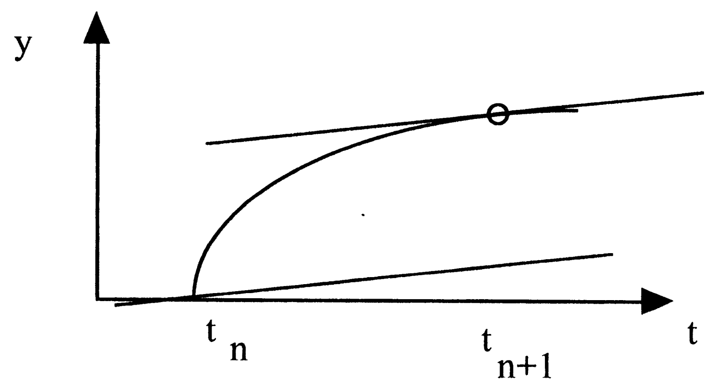
Explicit: linear in y' & easier to derive

- $y'_{n+1} = f(y_n, t_n)$



Implicit: more stable & nonlinear in y'

- $f(y_{n+1}, y'_{n+1}, t_{n+1}) = 0$



-

ADAMS

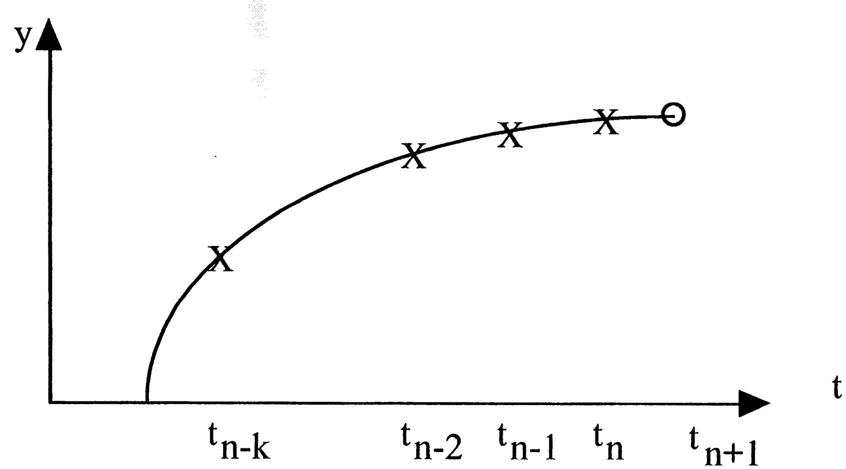
Variable Step Methods

- *Multistep Methods*
- *Nonstiff Methods*
- *Stiff Methods*

Mechanical
Dynamics

Multistep Methods

- *Use History of Multiple Steps*



-

Nonstiff Methods

- *ADAMS Uses a PECE Method*
- *Best for mechanisms dominated by constraints and small, smooth forces*

ADAMS Uses a PECE Method

- *Predict*
  - *Adams-Bashforth (1st order)*
  - $y^{(p)} = y_n + hf(y_n, t_n)$
- *Evaluate*
  - $f(y^{(p)}, t_{n+1})$

ADAMS Uses a PECE Method (cont.)

- *Correct*
  - *Adams-Moulton (1st order)*
  - $y^{(c)} = y_n + hf(y^{(p)}, t_{n+1})$
- *Evaluate*
  - $f(y^{(c)}, t_{n+1})$ *for error test and next step*

ADAMS

Best for mechanisms dominated by constraints and small, smooth forces

- *Typically are not numerically stiff.*
- *Example: A rigid satellite in orbit.*

Mechanical Dynamics

ADAMS

Stiff Methods

- *Necessary for stiff problems*
  - $\lambda_{max}/\lambda_{min} > 200$
- *Backward Differentiation Formula*
  - $y_{tn+1} = h\,\beta_0\, y'_{tn} + \Sigma \alpha_i y_{tn-i}$
  - *Predict with this polynomial*
  - *Correct using Newton-Raphson, but use BDF to relate y, y'*

Mechanical Dynamics

Differential/Algebraic Equations

- *Systems of DAEs are classified by their INDEX*
- *Problems arise with High Index DAEs and BDFs*

Systems of DAEs are classified by their INDEX

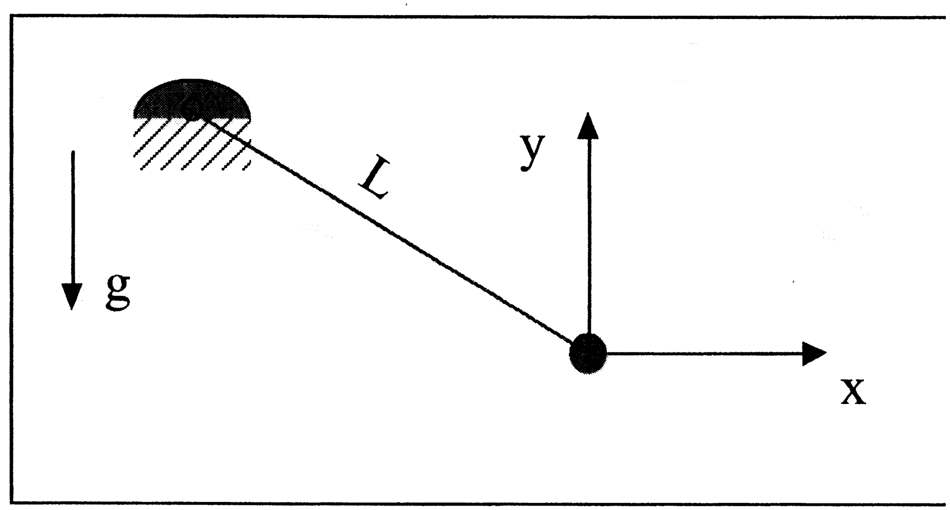
- *Index = # of differentiations necessary to derive ODEs*
- *Basic Illustration of Index*

ADAMS

Basic Illustration of Index

1st order equations of motion

- $x' = u$
- $y' = v$
- $u' = \lambda x$
- $v' = \lambda y - g$
- $x^2 + y^2 - L^2 = 0$



Mechanical Dynamics

ADAMS

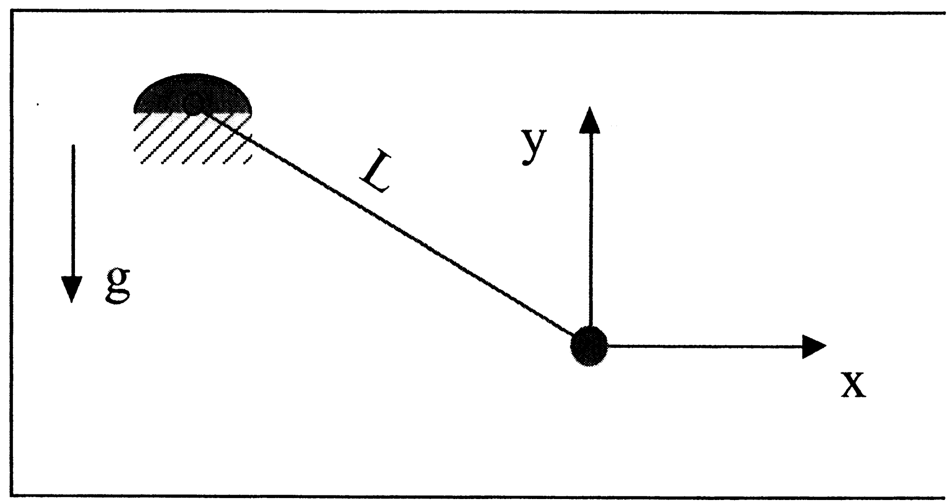
Basic Illustration of Index (cont.)

Differentiate constraint once

- $xx' + yy' = 0$
- Substitute u, v, for x', y'
- $xu+yv = 0$

Differentiate again

- $xu' + yv' + u^2 + v^2 = 0$



Mechanical Dynamics

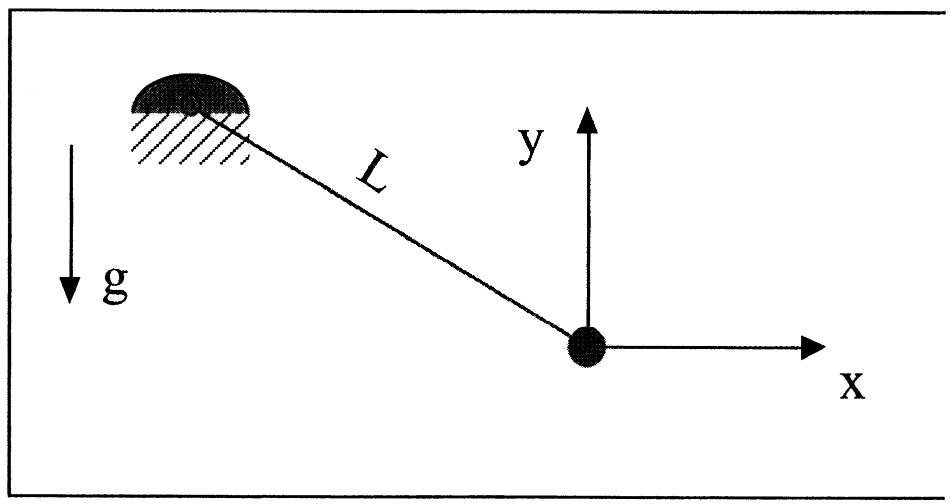
Basic Illustration of Index (cont.)

- Substitute λx, λy for u', v'
- $x^2\lambda + y^2\lambda - yg + u^2 + v^2 = 0$
- $L^2\lambda - yg + u^2 + v^2 = 0$

Differentiate to solve for λ'

- $\lambda' = (vg - 2\lambda ux - 2v(\lambda y - g))/L^2$

Thus, index is 3.



ADAMS

Problems arise with High Index DAEs and BDFs

- √ *Error test must not include errors in y'*
- √ *Newton convergence test must be modified*
  - ◆ *Matrix for Newton Raphson is ill-conditioned*
    - *especially at high temporal resolution*
    - *Examples of High Temporal Resolution*
      - *Impacts*
      - *IF, STEP, HAVSIN*
      - *Active High Frequencies > 100KHz*
      - *Hyperaccurate Accelerations*

Mechanical Dynamics

ADAMS

Strategies for Using the ADAMS Integrators

- *Select the proper method.*
- *Select the proper tolerances.*
- *Solve Corrector Difficulties.*

Mechanical Dynamics

ADAMS

Select the proper method.

- *Use ABAM for non-stiff problems.*
  - *Use ADAMS/Linear to predict numerical stiffness.*
- *Use BDF Methods for stiff problems.*
  - *GSTIFF is most efficient*
  - *Use WSTIFF for improved velocity & acceleration accuracy.*

Select the proper tolerances.

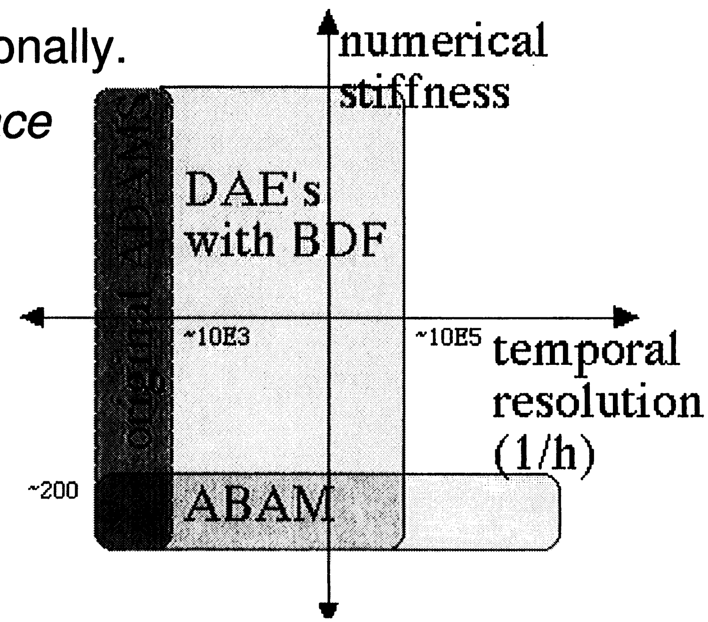
- *Start with ERROR = %Accuracy/(2*# of steps)*
- *Reduce ERROR Until Displacements Converge*
- *Reduce HMAX Until Accelerations Converge*

ADAMS

Future Vision of Solution Techniques

Ultimate Goals

- *Automatic Selection of Methods & Parameters*
- *ADAMS automatically chooses perfect defaults.*
- *User* can *change everything* optionally.
- *Continually Expand Solution Space*



Mechanical
Dynamics

ADAMS

Solve Corrector Difficulties.

- *Improve Accuracy of Linear Solution*
  - *LSOLVER/HARWELL*
- *Improve Accuracy of Nonlinear Solution*
  - *PATTERN = T*
  - *MAXIT = 25*
- *Relax Tolerances*
  - *CR_ADAPT*
- *Try CPBDF*

Mec[illegible]ical Dynamics