

Super Matrix Solver

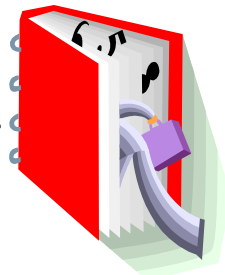
Product Introduction and Business Outline

August 2004

<http://www.vinas.com>

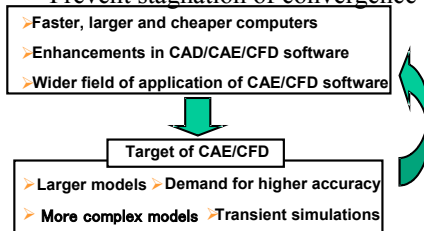
Who benefits from Super Matrix Solver?

- Developers of in-house CAE/CFD numerical analysis programs
- Those who are interested in speeding-up and stabilizing numerical analysis programs
- Those who are interested in speeding-up commercially available solvers



Issues in matrix calculation

- ✓ **Enhance Calculation Speed**
 - Contributes directly to speeding-up the whole CFD solver process
 - Increase convergence rate
 - Implement parallel processing
- ✓ **Improve robustness and convergence rate**
 - Prevent divergence of calculation
 - Prevent stagnation of convergence
- ✓ **Usability enhancements**
 - Reduce number of parameters to set
 - Introduce easier way of convergence judgement
- ✓ **Improve accuracy of Numerical Analysis**
 - Essential in large calculations
 - Eliminate cancellation of significant digits
 - Reduce accumulation of errors



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Approaches to faster simulation (virtual experiments) calculation

Conventional approaches

- Faster CPU
- Vector computers
- Parallel computers

Hardware-based solutions

But !

There are problems that can not be solved by hardware only!

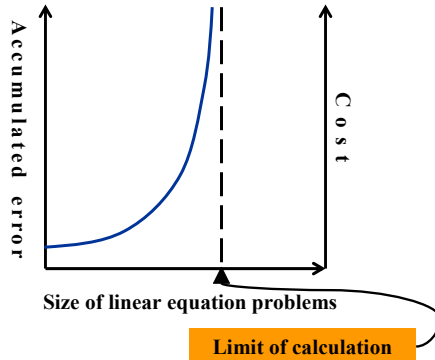
Software-based solutions are necessary!



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Challenges in increasing Speed and Size of simulation calculations

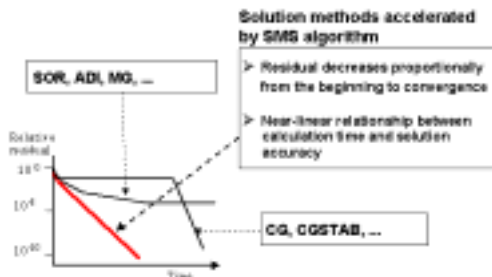
- Limit of calculation speed
- High cost
- Accuracy issues
- Calculation instability
- Difficult to determine convergence level



What is *Super Matrix Solver* (SMS)?

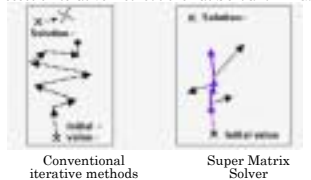
- ✓ Jointly developed with National Aerospace Laboratory of Japan*
- ✓ Acceleration technology for iterative matrix solution methods.
- ✓ It can be incorporated into various existing solution methods to accelerate and stabilize process of matrix calculation.

*currently the Japan National Aerospace Exploration Agency (JAXA)

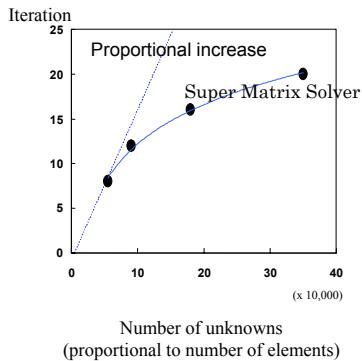


Algorithm of SMS

■ Super Matrix Solver has an optimization algorithm to accelerate and stabilize solution process of iterative methods such as SOR and AMG.



Special Feature of *Super Matrix Solver* (SMS)



- 1) Fast calculation
- 2) High stability and high convergence rate
- 3) Reduced parameter setting
- 4) Not liable to error accumulation
 - Keeps accurate solution
 - Suitable to very large calculations
- 5) Comparatively less iterations needed for large calculation



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Benefits of using *Super Matrix Solver*

- ✓ Speed-up the calculation process by numerical analysis programs without enhancing computer hardware resources
- ✓ Obtain converged solution for problems that have never been solved by conventional methods due to divergence and robustness of high-speed calculation methods
- ✓ Obtain accurate solutions for very large models in a stable way
- ✓ Minimize manual setting of parameters

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What is *Super Matrix Solver-AMG*?

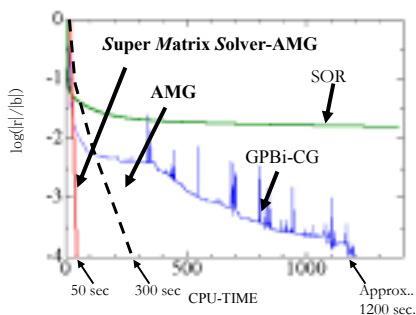
General AMG method

- ✓ AMG method stands for Algebraic Multi Grid method, which is an iterative method developed during 1980-1990 based on the latest calculation theories.
- ✓ It is a fast calculation method, but not widely used because of following problems.
 - ✓ **Difficult to program. Needs advanced mathematical knowledge.**
 - ✓ **Difficult to find out best combination of parameters due to large number of parameters to set.**

Super Matrix Solver-AMG

- ✓ Matrix solver based on AMG method and speeded-up and stabilized by Super Matrix Solver technology of VINAS.
- ✓ One module of Super Matrix Solver library.

Performance of *Super Matrix Solver-AMG*



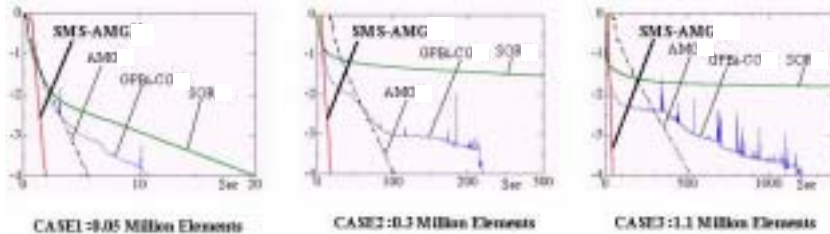
Advantages of *Super Matrix Solver-AMG*

- Based on AMG method and is made faster and more robust
- Much faster than CG methods
- Problems that have never been solved by other methods can be robustly solved
- Very stable convergence during calculation

* GPBi-CG is relatively fast and robust among CG methods

Super Matrix Solver-AMG and other solver methods

Performance of Super Matrix Solver-AMG



Results of convergence history of simultaneous linear equation by Super Matrix Solver-AMG, normal AMG, normal SOR, and GPBi-CG solvers are compared above. Reduction of common logarithms of relative residuals (ordinate) versus CPU time (abscissa) is plotted. Calculations were stopped when relative residuals reached $1.0 \text{ E-}4$.

* GPBi-CG is a solution method known by its speed and stability among CG methods.

Specifications of Super Matrix Solver-AMG

Specifications of Super Matrix Solver-AMG (1)

Type of matrix:	Sparse matrix Supports calculation of structured and unstructured grid in CFD and other analyses Supports calculation of asymmetric matrix
Zero diagonal elements:	Can not calculate
Number of unknowns:	No limitation
Type of variables :	(single and) double precision versions

Specifications may change without prior notice.

Specifications of *Super Matrix Solver-AMG*

Specifications of *Super Matrix Solver-AMG* (2)

Input parameters*:	Left side coefficient matrix (A), Right side constant vector (b) , convergence criteria, maximum iterations, ...
Output data:	Solution vector(X), Relative residual, Number of performed iterations, ...
Error messages:	Warnings and error messages are returned as return values (calculation information, system information, ...).

*Specifications may change without prior notice.

Specifications of *Super Matrix Solver-AMG*

Specifications of *Super Matrix Solver-AMG* (3)

Supported systems:	Windows, Unix(SGI/IRIX, ...), Linux and parallel versions planned * Please contact VINAS for details
Provided as:	Library (source is not available)
Documents:	Manual (explains data format, parameters, application development, and so on)
Sample data:	Sample program using Super Matrix Solver-AMG
Field of application:	Can be used for solving linear equation system in CFD, structural, electromagnetic and other analyses.
License management:	Managed by physical address of computer Runs on designated machine only

Specifications may change without prior notice.

Using Super Matrix Solver-AMG

Super Matrix Solver Can be incorporated with Fortran, C and C++ programs. Shown below is an example of using Super Matrix Solver-AMG from a Fortran program.

```
rtc=smsamgd(x,abrs,nstp,ad,alu,b,lnt,lnd,nd,ns,mstep,eps, lu0sw)
```

NOTE:

rtc = return code

x = solution of unknown x

abrs = achieved accuracy

nstp = actual number of iteration

ad = values of diagonal elements of matrix A

alu= values of non-diagonal, non-zero elements in matrix A

b = values of right-hand side constant vector b

lnt = column indices (j) of non-diagonal, non-zero elements in matrix A (i, j)

lnd = numbers of non-diagonal, non-zero elements in each row of matrix A

nd = dimension of matrix A

ns = number of non-diagonal, non-zero elements in matrix A

mstep = maximum iteration

eps = required accuracy/convergence level in relative residual

lu0sw = control switch for initial values of unknown vector x

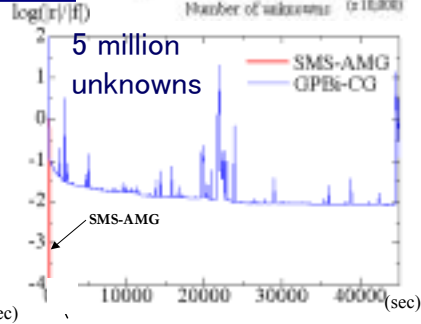
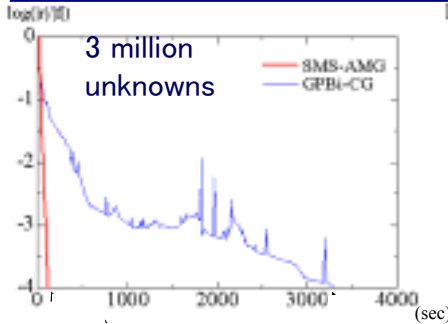
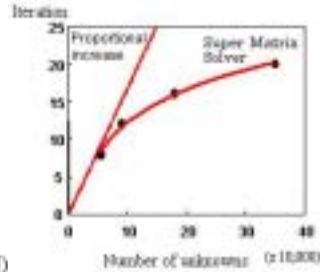
Specifications may change without prior notice. For the details about the parameters, refer to the product manual.

Performance and application examples

Features of Super Matrix Solver



1. Performs fast calculation in numerical analysis problems
2. High stability in calculation
3. Virtually no manual calculation parameter settings needed
4. Low accumulation of errors – Enables large scale calculations



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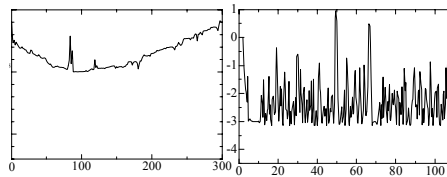
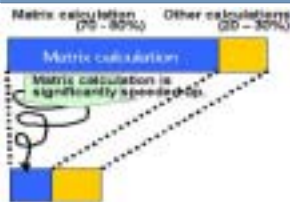
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Benefits of Super Matrix Solver



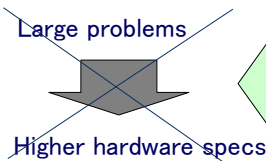
Faster numerical analysis calculations

Solutions to previously insoluble problems



Highly accurate solutions can be obtained for very large scale problems

Minimized manual settings of calculation parameters



More difficult problems (large condition number)

```
rtc=smsamgd(solution, coefficient matrix, right-hand side vector, number of iterations, normalization, convergence criterion, reduction)
```

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Application of SMS-AMG: Concrete strength study

Hokkaido University Structural and Geotechnical Engineering Division

[Field of application] Concrete breakage strength study

crack opening process simulation by meso scale model

[Solution method] Rigid body spring model (RBSM)

[Size of calculation] Several thousand times

of calculations in 250,000 to 400,000 unknowns

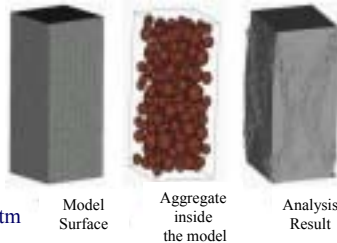
[Calculation speed]

SMS-AMG on a Windows PC was approx. 10 times faster than an ICGG library on a super-computer in completing same calculations.

[More information]

<http://www.hucc.hokudai.ac.jp/~m16120/hybridlab/index.htm>

**SMS-AMG enabled
10 times faster calculation by
a PC than a supercomputer**



**3D RBSM Analysis
75 x 75x 150mm Concrete
Compression Analysis Result**

(48,258 elements) loading plate is fixed horizontally

Source: Nagai, et al. NUMERICAL SIMULATION OF FRACTURE PROCESS OF CONCRETE MODEL BY RIGID BODY SPRING METHOD.

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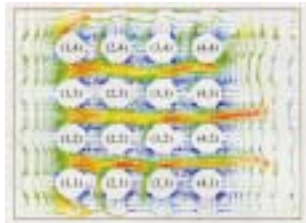


Application of SMS-AMG: Nuclear power plant fuel rods fluid force vibration analysis

Saitama Institute of Technology



Comment from Hisashi Hishida, Ph. D.,
Saitama Institute of Technology

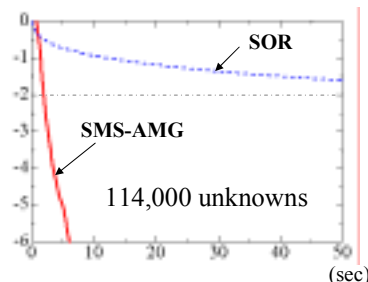


**Calculations to achieve
same accuracy (10^{-2})
were **speeded up 50 to
100 times.****

[Field of application] CFD
Nuclear power plant fuel rods fluid force vibration analysis.

[Calculation issues]

Trial of some large models took a few months to be solved by conventional iterative methods, but SMS-AMG has significantly sped up the calculation time.



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Application of SMS-AMG: 3D plastic mold flow analysis



Plamedia Corporation

Study of heat and flow inside a spiral mandrel die and quantitative analysis of residence time profile by using 3D finite element analysis

Previously insoluble problems solved in high speed

3.5 times faster calculations

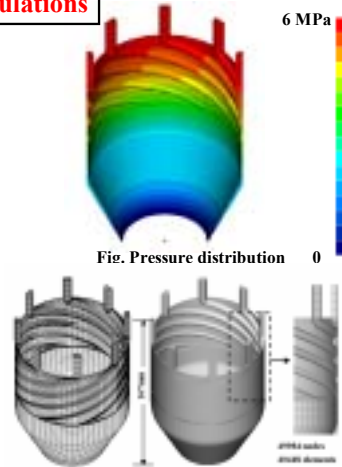


Table Comparison of CPU Time

Model	Eqn. 52357 Non-zeros: 4525296	Eqn. 143386 Non-zeros: 12144782
Direct solver	283.4 sec	Error (Memory over)
Iterative solver SMS AMG	81.9 sec	100.8 sec

(Pentium IV PC, 2.53GHz, 2Gb)

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Application of SMS-AMG: 2D plastic mold flow analysis



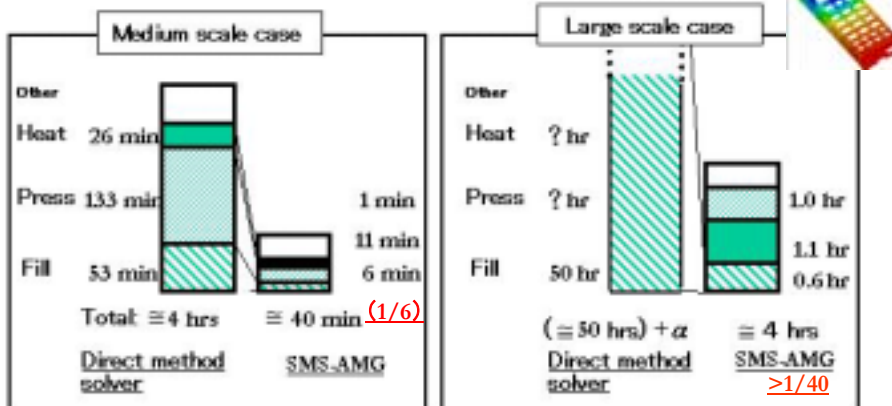
Plamedia Corporation

[Field of application]

Mold flow analysis of handheld phone

Previously insoluble problems solved in high speed

6 times faster calculations



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Application of SMS-AMG: Electromagnetic analysis



MU TECH Co., Ltd.

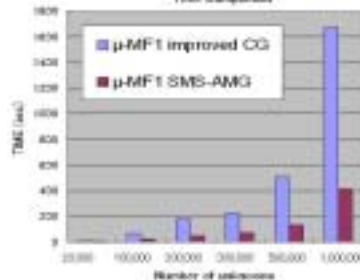
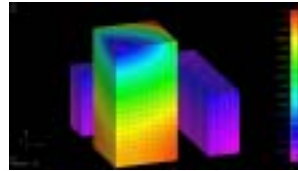
IEEJ's 3D static electromagnetic model for verification purpose

Iron core and coil model, one-eighth symmetric part

Hardware specifications:
 HP workstation x1100 / Pentium4
 2GHz/ RAM 786MB, Hard disk 32GB

[Client Comments]
 PC version of SMS-AMG from VINAS is capable of delivering its high performance in electromagnetic analyses through our performance tests. Speed of calculation is far above what can be expected from conventional solution methods. With appropriate computer hardware, SMS-AMG is expected to be able to handle calculations with DOF exceeding 2 million.

Four times faster in calculation of 1 Million DOF problem



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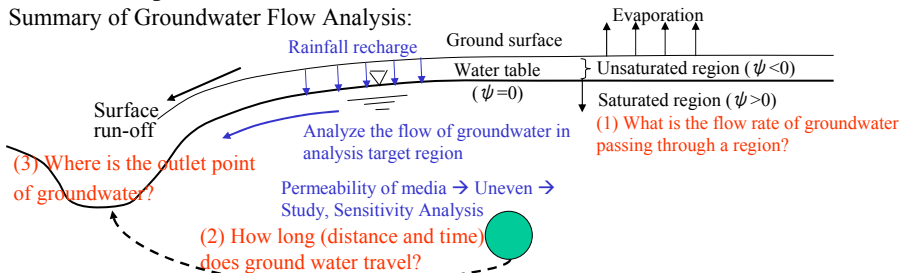
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Application of SMS-AMG: Groundwater flow analysis



Shimizu Corporation

Summary of Groundwater Flow Analysis:

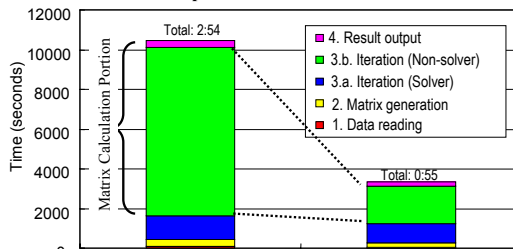


Mr. Tomonari Shiraishi, Chief Researcher
 Technical Institute, Atomic Energy Group
 Shimizu Corporation

[Client Comments]
 We are very happy about the fact that we can solve with SMS-AMG large scale problems (with 1 million unknowns) that we have never been able to solve in the past.

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Time spent on 7 non-linear iterations



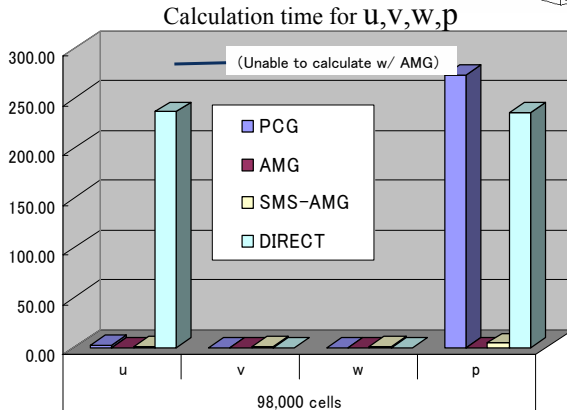
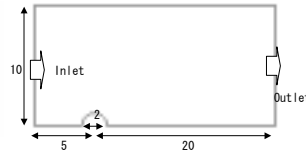
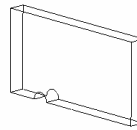
Windows (1 million unknowns) Unix (1 million unknowns)

Application of SMS-AMG: Electromagnetic and fluid coupled analysis

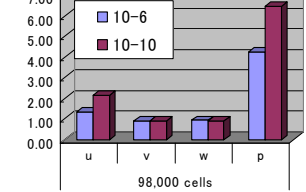


CRC Solutions Corporation

SMS-AMG is integrated into FINAS/CFD code



Inflow: Constant x-velocity (18.2)
Outflow: Gauge pressure = 0
Kinematic viscosity: 1.5×10^{-5}
Density: 1.0
Boundaries: Cylindrical surface has non-slip, other surfaces have slip condition.



Calc. Time for different convergence level
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Application of SMS-AMG: Incompressible fluid flow analysis



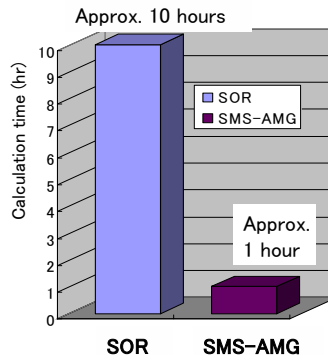
The Institute of Space and
Astronautical Science of Japan

**Previously insoluble problems solved
in high speed**

No. of elements: Approx. 40,000
 Reynolds number: 1,000
 Unknowns: 40,000
 Conv. Criterion: $1E-4$
 Method: MAC method

10 times faster than before

[Client Comments]
 Better convergence performance was observed at the beginning of calculation where instability is often observed. One of SMS-AMG's advantages is that it can carry out calculation more stably than SOR even with a larger time step.



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