*S*uper *M*atrix *S*olver-P-ICCG:

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Project Development Dept.

URL: http://www.vinas.com

What is ICCG?

- *ICCG* is an iterative solution method for linear equations based on CG (Conjugate Gradient) method. In ICCG, the calculation speed of CG method is enhanced with pre-processing technology (Incomplete Cholesky Factorization). Compared with CG method that has no pre-processing, ICCG method is faster and more stable method.

- *ICCG* is an iterative method with many actual performance results in diverse analyses fields such as structural, electromagnetic and computational fluid dynamic analyses.

Parallel Version ICCG Solver (P-ICCG)

- Co-developed with Kyoto University (Academic Center for Computing and Media Studies)
- 3 types of parallel algorithm:
  - Block-ICCG
  - Part-ICCG
  - AMC-ICCG (Algebraic Multi-Color Ordering Method)
- Commercialized Block-ICCG with great parallelization effect
- SMP Parallel
  - Easily parallelized in Windows, UNIX and Linux environment
  - Makes the solver a black box on module basis for ease of use

Performance Comparison of P-ICCG vs. SMS-AMG

	P-ICCG	SMS-AMG
Asymmetric problem	-	Good
Zero-diagonal problem	Good	-
Complex numbers	Good	-
Parallelization (SMP)	Good	-
Calculation speed	Fair-Good	Excellent
Difficult Problems	Fair	Good

NOTE: “ - ” indicates items that are not accommodated.

User demands:

Widely apply to various problems

Greatly speed up specific calculation

P-ICCG Summary Specifications (1)

- Parallel method: accommodates shared memory type (SMP)
- Object coefficient matrices: sparse matrices that are generated from discretizastion methods such as finite element, finite volume, and differential methods.
- Maximum number of CPU's : unlimited; however, 1 to 8 CPU's are recommended.
- Types of unknowns : real and complex numbers
- Symmetry of problems : limited to symmetric problems only (cannot calculate asymmetric problems)
- Zero-diagonal problems : able to calculate[1]

1. cannot solve all of the problems with zero elements in diagonal

P-ICCG Summary Specifications (2)

- Environment : Windows, Unix and Linux (refer to the next page for details)
- Able to be installed into programs written in computer languages such as C and Fortran[2]

  2. Installation into programs written in other languages has not yet been confirmed.

- Parameters that can be specified : convergence criteria, number of iteration, initialization condition, and so forth[3]

  3. refer to the next page for summary of arguments; refer to the product manual for detailed information.

- Program format : provided in executable module format such as DLL[4]

  4. source code will not be disclosed

- Accessories : manual, sample installation data, etc.

Environments supported by P-ICCG

Rev A: November 15, 2010

	OS	Recommended Environment	Recommended Compiler	Environment for which operation is noted	Compilers for which operation is noted	Remarks
32-bit machine	Windows	Windows 2000 Windows XP	(1)Fortran ・Compaq Visual Fortran 6.6A (2) C / C++ ・Microsoft Visual Studio 6.0 ・Microsoft Visual C++ 6.0 and later		・Compaq Visual Fortran 6.5	
	Linux	Red Hat Linux 7.3 gcc : 2.96 glibc : 2.2.5 kernel : 2.4.18	gcc 2.96 Intel Fortran 7.0	・Red Hat Linux 8.0 ・Red Hat Linux 9.0		Environment under which the module might operate: gcc 2.96 and later, glibc 2.2.5 and later, kernel 2.4.18 and later
64-bit machine	Windows (AMD64/ EM64T)	Windows XP x64	(1)Fortran ・Intel Fortran 9.0 and later (2) C / C++ ・Microsoft Visual Studio 2005 ・Microsoft Visual C++ 6.0 and later			
	Linux (AMD64/ EM64T)	Fedora core 4 (Red Hat 4) gcc : 4.0.0 glibc : 2.3.5 kernel : 2.6.11	gcc 4.0.0 Intel FORTRAN Version 8.1			Environment under which the module might operate: gcc 4.0.0 and later, glibc 2.3.5 and later, kernel 2.6.11 and later

How to Call P-ICCG Function

Example: C language

```
int  PICCGD(
        double  *X,
        double  *Abrs,
        int     *Nstp,
        double  *AD,
        double  *AU,
        double  *B,
        int     *LNT,
        int     *LND,
        int     ND,
        int     NS,
        int     Mstp,
        double  EPS,
        int     Lop1,
        int     Lu0sw,
        double  GAMMA,
        int     COLOR
        );
```

Partial list of arguments
(an excerpt from the product manual)

Arguments	Definition (C)	Definition (FORTRAN)	Dimension	Attribute	Meaning of variable (at the time of input)	Meaning of variable (at the time of output)
X	double*	Real*8	Array	I/O	Initial value of unknown ***x*** (vector) (when the value of Lu0sw is 4)	Solution of unknown ***x*** (vector) (the latest value, if not converged.)
Abrs	double*	Real*8	Array	O	Set the storage area for output. (For C language, pass pointers of variables.)	Achieved accuracy (in relative residual)
Nstp	int*	Integer*4	Array	O		Actual number of iteration.
AD	double*	Real*8	Array	I	Values of diagonal elements of matrix ***A***	Values after computation are not guaranteed.
AU	double*	Real*8	Array	I	Values of non-diagonal, non-zero elements in upper half of matrix ***A***.	
B	double*	Real*8	Array	I	Values of right-hand side constant vector ***b***	
LNT	int*	Integer*4	Array	I	Column indices (j) of non-diagonal, non-zero elements in upper half of matrix A (i, j).	
LND	int*	Integer*4	Array	I	Numbers of non-diagonal, non-zero elements in each row of upper half of matrix ***A***.	
ND	int	Integer*4	Value	I	Dimension of matrix ***A***. (= number of unknowns in the simultaneous equations = length of array X, B, AD, or LND)	
NS	int	Integer*4	Value	I	Number of non-diagonal, non-zero elements in upper half of matrix A. (= length of array AU or array LNT)	

P-ICCG's Parallel Calculation Performance (1)

- Actual Calculation Time

Types of Problems Analyzed	Approximate number of unknowns	Convergence Time (sec.); target convergence: norm<1.0e-10			
		1-CPU	2-CPU	4-CPU	8-CPU
Magnetic field analysis	220K	1.0	2.0	3.3	6.5
Fluid analysis	500K	1.0	1.4	2.4	4.1
Structural analysis	250K	1.0	1.6	3.1	5.5
Fluid analysis	1000K	1.0	1.3	2.2	3.7

- Comparison of Calculation Performance

(1 CPU calculation speed as 1)

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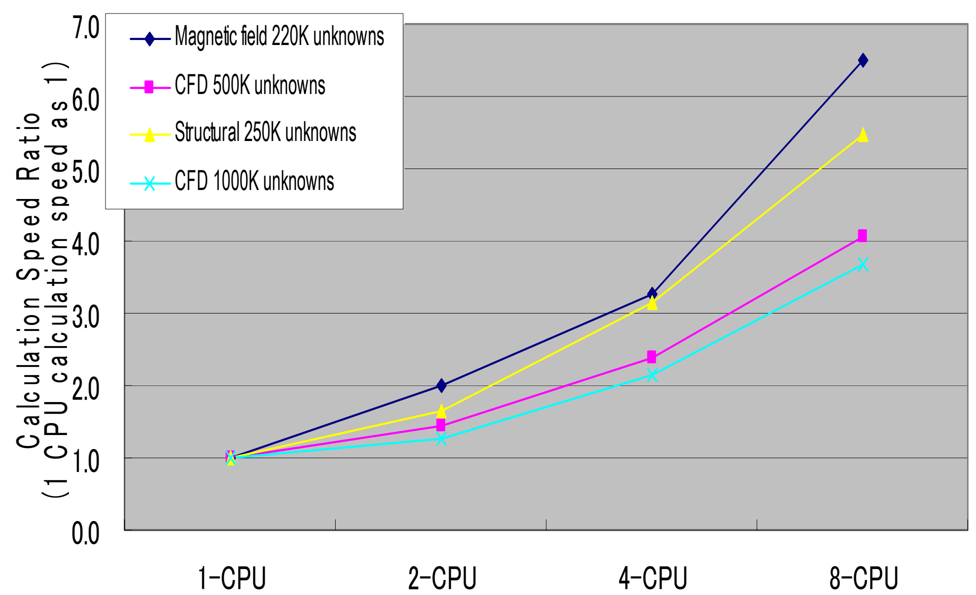
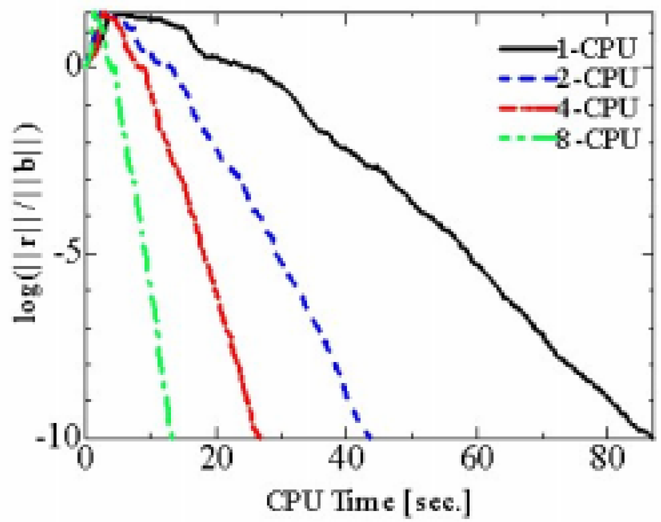


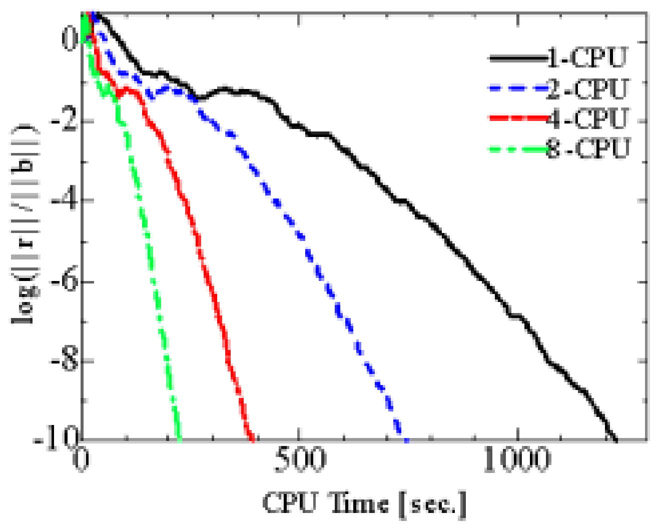
Fig. P-ICCG Parallelization Performance

P-ICCG's Parallel Calculation Performance (2)

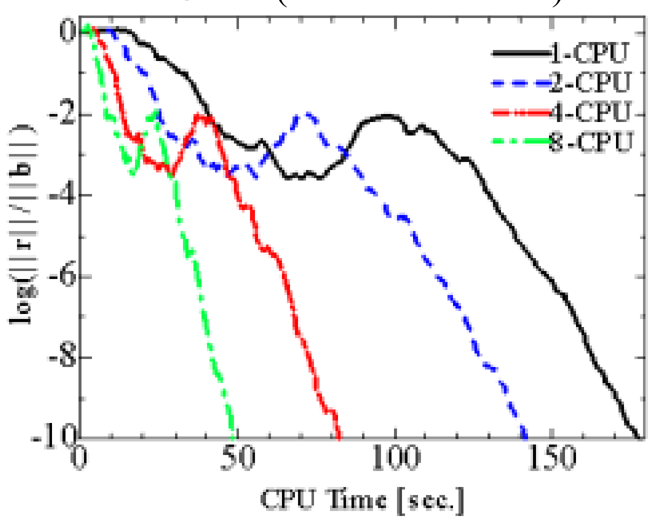
Magnetic Field Analysis (220K unknowns)



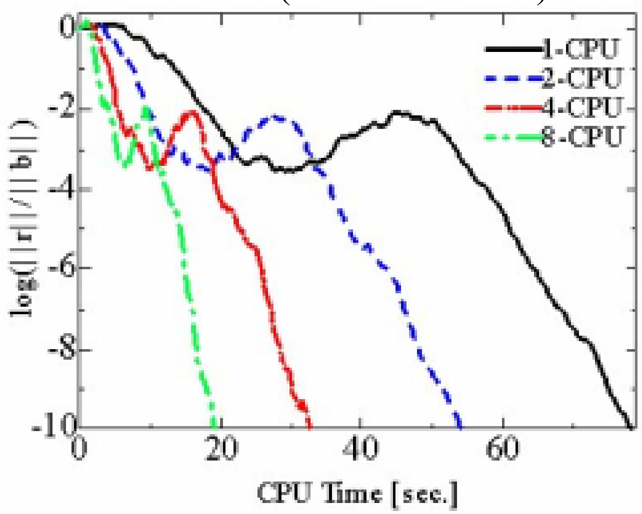
Structural Analysis (250K unknowns)



CFD (1000K unknowns)



CFD (500K unknowns)



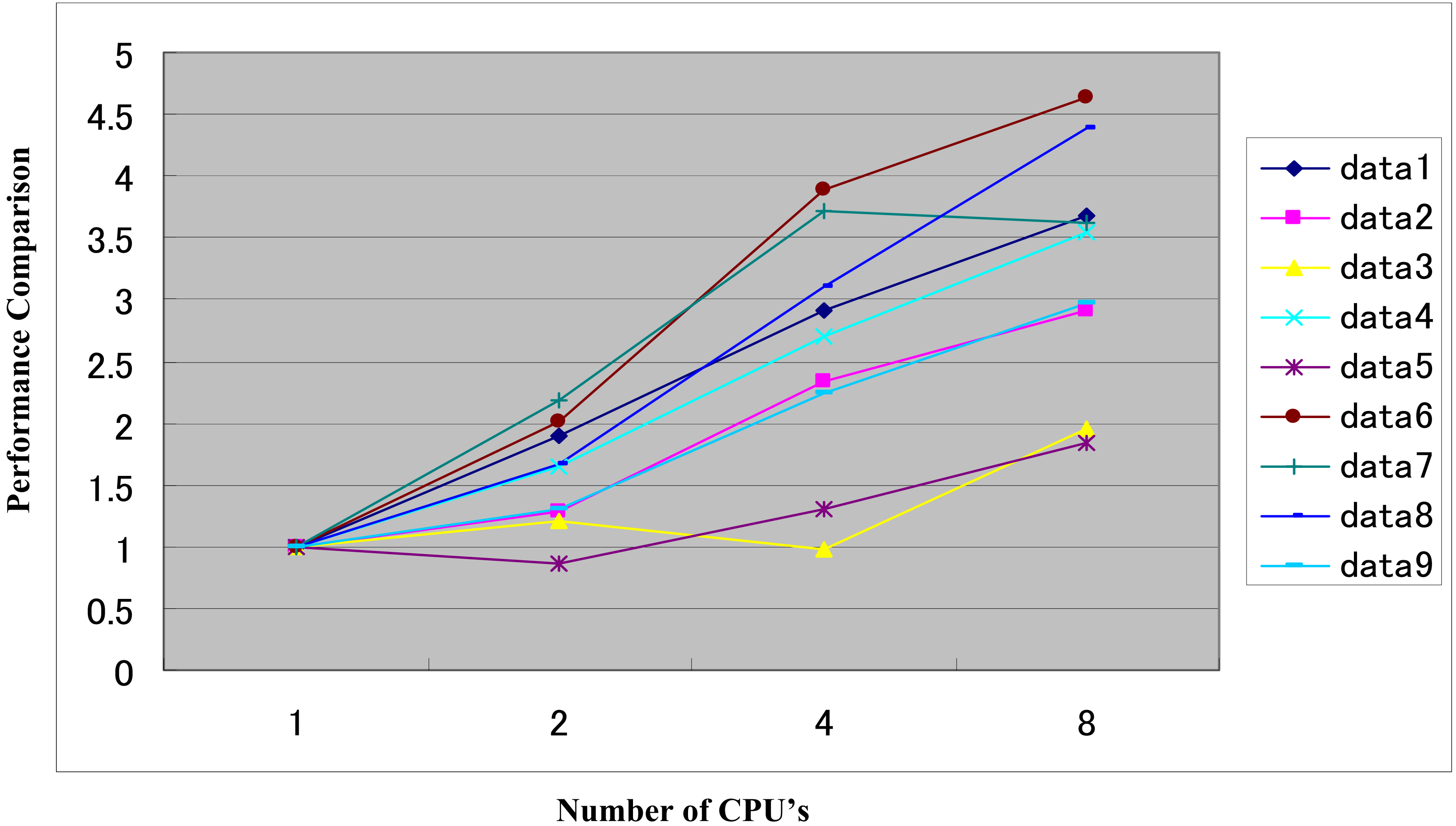
Data for Confirmation of P-ICCG's Performance

Calculation Time for P-ICCG Process: Electromagnetic Analysis with JMAG of Japan Research Institute

Data No.	Data Name	Model Dimension	Real／Complex Number	Dimension	ICCG Calculation Time in hours (Ratio to 1cpu Calculation Time)			
					1cpu	2cpu	4cpu	8cpu
1	Magnetic Head	3D	Real	647,701	0.70	0.37 (1.89)	0.24 (2.92)	0.19 (3.68)
2	Outer Rotor	2D	Real	148,959	7.42	5.74 (1.29)	3.17 (2.34)	2.54 (2.92)
3	IPM Motor	2D	Real	10,899	0.51	0.42 (1.21)	0.52 (0.98)	0.26 (1.96)
4	Conductor Cable	2D	Real	67,075	0.46	0.28 (1.64)	0.17 (2.71)	0.13 (3.54)
5	Inducing Machine	3D	Complex	385,610	2.01	2.33 (0.86)	1.55 (1.30)	1.09 (1.84)
6	Craw Pole Alternator	3D	Real	769,635	6.59	3.28 (2.01)	1.70 (3.88)	1.42 (4.64)
7	Large Craw Pole Alternator	3D	Real	2,464,702	6.64	3.03 (2.19)	1.79 (3.71)	1.83 (3.63)
8	Transformer	3D	Real	680,448	3.69	2.21 (1.67)	1.19 (3.10)	0.84 (4.39)
9	Rotating Conductor	3D	Real	769,496	9.79	7.52 (1.30)	4.35 (2.25)	3.30 (2.97)

Results of Confirmation of P-ICCG's Performance

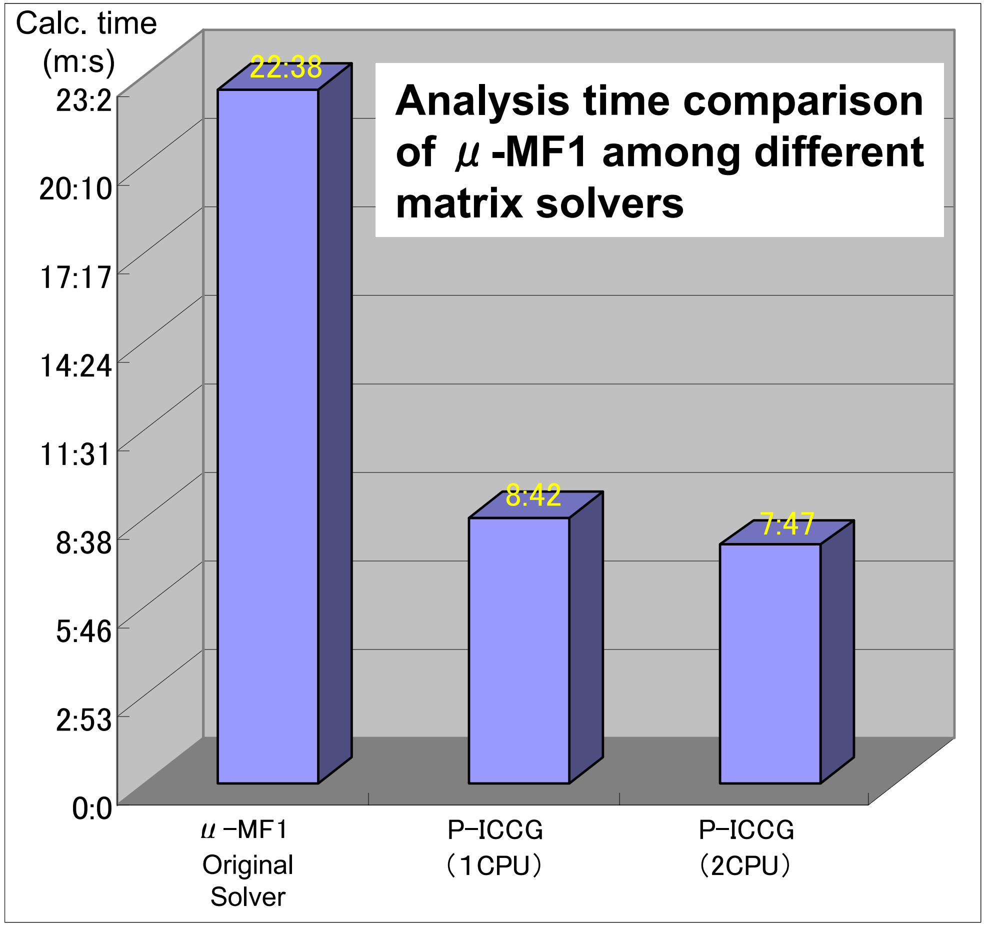
Calculation Time for P-ICCG Process: an example of electromagnetic analysis by JMAG of Japan Research Institute



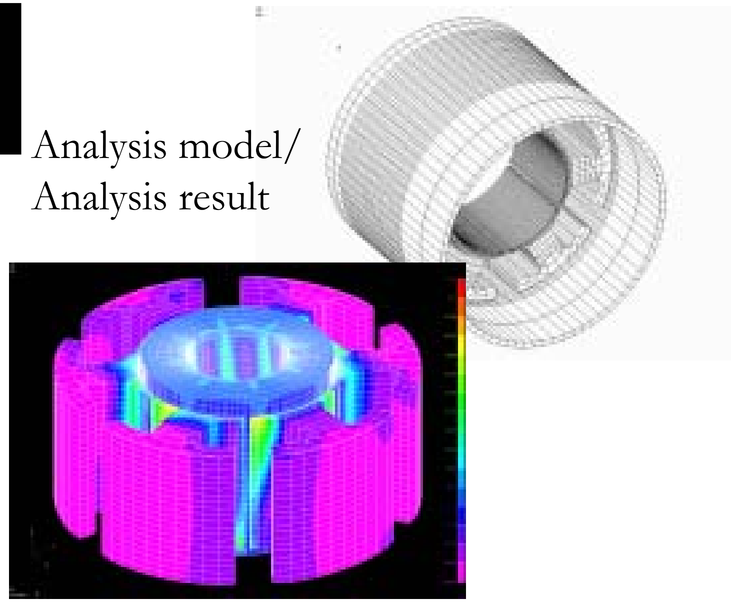
Courtesy: Japan Research Institute

Application Example of P-ICCG (μ -tec Co.,Ltd.)

Verified improvement by applying P-ICCG in calculation speed of μ -MF1



Analysis model/
Analysis result



【Details of Analysis】

Non-linear static magnetic field analysis of 8-pole 6-slot brushless DC motors

- Number of nodes: 194724
- Number of elements: 203840
- Number of unknowns: 189315

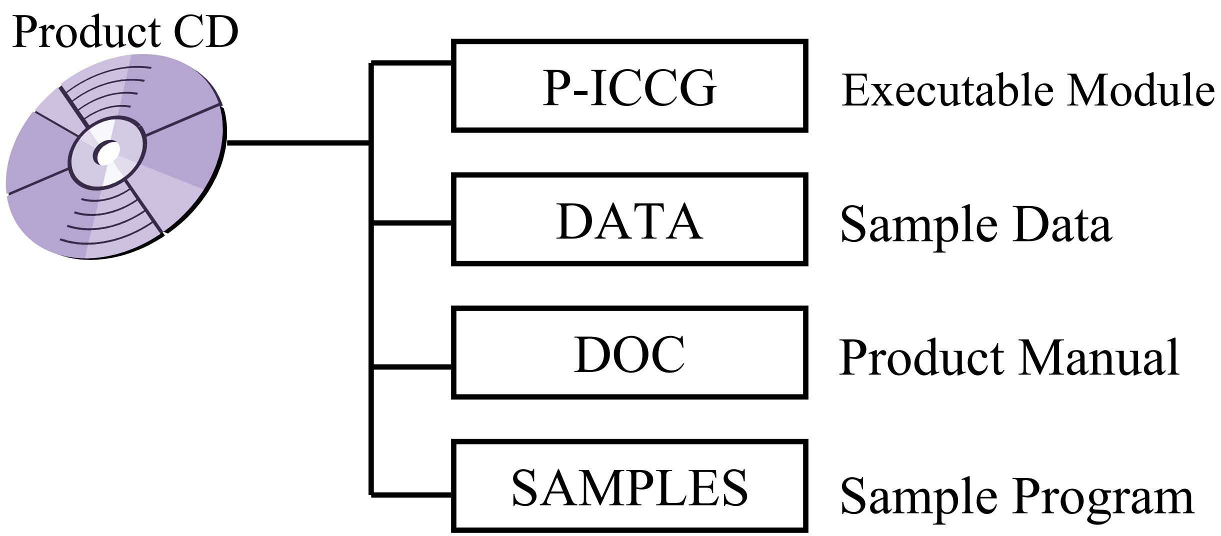
【System environment】

CPU: Xeon 2.4GHz, 2GB-Memory

OS: Windows XP

μ -tec Co.,Ltd web site: http://www.mutec.org/

P-ICCG software product consists of:



For further information on SMS-P-ICCG such as

•Benchmark Testing (BMT)

•Evaluation module

•Other inquiries

Please contact:

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